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Agile Approaches for Successfully Managing and Executing Projects in the Fourth Industrial Revolution

Hür Bersam Bolat and Gül Tekin Temur

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A volume in the Advances in Logistics, Operations, and Management Science (ALOMS) Book Series

Published in the United States of America by
IGI Global
Business Science Reference (an imprint of IGI Global)
701 E. Chocolate Avenue
Hershey PA, USA 17033
Tel: 717-533-8845
Fax: 717-533-8661
E-mail: cust@igi-global.com
Web site: http://www.igi-global.com

Library of Congress Cataloging-in-Publication Data

Names: Bolat, Hur Bersam, 1971- editor. | Temur, Gul Tekin, 1983- editor.
Title: Agile approaches for successfully managing and executing projects in the fourth industrial revolution / Hur Bersam Bolat and Gul Tekin Temur, editors.
Description: Hershey, PA : Business Science Reference, [2019]
Identifiers: LCCN 2018037196| ISBN 9781522578659 (hardcover) | ISBN 9781522578666 (ebook)
Subjects: LCSH: Project management. | Management--Technological innovations. | Big data. | Industrial revolution.
Classification: LCC HD69.P75 A395 2019 | DDC 658.4/04--dc23 LC record available at https://lccn.loc.gov/2018037196

This book is published in the IGI Global book series Advances in Logistics, Operations, and Management Science (ALOMS) (ISSN: 2327-350X; eISSN: 2327-3518)

British Cataloguing in Publication Data
A Cataloguing in Publication record for this book is available from the British Library.

Advances in Logistics, Operations, and Management Science (ALOMS) Book Series

John Wang
Montclair State University, USA

ISSN:2327-350X
EISSN:2327-3518

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in dealing with these complexities. In this study, the project management style is defined as a dominant paradigm that a manager uses as a mental model in dealing with the management problems. The chapter investigates the effects of the alignment between project management style and project complexity on the project management outcomes. The implications of this research are that with the increased complexity as in the case of Industry 4.0, the project management approaches will need to become more agile, with shortened planning horizons and more involvement and communication with the stakeholders.

Advancements in technology, especially ICTs, has caused a revolutionary change in every aspect of life. The reflection of these advancements on manufacturing industry is named “The Industrial Internet,” or “Industry 4.0.” New generation factories are to be equipped with cyber-physical systems. Teams integrating physical industrial components, and advanced modern sensing and networking technologies to form new smart systems. These systems will have more capabilities than the systems which are already in use. These winds of change will also affect projects and project management. Clearly, success in agile project management will become more crucial. At this point, technologies enabling Industry 4.0 will help project managers. Project organizations have the flexibility to get adapted to new situations fast. In this chapter, benefits of the technologies enabling Industry 4.0 in project management are introduced.

During this fourth industrial revolution, the fundamental purpose of industrial transformations is to carry competitive edge of the companies to an upper level by increasing efficiency and effectiveness of sources and decreasing the operational costs. Therefore, the companies need to invest in the right project in the right time in order to provide a competitive edge against their competitors and to gain a desired level of profit. The aim of the project cost analysis is, in the simplest terms, to calculate optimal project costs and to consider if there is any difference between the planned budget and the optimal cost; and in case of a difference, to take necessary actions. The purpose of this chapter is, as a result of principles and conceptual framework of Industry 4.0, to describe how adaptive robotics, artificial intelligence, big data, augmented reality, additive manufacturing, internet of things, cloud computing and cyber security technologies, which are building blocks of Industry 4.0, changed the project cost analysis.

Management of Industry 4.0 projects needs to have a distinct discourse, be flexible, iterative and creative. These projects are tightly linked with the way people work which is directly related to both their capabilities and their ways of thinking. Challenging Industry 4.0 projects entail out-of-the-box thinking. The basic premise of this research is that the complex transformation accompanying Industry 4.0, which involves various dimensions, requires extensive and effective project management that can leverage novel approaches and techniques such as design thinking. This new approach may overcome the limitations of the dominant model of standard project management and has the potential to bridge the gap between a refreshed project management perspective and the tools/techniques in practical use. Deciding whether, and to what extent, design thinking needs to be adopted in practice in Industry 4.0 project management is a challenge. However, it is time to start exploring the challenges governing the interface between agile approaches such as design thinking and Industry 4.0 project management.

In a fast-paced and changing world demanded by Industry 4.0, the continuous delivery of products and level of integration of technologies are required. This is achieved through the introduction of agile but agile itself demands changes in the way projects are managed. The role of the project manager itself is changing from a command and control to a collaborative and coaching style of leadership. Project teams on the other hand should be self-organizing and self-directed to be agile. Managing agile teams requires a different approach as the idea is to deliver workable solutions and products at a faster space. New project manager skills and competencies are required as well as ways to manage agile teams. A conceptual model is introduced, highlighting the required enablers for an agile environment. The enablers have an impact on how the agile project manager interacts with the agile team. The end result is that products are faster deployed enabling organizations to react to the changes demanded by Industry 4.0.

Three out of four projects are not getting off the ground. It is questionable whether industry 4.0 represents an additional obstacle to the execution of projects or contributes to overcoming these barriers. The fourth industrial revolution extends to all phases of the value-creation process. The project, ubiquitous in Industry 4.0, suffers a fundamental change covered by the definition of a Project 4.0. Uncertainties arising from the far-reaching changes in the environment and companies over the entire lifecycle of a project are not taken into account yet. Considering the uncertainties, there is an uncertainty descent from early to late stages of the Project 4.0 lifecycle. Here, by describing anomalies of subjective uncertainty assessment, the massive uncertainties perceived by decision makers were put into perspective. This serves as prerequisite for the design of a sound tool for an unambiguous decision on the execution of a Project 4.0. This tool contributes to insuring that more than one out of four projects succeeds.

In the Fourth Industrial Revolution, customers expect companies to provide journeys in line with rapidly changing expectations. This allows for great potential for project portfolios that can enable tailored experiences, powered by technology and insights coming from the 360° view of the customer, to improve

Preface

OVERVIEW

A project management consists of utilization and application of information, materials, labor, equipment, supportive tools and approaches to meet the needs of projects within an expected time, quality and budget. In general, there are five important phases in a project management process: initiating, planning, executing, monitoring-controlling, and closing. The success of a project depends on fulfillment of goals, efficient use of resources and effective scheduling. By the effect of Industry 4.0, which is a new digital transformation era, project management dynamics will change according to effects of automation and utilization of big data analytics. Not only Industry 4.0 focusing projects, but also out-of-Industry 4.0 projects will be affected by that change.

Industry 4.0 in which technological hardware and automation will collaborate each other and robotics are combined to computer systems by the help of machine learning algorithms, introduces monitoring physical processes to develop a decentralized decision systems. Industry 4.0 is emerged in Germany and its tools have been widely applied in developed countries (Morrar et al., 2017). In Industry 4.0 applications, inputs of a system are gathered from machines, devices, sensors rather than humans. Communication between machines and humans are conducted via Internet of Things (IoT) technology. Each actor can track the situation of a sub task (ready for start, still in work, finished or etc.) on time and can also have foresight about unexpected events which can occur in the future. That kind of decentralized decision making system make companies has decisions autonomously; it will also affect the decisions made within project management. New practices of managing change in complex projects might be expected as we enter an era of ‘big data’, in which internal and external data-sets become linked and asset information becomes a project deliverable. Prior research suggests digital technologies enable rapid, flexible forms of project organizing in complex projects where the integrity is very important. For example; new employment and working time models will be improved and it will be possible to work anywhere you want. Also new formal and informal competencies will exist. More cooperation across companies and industries will be built and new working and business models will be created.

Adoption to Industry 4.0 within project management will force managers learn how to

- Use big data analytics within vital issues such as project life cycles and project risk management,
- Develop an agile approach to configuration management through a system to accommodate small continuous changes and manage the additional complexity across dispersed teams,
- Benefit from IoT, mobile devices and cyber-physical systems for coordinating, planning and controlling the decentralized projects,

- Utilize artificial intelligence to improve estimating man-machine-hours-costs and quality of projects.
- Train project managers and team members for improving their IT based skills.

Because complexity, uncertainty and time constraints become inevitable in projects in digital transformation era; traditional project management approaches are not capable for satisfying stakeholders' requirements. One of the main reason of uncertainty is originated from the fact that it is unknown how and when high investments will give advantageous outputs to the system. For example, employees do not have appropriate skills that are sufficient for handling Industry 4.0 operations, therefore standardization based problems can cause high uncertainty (Kamble et al., 2018).

Therefore, flexible and agile approaches are preferred by practitioners. As Highsmith (2002) specifies, agility is the ability to perceive and respond to business expectations to stay creative in a rapidly changing business environment. For the practitioners who are managing projects, the importance of being agile should not be ignored under the conditions of Industry 4.0 revolution.

Due to the expected changings and expectations explained above, the aims of this book can be categorized into two groups: (1) to show how various stages of project management discipline will be changed in agile manner by the effect of Industry 4.0 and (2) to introduce challenges of managing Industry 4.0 projects.

CHALLENGES

At the end of the 18th century, by the effect of utilization of water and steam-power in production facilities, First Industrial Revolution actually started. The increase in production capacities was realized in parallel with the increase in labor force. At the beginning of the twentieth century, it was followed by the introduction of the mass production of electrical energy and the division of labor, and then the foundations of the Second Industrial Revolution were laid. The first programmable logic controller (PLC) which is developed in 1969 affected the foundation of the Third Industrial Revolution. During this period, the rapid development of electronics and information technologies were laid. Nowadays, the focus of the value-producing firms is adapting the Fourth Industrial Revolution, in other words, “Industry 4.0” or “Digital Transformation Era”. The aim of this era is to increase digital abilities, succeed collaboration in the ecosystem, and implement data architecture to differentiate quick-release cycles. The advantages of this era can be grouped into four parts: increasing flexibility, decreasing lead time, increasing individual specific units, introducing new offering by using big data (Mitra, 2017). These advantages can be revealed by simplifying the management of data, proposing customer specific solutions with cheaper options and automating the operations.

Recently, enterprises have attached high importance to integration of digitalization not only with operational activities but also with management principles in tactical, operational and strategic levels. Because, digital transformation necessities are not limited with utilization of information technologies, new business models also should be developed in accordance with digitalization (Xu et al., 2018). Parallel to this, it is also noticeable to state that the transformation of the employees at all management levels has vital importance, because it is required to make the people ready to use digital transformation tools and methods efficiently, such as robot and automation, big data and analysis, artificial intelligence and intelligent systems, horizontal and vertical integration, sensors, simulation, augmented reality, additive production, cloud systems and cyber security. Furthermore, for adaptation of team works to agile conditions of digitalization, multi-skillfulness should be increased. These teams also obtain significant information from on-site customers (Abrahamson, Solo, Ronkainen, & Warsta, 2002).

It is evident that these developments have direct impact on socio economic, technical and human based environment of unique industrial systems which are mostly planned with project management procedure. In Industry 4.0, project managers have to provide a new perspective that handles simultaneous relations between behavioral, technical and contextual competences. Digital transformation forces project managers organize their digitally developed structure by using agile approaches. Although agile approaches were initially started to be used in IT projects, other industries have attached high interest on it across time. Linear structure of traditional project management principles is not enough to deal with the changing conditions of today's world. Therefore, iterative methods, such as agile approaches which are adaptable to dynamic conditions are accepted as more satisfactory. By the help of agile project management, planning is rechecked throughout the life cycle of project and it is necessary to involve customers to the process continuously. As a result, enterprises become able to adapt the necessities of the digital transformation process faster. It is a key point for companies who goal to remain or increase their market power while satisfying the highly dynamic requirements of customers. Digitalization allows project managers benefit from smart tools and interrelated technologies that reduce time and complexity, and increase the controllability and interference ability.

Although there is a high interest on digital transformation in the literature, there is a lack of studies handling project management in Industry 4.0 and management of Industry 4.0 projects. In the study of Cerezo-Narvaez et al. (2017), a structural equation model is proposed for evaluation of importance of project management in Industry 4.0. Semolic and Steyn (2017) criticize the effect of Industry 4.0 on value chains and collaborative projects. In the literature, there is still a big gap about the study field on project management in digital transformation era. Therefore, this book contributes to the relevant literature by handling both of following issues in different sections as a first time:

1. **Project Management in Industry 4.0:** This section describes how to plan, execute, organize and control projects in digital transformation era under certain and uncertain conditions by using agile approaches.
2. **Management of Industry 4.0 Projects:** This section describes how projects related with Industry 4.0 can be successful by using agile approaches. This section handles management of Industry 4.0 projects from theoretical and academic perspective.

TARGET AUDIENCE

This book will be directly beneficial for each group given below:

- Project Managers
- The Departments of Universities in Which Project Management Courses are Given.
- Master and PhD Students Dealing with "Project Management" Discipline
- Master and PhD Students Dealing with "Industry 4.0"
- Academicians Dealing with "Project Management" Discipline
- Academicians Dealing with "Industry 4.0"

- Technology Transfer Offices
- Project Management Offices
- Project Management Institutes
- Project Management Associations

The target audience includes but not limited to the listed above. Team members of a project team, people who want to improve their skills on Industry 4.0 tools, governmental institutions which aim to figure out the current digitalization position of project oriented sectors such as construction sector etc. can also be interested in this book.

THE IMPORTANCE OF EACH OF THE CHAPTER SUBMISSIONS

The book is organized into two sections under the titles of "Project Management in Industry 4.0" and "Management of Industry 4.0 Projects". In the first section, there are 12 chapters. Because the topic of this book has not been handled in the relevant literature until now, some researchers define the scope and frame of the topic independently. They mostly preferred to overcome the problems occur because of uncertain conditions of digital transformation era, and proposed their unique agile approaches that help to increase the success not only in project planning, but also in cost controlling, monitoring team works and managing customers. In the second section, there are six chapters which discussed how the performance of digital projects such as software development projects can be measured and how project managers can deal with barriers occur in digital transformation era. In both sections, theoretic and academic approaches were proposed by conducting case studies from real world.

A brief description of each of the chapters follows:

Section 1: Project Management in Industry 4.0

Chapter 1 highlights how the fourth industrial revolution impacted the evolution of agile project management practices. It discusses how these could be applied in conjunction with traditional waterfall project management or as a standalone approach. Topics discussed include a definition and elements of project management, waterfall vs. agile project management, transitioning to agile methods, developments in agile project management, agile practices, and leading agile projects and project managers.

Chapter 2 clarifies the link between the complexities associated with the projects and the project management style in dealing with these complexities. In this study the project management style is defined as a dominant paradigm that a manager uses as a mental model in dealing with the management problems. The chapter investigates the effects of the alignment between project management style and project complexity on the project management outcomes.

Chapter 3 discusses Industry 4.0 technologies used in project management. It intends to introduce how industry 4.0 technologies reshape project management practices and support the efforts of project teams becoming "agile" with examples from different industries.

Chapter 4 describes how adaptive robotics, artificial intelligence, big data, augmented reality, additive manufacturing, internet of things, cloud computing and cyber security technologies, which are building blocks of Industry 4.0, changed the project cost analysis as a result of principles and conceptual framework of Industry 4.0.

Chapter 5 establishes a basis for elaborating on how design thinking can provide project management with new perspectives for addressing Industry 4.0 challenges. This chapter takes into account both conceptual and empirical aspects of an evolving basis for this research issue. It requires a conceptual examination as three relevant notions (design thinking, project management, Industry 4.0) are intertwined.

Chapter 6 introduces a conceptual model highlighting the required enablers for an agile environment. It is believed that the enablers have an impact on how the agile project manager interacts with the agile team. The end result is that products are faster deployed enabling organizations to react to the changes demanded by Industry 4.0.

Chapter 7 starts with the statement that three out of four projects are not getting off the ground. Main reason for the failure of so many projects were misguided decisions about the execution of a project. Therefore this chapter focusses on supporting decision makers about the execution of a project with a suitable decision method.

Chapter 8 illustrates how the Fourth Industrial Revolution influences the project portfolio that companies set up to realize this transformation. Firstly, it has been explained that Industry 4.0 induces new types of projects. Secondly, the duality of project drivers arising in the Fourth Industrial Revolution has been analyzed. On the one hand, it has been illustrated that customer journey projects still require a solid dose of change management and governance. Moreover, as project delivery remains the bottom line goal of project portfolios, projects have to continue to function partially as they do, to enable senior stakeholders to take the necessary decisions.

Chapter 9 defines the processes and technologies required in the Industry 4.0 transition. Since the projects related to different technologies may require the prioritization of project management dimensions to cope with complexity and uncertainty, agile project management criteria are specified to prioritize them adopting a multi-criteria decision making approach, namely the Analytical Network Process. Using the results obtained, suggestions for the creation of a framework to manage the Industry 4.0 transformation in an agile manner were presented.

Chapter 10 focuses on the efficiency of the projects in the era of Industry 4.0 and a numerical example is conducted in construction sector by utilizing data envelopment analysis.

Chapter 11 arranges KANBAN shelving in order to calculate the optimum order quantity of the materials supplied for the TV main boards in an electronic factory and to minimize the stacking of material waiting in the production area. To optimize this problem, a mathematical model is developed and solved in an optimization program. In addition, a number of proposals have been submitted under an Industry 4.0 to manage deficiencies in material following.

Chapter 12 proposes a project management methodology for software companies' Industry 4.0 strategy. The framework is applied in a global ERP firm's solution partner and the results are satisfactory. For the software companies, Industry 4.0 and its transformation are found as a must strategy.

Section 2: Management of Industry 4.0 Projects

Chapter 13 proposes an approach to apply Theory of Constraints to remove the problems that may be encountered with the implementation of the agile methods during identifying the problem and determining its solution. The proposed solutions to uncover the reasons not reaching the targeted quality and removing the obstacles will be a guide for software project managers.

Chapter 14 defines critical success factors in the transition processes to Industry 4.0 projects. In this chapter, first of all a literature study was conducted to identify the critical success factors in the transition processes of Industry 4.0. and, the survey instrument, a questionnaire form, was designed. The results of this research show that big data management is the most important success factor of Industry 4.0.

Chapter15 investigates how the Project Management framework proposed by Project Management Institute (PMI) can be effectively adapted to big data projects to reduce failure rates. The application of processes as mentioned in this chapter can help to eliminate the causes of failure in the early stages of the project; thus, increasing the successful completion rate of such projects.

Chapter 16 determines the Industry 4.0 barriers in implementation process in Turkey's conditions investigate the interrelations among them and develop a model that can measure the interacting effects of the barriers on the other barriers in the Industry 4.0 implementation process. To reach that aim, interpretive structural modeling (ISM) and decision-making trail and evaluation laboratory (DEMATEL) are used. According to results, one of the most important findings is the lack of digital vision which found as the only affecting barrier and it affects all the other barriers.

Chapter 17 designs a proper Agile Project Management performance measurement model for start-up software companies. Firstly, all key performance indicators are listed related to agile development in the literature. Then, KPIs that are provided from literature review with content analysis have been reviewed and categorized by expert opinions that were collected through in-depth interviews. Seven strategic KPIs and their data collection systems are defined and designed. Lastly, process and data collection improvements are recommended in order to sustain agile development measurement model.

Chapter 18 redefines general feasibility analysis steps for the Industry 4.0 projects. In addition to the traditional feasibility analysis steps, for Industry 4.0 projects, scenario analysis and decision trees are implemented to feasibility analysis that enables to identify outcomes of several scenarios for the risky parameters. At the end of the chapter, proposed feasibility analysis procedure is applied to an Industry 4.0 project.

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Section 1

Project Management in Industry 4.0

This section describes how to plan, execute, organize and control projects in digital transformation era under certain and uncertain conditions by using agile approaches.

Chapter 1

Agile Approaches for Successfully Managing and Executing Projects in the Fourth Industrial Revolution

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ABSTRACT

The fourth industrial revolution utilizes artificial intelligence by automating large quantities of numbers to increase the chances of project success. The Project Management Institute lists examples of project outcomes, including but not limited to the Pyramids of Giza, the Great Wall of China, the Panama Canal, and the placement of the International Space Station into Earth's orbit. This chapter highlights how the fourth industrial revolution (Industry 4.0) impacted the evolution of agile project management practices. It discusses how these could be applied in conjunction with traditional waterfall project management or as a standalone approach. Topics discussed include a definition and elements of project management, waterfall vs. agile project management, transitioning to agile methods, developments in agile project management, agile practices, and leading agile projects and project managers.

DOI: 10.4018/978-1-5225-7865-9.ch001

INTRODUCTION

Project management (PM) practitioners often discuss the waterfall PM approach, which involves progressive elaboration of plans and scope of project (Project Management Institute, 2017). The evolving complex business environment requires a different set of knowledge and skills to effectively manage projects. Therefore, the agile PM approach serves as a bridge to connect the waterfall to the demands of the current business environment.

Industrial revolutions have been characterized by technological leaps and bounds that have led to paradigm shifts. According to Lasi, Fettke, Kemper, Feld, and Hoffmann (2014), the fields of mechanization, water power, and steam power represent the first industrial revolution. The intensive use of electricity through mass production and assembly lines represent the second industrial revolution (Lasi et al., 2014). The widespread use of digitalization and automation is the third industrial revolution. The fourth industrial revolution is advanced digitalization with the combination of Internet technologies and future-oriented technologies in the field of smart machines and products. Cyber-physical systems manage projects during the fourth phase. Iterative systems, like robotics and real-time cloud computing, are intertwined state-of-the-art autonomous frameworks offering a new approach for uncovering the possibilities in data (Reynolds, 2016). Pinkham (2017) wrote that the fourth industrial revolution is commonly referred to as Industry 4.0.

This chapter draws from researchers' extensive review of literature on PM practices, the waterfall method, and agile PM approaches. Researchers have synthesized their findings to highlight how the fourth industrial revolution supports agile PM as both a standalone and in conjunction with the waterfall PM methodology.

DEFINITION AND ELEMENTS OF PROJECT MANAGEMENT

A project is defined as a set of unique temporary interrelated activities that are executed within a fixed time (schedule), meeting a certain cost, and following limitations (scope) to achieve a specific goal (Project Management Institute, 2017b). PM is the application of knowledge, skills, tools, and techniques to project activities that meet the desired project requirements on time, on budget, and within a defined scope (ibid, 2017).

Although used by industries for many years, PM received minimal recognition until the 1950s and 1960s (Loucks, 2008). Over the last 25 years, PM has adapted to changes in society by increasing professionalism in special projects (Thomas & Adams, 2005). Organizations set and achieved goals with PM through an iterative four-step process of plan, do, check, and act (PDCA). These steps fall into the following process groups in PM: (1) initiating; (2) planning; (3) executing, monitoring, and controlling; and (4) closing (Project Management Institute, 2017b). These phases help the project manager understand the project scope, recognize challenges, and resolve issues connected to PM (Melton, 2004). This process has also assisted businesses and industries to recognize (rather than repeat) mistakes (Owen & Burstein, 2005).

The initiating process group is the first phase for PM. During this phase, the project manager communicates with other members of management to establish objectives and determine their project needs (Suttle, n.d.). When the team has decided on whether to accept or reject the project, they may use descriptive analytics, predictive analytics, and prescriptive analytics (Kelly, 2017). Descriptive analytics provide data aggregation and data mining to inform team members on information concerning the past. Predictive analytics use statistical modeling to understand the future. To assist in possible outcomes, project managers may use prescriptive analytics to optimize and simulate algorithms (Kelly, 2017).

The creation of a project plan may vary between organizations (Allen, McLees, Richardson, & Waterford, 2015). According to Kerzner (2009), the key elements of a project plan are "project requirements, project management, project schedules, facility requirements, logistic support, financial support, manpower, and organization" (p. 5). Allocating the right resources at the right time ensures a plan's successful. Planning increases the chances for project success. Failure to plan is planning to fail (Kerzner, 2009).

The planned work begins during the executing process group phase. The project manager, having analyzed the project's plan, scope, and schedule, determines if the baselines will be impacted by available information and begins its execution (Alecu, 2011). During project execution, the project manager monitors and controls tasks to ensure that they remain within the scope, cost, and schedule. In addition, they manage the success of the project's overall objective. Monitoring and controlling the project addresses issues as they arise. Management should be a daily task achieved through monitoring the work, identifying and resolving issues, tracking the project, and taking corrective action to resolve issues (Young, 2007).

The closing process group, which is the final phase of a project, occurs for two reasons. The first reason to close a project is because the phase or project is complete. In this case, the project adhered to the plan and met its objectives (Young, 2007). The second reason for closing a project is because the activities across the process groups have been completed and the project is accepted by the owner. The owner's acceptance is because the project objective has been met or the project has become obsolete/irrelevant to an organization's objective (Project Management Institute, 2017b; Young, 2007).

PM has 10 knowledge areas (Project Management Institute, 2017b):

1. Integration management
2. Scope management
3. Time management
4. Cost management
5. Quality management
6. Human resources management
7. Communication management
8. Risk management
9. Procurement management
10. Stakeholder management

These knowledge areas are often used on projects. All five process groups must be applied from start to finish (ibid, 2017). Table 1 shows a mapping between knowledge areas and process groups. It also includes activities conducted in the process groups.

The activities outlined in Table 1 are key to ensuring that any project is managed effectively. Activities can be seamless when project managers understand interactions between the knowledge areas and process groups, as well as implement the outlined activities to effectively communicate and gain knowledge by leveraging the power of cloud computing, Internet connectivity, and process integration (Cervone, 2011). This will ultimately increase the chances of completing a successful project.

Table 1. Mapping of PM process groups and knowledge areas

Knowledge Areas	Project Management Process Groups				
	Initiating Process Group	**Planning Process Group**	**Executing Process Group**	**Monitoring and Controlling Process Group**	**Closing Process Group**
Project Integration Management	Develop Project Charter	Develop PM Plan	Direct and Manage Project Work	Monitor and Control Project Work Perform Integrated Change Control	Close Project
Project Scope Management		Plan Scope Management Collect Requirements Define Scope Create WBS		Validate Scope Control Scope	
Project Time Management		Plan Schedule Management Define Activities Sequence Activities Estimate Activity Duration Develop Schedule		Control Schedule	
Project Cost Management		Plan Cost Management Estimate Costs Determine Budget		Control Costs	
Project Quality Management		Plan Quality Management	Perform Quality Assurance	Control Quality	
Project Human Resources Management		Plan Human Resource Management	Acquire Project Team Develop Project Team Manage Project Team		
Project Communication Management		Plan Communications Management	Manage Communications	Control Communications	
Project Risk Management		Plan Risk Management Identify Risks Perform Qualitative Risk Analyses Plan Risk Responses		Control Risks	
Project Procurement Management		Plan Procurement Management	Conduct Procurements	Contgrol Procurements	Close Procurements
Project Stakehlolder Management	Identify Stakeholders	Plan Stakeholder Management	Manage Stakeholder Engagement	Control Stakeholder Engagement	

Source: Project Management Institute (2017b)

WATERFALL VS. AGILE PROJECT MANAGEMENT

Waterfall PM is a traditional method used in software development (Pedersen, 2013). It requires many phases to implement, including conceptualization and requirements determination, designing, implementation, verification, and maintenance (Ledbrook, 2012). The waterfall method requires extensive planning in the early part of the project. It can effectively and carefully monitor systems to avoid mistakes (Russell, 2012). There are both benefits and disadvantages to this method.

The waterfall method has three benefits: (1) reduction of repetitive work; (2) reduction of bottlenecks; and (3) delivery of value to the project before completion. This method will reduce repetitive work by allowing separate teams to work on parallel sections of the project, which reduces the cost and time it takes to complete the project (Jackson, 2012). Waterfall delivers value to PM through interaction and communication. Waterfall also allows project managers to adjust resources as needed and notify stakeholders of changes (ibid, 2012). Teams can communicate data on a regular basis to assist in early detection of issues.

Cost prohibitive disadvantages of the waterfall method include external factors influencing the project, a lack of adapting to change during phases, a poorly structured system, time wasted on documentation, and premature software testing (Pedersen, 2013).

Agile PM is also used in software development. This approach is more flexible and quickly adapts to changes during development (Pedersen, 2013). The agile approach has an increased return on investment, as well as early detections to help the team adapt to customer needs (Kataria, 2016). This improves customer service and project control. The agile framework includes an agile development measurement index and a four-stage process to adapt to changes (Pedersen, 2013).

This component measures a company's agility with three components. The first component assesses and measures an organization's potential for agility. The second measures and identifies the agility level for a project that aspires to adopt an agile method. Third, it assists in developing teams with essential agile qualities to reach certain objectives and measure organizational agility (Sidky, 2007).

The four-stage process consists of: (1) the identification of discontinuing factors; (2) project level assessment; (3) organizational readiness; and (4) reconciliation. Stage 1 identifies whether the organization is capable of transitioning to agility. The organization must decide if the journey is worth the time and money. In addition, the organization must determine if it is ready for these changes. Once the decision has been made to proceed with the project, stage 2 focuses on identifying and assessing factors outside of the organization's control. The PM team researches factors that could jeopardize a successful agile practice (Sidky, 2007). During stage 3, the team decides if the organization is ready to adopt the project's objective. The team will perform an assessment to address how agile practices fit with the organization's operational procedures. Stage 4 reconciles differences between the two levels. The coach will apply the agile adoption framework after the issues are presented (Sidky, 2007).

Both waterfall and agile methods are important in PM. However, the agile approach is more user friendly than the waterfall method. The agile approach adapts to the needs of the organization in real time, which increases return on investment, project control, and customer service (Kataria, 2016). The waterfall method focuses on plans, tools, and templates. It has the potential to reduce repetitive work, decrease bottlenecks, and deliver value to the project before completion (Project Management Institute, 2017a).

WHY THE AGILE APPROACH?

From a strategic and technological perspective, the 21st century requires businesses to restructure and reengineer their processes and procedures to adhere to clients who demand superior, low- cost products that are explicit to rapidly changing needs in their markets (Gunasekaran, 2001). Agile methods address challenges faced by today's businesses. For example, Gunasekaran (2001) described agile manufacturing as the ability to survive and flourish in markets that drive change due to quick response in a world of rapid and unpredictable change.

A group of PM professionals was asked, "What does agile mean to you?" Astonishingly, no one had the same answer (Fewell, 2017). First, individuals and/or organizations must recognize the need for an agile approach:

- Does your software project need correlation?
- Does your model require significant change?
- Is product quality a concern?

Once these questions are answered, individuals and/or organizations can explore value-oriented procedures. An organization may need a skilled facilitator to assist with identifying the source of the problem. After an organization tailors a technique to addresses its needs, then it can begin to modify specific parts to emphasize and/or ignore using an agile approach (Fewell, 2017). It is key to concentrate on identifying and solving one problem at a time (Fewell, 2017).

Businesses must push the envelope in response to delivery time, increased product quality, and excellent customer service and satisfaction (Gunasekaran, 2001). Agile approach ingenuity harnesses new opportunities offered by the fourth industrial revolution to meet the challenges of physical and digital technological needs. Industry 4.0 digitally establishes an interconnectedness fostering capabilities for improved, well-informed decision making. The age of the agile approach and Industry 4.0 is merging physical and digital technologies by integrating analytic systems to process data with advanced algorithms.

Cognitive computing offers a different approach by looking within and across unrelated data sets (i.e., rich media and text). Cognitive computing recognizes conflicting data, uncovers surprises, looks for patterns and context, and offers suggestions and solutions (Reynolds, 2016). Artificial intelligence (AI) applications, which include automated supermarkets handled with limited (or no) human supervision, are sparking new debates due to extreme automation (Özdemir & Hekim, 2018). The IoT is built on broadband wireless Internet connectivity, which utilizes miniscule sensors implanted into both animate and inanimate objects (Özdemir & Hekim, 2018).

The agile approach and Industry 4.0 are creating systems that are digitally and physically connected. These systems improve operations, production, innovation, and advancement as they use data to drive intelligent action throughout the value chain (Denning, 2017). In addition, during the unstoppable 4.0 revolution, manufacturing will witness the invention of cyber-physical systems (Loffler & Tschiesner, 2013). Industry 4.0 is creating intelligent systems connecting machines, systems, and work pieces to control each system autonomously (Loffler & Tschiesner, 2013). Possibilities include the decentralization of production control, smart machines that predict future complications and prompt maintenance procedures autonomously, or systems that react to the unexpected (Loffler & Tschiesner, 2013).

In fact, some organizations have already been using the agile approach. Businesses like Apple and Samsung use technology that customers can tailor to meet individual wants and needs (Denning, 2017).

Companies like Tesla, Saab, and Ericsson are applying advancements to cars, planes, and networks, which continue to upgrade by delivering software to these products via the Web (Denning, 2017). Some businesses cross over to agile methods more slowly as they reflect on their traditional management methods. However, they face frustration when they realize they are seeing the same problems repeat as their solutions fail.

Cyber-physical systems merge physical and software components to operate on different scales. For example, some of the combined systems include self-governing automobile systems, medical monitoring, process control systems, robotics, and automatic pilots. These systems come together in the IoT, which is operated through sensors and actuators in both wired and wireless networks over the Internet protocol (Loffler & Tschiesner, 2013).

This new paradigm shift allows team, units, and complete enterprises to agilely upgrade and adapt products and services through quality improvements or new products (Denning, 2017). Some firms embrace this shift. Others resist the change. Mature organizations that have successfully operated in a more traditional manner may find it hard to change their processes, routines, attitudes, and values (Denning, 2017).

Managers who have not embraced the new technology noted that they do not see how the momentum came from software development, especially because this was an area with no prior "reputation for excellence" for managers (Denning, 2017). Many doubted that they could learn management skills based on software development and technology. In reflecting on managing in the 20th century, managers flourished in their careers based on concepts they were taught (and are still being taught) in business schools (Denning, 2017). These organizations do not understand that access to evolving technology is not the complete answer. Instead, agility and willingness to adjust to technology allows their organizations to best meet customers' needs (Denning, 2017).

To understand the agile approach, managers must start a conversation about why different habits, processes, attitudes, and principles are necessary, and why a shift in software is fundamentally creating a different approach to management (Denning, 2017). Managers and teams must explore quality-oriented techniques and procedures that pair team members with differing processes. These strategies allow an organization to accept the paradigm shift as businesses become software dependent and the agile platform accelerates (Denning, 2017).

TRANSITIONING TO AGILE METHODS

Numerous challenges related to agile transition are related to humans as noted in a grounded theory study conducted in 13 countries with 49 agile experts (Gandomani & Nafchi, 2016). The challenges can be categorized into "impediments to agile transition" and "perceptions about the change process" (Gandomani & Nafchi, 2016). The list includes:

- Deficiency in knowledge
- Cultural problems
- Resistance to change
- Flawed attitude
- Nonconformity to collaboration

Data analysis of the grounded theory study revealed that individuals held flawed attitudes toward agile transition based on misguided information, apprehension about the transition, uncertainty and indifference to change, and improbable expectations (Gandomani & Nafchi, 2016).

Although an organization's agile transition may seem straightforward, the process can be challenging (Gurses, 2006). A flawless transition sounds good, however, organizations can make avoidable mistakes. The biggest mistakes include pilot projects with poor time management, new methodologies, inadequate research, the wrong people, tight deadlines (Gurses, 2006). Organizations should proceed carefully and include stakeholders in the development of the agile transition. Established networks and processes are required, as well as consideration of the corporate culture. This includes project planning, teamwork, employee attitudes, departmental politics, and project pace. It is beneficial to hire staff with previous agile transition design experience. Therefore, organizations should hire a consultant (Gurses, 2006). Key factors to a smooth transition are "up front analyses and constant real-time monitoring" (Gurses, 2006, p. X).

A case study was conducted on 17 organizations that used agile methods for more than three years. The study's compilation of serious challenges listed the following as the top problems: (1) people; (2) recruitment; (3) training; (4) motivation; and (5) performance evaluation (Conboy, Coyle, Xiaofeng, & Pikkarainen, 2011). Current trends related to agile method transitions focus on alignment through customers, suppliers, consultants, and the public sector (Conboy et al., 2011).

In the fourth industrial revolution, software will monitor conditions and supply diagnoses. This permits systems to self-monitor and self-predict, as well as allows managers more insight into the health of processes and procedures. The Allegro Group, according to Raczka (2015), needed a system to respond quickly to changes in organizational operation and market response. The organization realized that their waterfall process was no longer meeting their needs. However, some individuals in the organization were not committed to the adoption of an agile method (Raczka, 2015). Within two days, an experienced agile coach met with employees from all levels and departments of the organization to review the flow of the transition. This coaching approach immediately addressed issues related to communication and team members' availability (Raczka, 2015). Management had the opportunity to make changes using their management style in collaboration with the agile approach.

Overall, the Allegro Group's transition was not difficult. However, the organization's initial agility was problematic (Raczka, 2015). Managers had to adjust their way of thinking as they recognized and acted on necessary changes. Adapting to new situations is not always easy. Yet seeing successful results in an agile transition is encouraging. The Allegro Group enjoyed shorter times to market, experienced a renewed relationship between business and information technology, and saw satisfied employees (Raczka, 2015).

Agile transitions should be completed in several phases (Couture, 2013). For example, after using a two-week development plan and a two-week quality assurance (QA) approach, one business identified key capabilities that could be finalized through a four-week development plan (Couture, 2013). After four weeks, the business team established capabilities from "data intake to data transformation to reports" (Couture, 2013, p. X). Transitioning to agile methods is not simply adopting a different approach. Agility must be adapted to fit an organization's specific needs and challenges, as well as prepare for future changes (Couture, 2013).

DEVELOPMENTS IN AGILE PROJECT MANAGEMENT

PM has gone through several changes to include the development of agile practices. This section reviews current developments, trends, and events in agile practices. According to Stankovic, Nikolic, Djordevic, and Cao (2013), the development of agile PM provides stability in many software applications. Stankovic et al. (2013) opined that agile PM has been successful in many countries, including Yugoslavia. Stankovic et al. (2013) presented current phases of development in agile PM and discussed how the phases improve an organization's efficiency and effectiveness through:

- Software development
- Product development
- Opportunities created by agile PM
- Values and principles driving management
- Organizational growth through agile PM

A 2012 IBM Institute study on agile practices showed the impact and trends embraced by society, including mobile devices, unstructured data, intelligent and connected devices, and sensors. According to Randall (2014), most managers endorse these trends due to competitive advantages. Although advantageous, Randall (2014) reported that only 25% of teams have effectively implemented agile practices.

Due to ineffective implementation, industries have experienced execution gaps and missed opportunities in management. When used correctly, agile practices (i.e., cloud computing and cognitive computing) can reduce waste by prioritizing business values through redesigned projects in a more efficient climate. Project managers will be required to use impactful agile practices to lead teams through problems and issues in an open and transparent environment. Randall (2014) noted that organizations must develop dynamic capabilities to achieve open and transparent environments. Industry 4.0 enables agile project managers to provide a correlation of shared computing services in cloud computing and mobile applications. Khalid, Zara, and Fahad (2014) explained that development teams must face several complications to advance successful mobile applications. If facilitated correctly, agile teams can successfully manage the 4.0 environment in relation to innovative standards, changing platforms, and efficient interface.

Current Developments

Agile practices have been influential in software development and a forward-thinking industry. Azuara (2015) stated that agile practices gave birth to essential software applications, including mobile devices, extreme programming, and scrum. Agile teams have adapted extreme programming and scrum to provide a basis to assign and complete work in an incremental and interactive process with frequent customer consultation (Bond, 2015). Stakeholders can communicate and coordinate tasks, as well as set goals for usability and feasibility. Turk, France, and Rumpe (2005) characterized these new applications within Industry 4.0 as: (1) sustained interactions over processes and tools; (2) active and efficient software providing comprehensive documentation; (3) enhanced customer collaboration over contract negotiations; and (4) responses to change regarding planning stages.

4.0 Revolution

Industry 4.0 has a huge impact on agile PM practices. Organizational project managers use agile practices to react accordingly to architecture, increase technology, and assist in the development of techniques and methodology. Ghilic-Micu, Stoica, and Uscatu (2014) concluded that agile practices enhance Industry 4.0 regarding cloud computing, cognitive computing, cypher- physical systems, and the Internet of things (IoT). Project managers use these practices to increase productivity through technological advancements in robotics, artificial intelligence, nanotechnology, quantum computing, and biotechnology. For instance, cloud computing has provided agile implementation to organizations in the form of easier access and flexibility. Ghilic-Micu et al. (2014) stated that cloud computing is one example of how agile practices have positively impacted today's society. The following list offers concepts and advancements through agile management impressions (Ghilic-Micu et al., 2014):

- Information technology provide service-oriented approaches
- Scalable and massive infrastructures
- Shared, configurable, flexible, and dynamic resources
- Internet access to all devices
- A platform providing self-management and autonomy
- Employment model based on self-service
- Billing based on measured services

Communication

Poor communication during the process of change can present challenges and dissatisfaction. Connecting the agile practice framework to traditional techniques contributes to a challenging paradigm related to communication connectivity (Jamieson & Fallah, 2012).

Bjarnason, Wnuk, and Regnell (2012) stated that stakeholder communication can cause negative aspects of team involvement if stakeholders fail to reach a goal agreement. This can cause an excessive burden on the scope of the project. Improper communication can also result in adverse aspects of customer feedback.

Agile practices provide essential interactions and flexibility within the project team. As a result, teams can identify customer needs and/or wants. Conversely, Olsson, Alahyari, and Bosch (2012) opined that the project may fail if the team does not promptly receive customer feedback.

AGILE PRACTICES

Agile practices are a set of management practices that involve collaboration between self-organizing and cross-functional teams. It provides stability and productivity in communication, as well as allows for adaptive planning and continuous improvement (Denning, 2017). Turk et al. (2005) identified the following principles instigating project performance:

1. Customer satisfaction through efficient software delivery
2. Support of customers' competitive advantages

3. Frequent and efficient deliveries
4. Enhanced collaboration between team members, developers, and consumers
5. Improved PM
6. Autonomy in the project team, including trust and support
7. Face-to-face conversations to communicate project information
8. Sustainable development
9. Technical excellence
10. Simplicity
11. Organized teams

Most studies have covered outcomes associated with three processes: (1) scrum; (2) kanban; and (3) lean. The processes work together to deploy teams that provide interactive, real-time perspectives to customers and vendors.

- **Scrum:** An interactive product development strategy in which a development team works as a unit to reach a common goal and challenges assumptions of the traditional, sequential approach to product development.
- **Kanban:** A scheduling and inventory-control system used to manage the delivery of work. By controlling the amount of work, the approach aspires to increase the flow of finished work.
- **Lean:** Continuous improvement and respect for people. This process is associated with improvements, reduced cycle time, and improved efficiency.

In today's Industry 4.0 society, these practices optimize tools that place organizations in a certain mindset. For example, managers can focus on customer and user innovations rather than short-term profits (Denning, 2017). Second, agile practices question how managers view themselves in relation to PM. Managers can draw on the full talents and capacities of their employees. Drury-Grogan (2014) opined that agile practices provide stability and productivity in communication, coordination, and team objectives. Moreover, agile practices allow for autonomy, which leads to the pursuit and accomplishment of mission-critical tasks.

McHugh, Conboy, and Long (2012) explained that organizations using agile practices measure a level of self-management in which teams are empowered and responsible for their projects and goals. However, the most critical mindset is the advocacy of transparency. This results in improved products and services like software applications. Holmstrom, Fitzgerald, Agerfalk, and Conchuir (2006) stated that agile practices decrease the reduction of temporal, geographical, and subcultural issues in software. Teams gain empowerment and responsibility in goal attainment. To further illustrate the provision of agile practices, Table 2 and Table 3 provide beneficial characteristics to PM teams.

Agile Practices and Traditional Project Management

Traditional practices of PM have been countered using agile PM methodologies. Issues such as a changing work scope, early part design freeze, infrequent customer interaction, and a rigid development process can result in excessive rework and a dissatisfied customer due to a missed target (Serrador & Pinto, 2015). Traditional PM has been designed to be efficient and linear (Conforto, Rebentisch, & Amaral, 2016). According to Conforto et al. (2016), innovative and sophisticated products require new processes

Table 2. Attributes of agile practices in Industry 4.0

Proactive	Anticipation of problems related to change. A solution of change-related issues. Personal initiative.
Adaptive	An interpersonal approach allowing for spontaneous collaboration, flexibility, and autonomy.
Resilient	Positive attitude toward changes, ideas, and technology. Tolerance to uncertain and unexpected situations. Assistance in coping with stress.
Collaborative	The ability to collaborate with other teams, functions, and organizations.

Source: Sherehiy, Karwowski, and Layer (2007)

Table 3. Benefits of agile teams

Purposefulness	Positive self-concepts to endure ambiguousness and stressful work situations.
Awareness	Active learning and an openness to ever-changing environments.
Action-Oriented	Taking initiative, acting or reacting as necessary, and establishing high levels of productivity while minimizing setbacks.
Resourcefulness	Ability to secure resources, talent, and support to meet goals.
Networking	Active relationships in the community. Creating a sense of connectedness and meaning.

Source: McCann and Selsky (2012)

and methods to fulfill the need for flexibility and improved flow of information. Teams benefit from the agile project through the completion of project requirements regarding iterations and/or reducing and limiting uncertainty in projects.

What is the difference in performance measures? Agile practices tend to encounter higher risks than traditional projects. However, they also provide more flexibility to easily adjust to changes in project requirements (Wysocki, 2006). In general, project managers reduce risk and preserve constraints of time and money.

These elements are required to realize success, goal and project completion, and customer satisfaction. Agile project managers provide an extra level of management control and success by focusing on deliverable business values and budget, which alludes to the delivery of the product. Traditional methods are known to adhere to a set process. Wysocki (2006) explained that agile project teams require colocation of team members and staff to embrace change and rapidly produce increments. By doing this, projects are worked in multiple locations, which allows for teams to use agile methods in each location. Since agile team members are called to take on more significant roles, the commitment level must be higher to provide flexibility and improved flow of information (Conforto et al., 2016).

LEADING AGILE PROJECTS

According to Nerur, Mahapatra, and Mangalaraj (2005), the current business environment is dynamic. Organizations strive to adapt their structures, strategies, and policies to suit this ever-changing environment. Allen (2017) noted that the changing environment reflects the industry 4.0 revolution's paradigm shift in industrial manufacturing. This shift has been analogue to digital transformations that connect a supply chain and the enterprise resources planner (ERP) to the production line to form an integrated, automated, and potentially autonomous process to improve the use of resources.

In comparing Industry 4.0, traditional PM approaches focus on the implementation of plans, best practices, and procedures with the use of specific tools and templates (Project Management Institute, 2017b). It follows a plan when responding to change and/or contract negotiations with customer collaboration (Cervone, 2011).

The agile PM approach is characterized by adaptability during the project lifecycle (Špundak, 2014). The focus shifts to adapting and responding to change vs. following the plan, individuals, teams, interactions, and communication over processes and tools, as well as a functional deliverable vs. comprehensive documentation (Cervone, 2011; Špundak, 2014). This shift in focus captures the essence of Industry 4.0, which marks the end of traditional centralized applications for production control. It focuses on a vision of an ecosystem of smart factories that respond in real time to customers' demands for tailored products (Almada-Lobo, 2015).

Špundak (2014) opined that the agile approach to leading projects requires a change in the project manager's thought process. Emphasis is placed on formal and/or informal communication and collaboration between project team members in the decision-making process (Nerur et al., 2005; Project Management Institute, 2017a; Špundak, 2014). This is a shift from the traditional, inflexible PM (Nerur et al., 2005). With Industry 4.0, agile PM integrates cyberphysical systems as it fuses the physical and virtual worlds to define target objectives and plan a transformational roadmap (Almada-Lobo, 2015).

AGILE AND PROJECT MANAGERS

The wave of new agile PM approaches has caused a paradigm shift from predictive project lifecycle to adaptive project lifecycle (Nerur et al., 2005). Each lifecycle contains one or more project phase associated with the development of the product, service, or result. These phases may be predictive, iterative, incremental, adaptive, or a hybrid of predictive and adaptive.

In predictive lifecycles, according to Nerur et al. (2005), changes to the project scope, schedule, and budget can be determined during the early phases of a project lifecycle. These triple constraints can be carefully managed. Iterative lifecycles determine the project scope early in the project; the schedule and budget estimates are routinely modified. Incremental lifecycles produce the deliverable through a series of iterations that add features and functionalities to meet customers' needs within a predetermined timeframe. Adaptive lifecycles are agile, iterative, or incremental. The detailed scope of this lifecycle is clearly defined and approved before the start of an iteration. This is the agile or change-driven process (Project Management Institute, 2017a).

The hybrid of predictive and adaptive lifecycles considers the aspects of the project that have fixed requirements to follow a predictive lifecycle; evolving aspects of the project follow an adaptive lifecycle (Cervone, 2011; Nerur et al., 2005; Serrador & Pinto, 2015). Overall, the PM team, with the leadership of the project manager, determines the best lifecycle for each project. Regardless, the project lifecycle needs to be flexible to accommodate the variety of business environmental changes.

How can project managers leverage Industry 4.0 in managing agile projects through adaptive lifecycles? This is possible due to the benefits of connectivity and advanced computing power, which is the main idea behind the fourth industrial revolution (Lasi et al., 2014). According to Almada-Lobo (2015):

…manufacturing equipment will turn into cyber-physical production systems (CPPS)—software enhanced machinery, also with their own computing power, leveraging a wide range of embedded sensors and actuators, beyond connectivity and computing power. (p. 17)

This means that Industry 4.0 has the potential to give way to mass customization. Each product at the end of the supply chain has unique characteristics defined by the end user.

SOLUTIONS AND RECOMMENDATIONS FUTURE STUDY

The purpose of this chapter looks beyond what currently exists in agile PM. It imbeds knowledge and understanding of agile approach frameworks to create successful, horizontal discussions in managing and executing projects in the fourth industrial revolution. Based on extensive review of the literature the study revealed that organizations, after identifying the necessary agile approach, are willing to try several techniques. It is also recommended that organizations should allot time between each project phase to identify high-end quality services and/or processes derived from least cost. In summary, organizations considering adapting an agile approach should focus on a key problem, implement an agile approach best suited to solving their problem, and keep moving forward (Fewell, 2017). As for future study, the researchers recommend replicating this study by applying a phenomenological research design with an appreciative inquiry approach. According to Heidegger, Stambaugh, and Schmidt (2010), this design would allow participants to be engaged in such a way that would allow them to offer their lived experiences in response to the research questions (Creswell, 2014).

CONCLUSION

The fourth industrial revolution, or Industry 4.0, has advanced digitalization with the combination of Internet technologies and future-oriented technologies in the field of smart machines and products (Pinkham, 2017). These advancements have led to a paradigm shift in business management, particularly PM. Agile PM integrates tools and templates applicable to various agile processes (i.e., waterfall, scrum, Kanban, and lean) while leveraging the benefits of technological advancements delivered by the fourth industrial revolution.

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KEY TERMS AND DEFINITIONS

Agile Methodologies: A framework with four ideologies: (1) response to change; (2) adaptive planning; (3) speedy delivery; and (4) constant improvement. This project management approach is implemented through software development.

Cloud Computing: An Internet service platform (generally, a pay for storage).

Cognitive Computing: A system that analyzes data by looking for and identifying potential conflicts, patterns, solutions, and suggestions.

Cyber Physical Systems: A system used to manage projects like robotics, cloud computing, and other autonomous frameworks.

Industry 4.0: Referred to as the integration of computers and automation, Industry 4.0 is the meeting of autonomous computer systems.

Project Management (PM): Application of tools, templates, and skills to ensure that an organization achieves a predefined objective within budget, scope, and schedule.

Software Development: A set of processes used for testing, designing, conceiving, and fixing frameworks and/or other software applications and components.

Waterfall: First introduced in 1970 by Dr. Winston W. Royce, this software development uses a particular cascading of steps.

Chapter 2
How to Manage Projects in Industry4.0 Environment:
Aligning Management Style With Complexity

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ABSTRACT

With the increased complexity in technology, projects are becoming more complex, and their outcomes are hard to predict. As we are entering the Industry 4.0 revolution, the complexities associated with technology will likely to increase to unprecedented levels. The main motivation of this chapter is to understand the link between the complexities associated with the projects and the project management style in dealing with these complexities. In this study, the project management style is defined as a dominant paradigm that a manager uses as a mental model in dealing with the management problems. The chapter investigates the effects of the alignment between project management style and project complexity on the project management outcomes. The implications of this research are that with the increased complexity as in the case of Industry 4.0, the project management approaches will need to become more agile, with shortened planning horizons and more involvement and communication with the stakeholders.

INTRODUCTION

Human history witnessed constant change over the millennia and the speed of change has been accelerating over the last couple of hundred years, mainly due to the scientific and technological advances starting with the first industrial revolution. There are two main views of change when regarding the human technological development (Agassi, 1973). The first one is the continuous view that sees the human development a constant change and the other one is the discontinuous view according to which the

DOI: 10.4018/978-1-5225-7865-9.ch002

change happens in a discrete, discontinuous manner as humans invent or innovate new solutions. Agassi (1973) posits that most historians take a hybrid view that there are both discontinuous and continuous change in human history. In reality there are usually a continuous change or development following a discontinuous change. And when several of these related discontinuities happen at the same era, they might cause a radical change in the society that we call revolution. Yoder (1926) defines a revolution as a radical change in society based on prior deeper changes in the human thinking. Even though the term has been mostly used in the political context, it has been applied to wide range of areas from agriculture to industry, to theology. Over the millennia humans achieved many revolutions in production, but the term, industrial revolutions, is applied to relatively recent periods in history where the confluence of enabling technologies instigated changes in industry and in overall society as first seen during the 8th century.

There has been almost universal consensus on the number of industrial revolutions to date in modern era (Vilenius, 2014). Industrial revolutions do not happen in vacuum, they are usually based on the accumulation of technology and knowledge of the previous eras. An industrial revolution is a juxtaposition of several disruptive innovations whose combined effects were far greater than the single innovation would have created. For example, the first industrial revolution started in textiles industry with the invention of flying shuttle that made weaving easy, spinning jenny that increased the productivity of yarn production exponentially and cotton gin, which mechanized the cotton production and to drive these machines the steam power.

Three industrial revolutions to date took place in stages starting from late 18th century to late 20th century and each of these revolutions caused great transformations in technology, culture and society Vilenius (2014). Also aligning the industrial revolutions with Kontradieff waves, which are long term economic cycles first theorized by Soviet economist Nikolai D. Kondratieff, Vilenius (2014) posits that humanity is at the beginning of the fourth industrial revolution.

Ever since the dawn of humanity, projects have been parts of human experience as societies evolved through creating artefacts for different needs. Some of these artefacts can still be seen in historical remains of old civilizations. A project is a planned, unique undertaking first conceptualized inside a human brain, then set to motion to achieve the intended outcomes. As projects are common in history, managing projects has always been a crucial job within societies. Even though the term project management is relatively new, there have always been people responsible for the management of the projects regardless of the era the project was undertaken. As the technology complexity increases, the outcomes of projects get more uncertain and project management discipline evolves.

In pre-industrial societies artisans and tradesmen were organized around trade organizations called guilds. At the top of this system there were masters, who by definition owned the business and employ other artisans. The aspiring artisans were educated and trained through apprenticeship and became journeymen within a trade guild. Until the first industrial revolution all major human projects were managed through master-journeyman-apprentice system. In a project managed by a master artisan, the patron or the customer provided the financing and the project would continue as long as the financing continued. The masters developed the projects, planned and hired other artisans. In the pre-industrial era, the scope of the project is determined by the mastery or the experience of the master who undertook the project. They are the technical and administrative leaders of the project.

The first industrial revolution started in England with the advent of mechanization with water power and later steam power to drive the machines in textiles industry. The major outcome of these advances was the unprecedented growth in productivity in manufacturing, that had further social, political and cultural consequences first in Britain, then all over the world. First time in human history, economies began to transition from an agrarian to industrial. Old mercantilist economy gave way to capitalist economy that is still dominant in the world. Prior to the first industrial revolution, private enterprises and their financing was not common. But the new capitalist economy was driven by the investment private citizens whose primary goal was to get the highest return of their investments.

In this first phase of first industrial revolution, financing the new projects was not a big concern as the new projects almost always promise increased productivity thus increased returns. In this environment the biggest constraint is the scope or the technical requirements as sometimes the technologies required for the project could have yet to be developed. The old apprentice-master system gave way to formal education of trades and further academic degrees. In the beginning of 19th century first engineering school was opened at the West Point Military Academy in US (Kozak-Holland, 2011). Also the production systems required the further specialization of jobs. But the management was still considered and art rather than a science. Even though the technical knowledge was based on academic studies rather that apprentice-master training, management of projects were similar to the previous era, the projects were managed by the most experienced technical administrator in the organization, and this would continue for another century.

The second phase of the first industrial revolution began around 1840s first with the proliferation of railroads and later invention of steel making. In 1830, the first commercial steam powered railway between Liverpool and Manchester and the other routes followed (Kozak-Holland, 2011). The development of steel making further expanded the horizons of railroad projects all around the world. The main characteristics of railroad projects were the availability of financial resources, scarcity of labor for the projects, no time constraints but sense of urgency. During this period the first project managers emerged among the ranks of railroad engineers. The most notable railroad project of this era was the Transcontinental or Pacific Railroad project, first advocated by T.H Judah (1857). In his essay promoting the need for the project Judah used the term project 24 times (Judah, 1857).

During the first phase of the second industrial revolution, the driving technologies were the electric and chemical technologies. In production, the batch production method of the first industrial revolution gave way to assembly line mass production. This phase witnessed the transition of project responsibility from the domain of the technical administration to the experienced project manager as in the case of the Panama Canal project. During this project, managers were assigned not only for their technical skills but also for their managerial skills. This period also witnessed the birth of the scientific management discipline and the first tools of project management discipline still used today like Gantt Charts. These tools and techniques would play very important roles in the establishment of project management discipline.

The second stage of second industrial revolution began with the great economic depression of 1930s, followed by the Second World War, during which massive undertakings and mobilizations like Manhattan project and D-Day operation in Normandy consumed enormous amount of resources, involved hundreds of thousands of people and required highest level of leadership and coordination (Morris, 1994).

Based on the experience and knowledge gained during the 2nd world war, early methods of project management like CPM and PERT which are emerged during the 1950s during cold war where both sides rushed to develop nuclear arms and space technology. During the early stages, project management discipline was mainly based on the Taylor's deterministic scientific management.

During 1960s, project management became an accepted management discipline with new project management tools like work breakdown structures and precedence diagrams. The crowning achievement of new project management discipline in this era is the massive undertaking of sending men to moon. Also during this era, the Project Management Institute (PMI) was established.

Third Industrial Revolution started with the proliferation of computer technologies by 1970s-80s and can be defined by the automation of production and globalization of communications, transportation, trade and industry. During the 1970s and 1980s, the project management discipline continued to proliferate and became a mainstream established with courses and programs in academia as well as certification by professional organizations. Also during this era, advances in computer technologies led to computer based project management systems and application of information technology (IT) projects to new organizational areas in order to increase effectiveness. As the first industrial revolution emphasized batch production and the second industrial revolution the mass production and economies of scale, third industrial revolution gave way to lean production systems originated first in Japanese auto industry, later spread over the world in many other industries. The main principles of lean thinking are adding value through eliminating waste in the production value stream and continuous improvement. The importance of lean would extend beyond the third revolution, as the digital transformations required later in the fourth industrial revolution would also depend the lean management principles extensively.

Starting with 80s, the project management started to transcend beyond its traditional engineering and technology applications and turned into an instrument for organizational change and improvement. Another significant development in 1980s was the introduction of iterative rather than traditional sequential project management approaches that would eventually lead to agile methods as we know today (Gilb, 1985, Boehm, 1986). During the same time, inspired by the continuous improvement teams of Japanese auto companies, Takeuchi and Nonaka (1986) proposed an iterative approach to product development projects which involved "the constant interaction of a hand-picked, multidisciplinary team whose members work together from start to finish" (p 138) like rugby game as opposed to traditional sequential approach where "a product development process moved like a relay race, with one group of functional specialists passing the baton to the next group" (p 137). 1990s witnessed further development of agile methods like rapid application development (RAD), extreme programming and Scrum. Theni at the start of the new millennium, (Beck et al., 2001) published Agile Manifesto which led to the growing dominance of Agile methods among IT and software development projects. Initially agile methods were most suitable for the small scale software projects, but as the benefits of agile methods became apparent agile methods for large project like Large Scale Scrum and Scaled Agile, paving the way for agile approaches to proliferate beyond software application development projects.

Since its first manifestation at the at the industrial fair in Hannover, Germany in April 2011, the 4th Industrial Revolution or Industry 4.0 has become one of the main themes of academic discussion across a wide spectrum of disciplines (Mosconi, 2015). The main theme of the fourth industrial revolution is the connectivity of systems and components (human to human, human to machine or machine to machine) within a supply chain sharing digitized data and information using cyber physical systems, internet of things (IoT) and internet of services (IoS) (Roblek, et al., 2016). The purpose of such a connected system is to respond to customer requests (primary data point) quickly and in a cost effective manner irrespective of the size of the order, thus staying profitable even with a lot size of one (Brettel et al., 2014). Lasi et al. (2014) classifies the triggers for the fourth industrial revolution as application pull and technology push. Application push triggers are (Lasi et al., 2014):

- Short development periods (time to market)
- Individualization on demand: Buyer's market leads to an increasing individualization of products
- Higher flexibility in product development and production
- Decentralization, or leaner organizational hierarchies to ensure faster decision making

- Economic and ecological increase in resource efficiency

Technology pull triggers are (Lasi et al., 2014):

- Ever increasing mechanization and automation
- Digitalization and networking
- Miniaturization
- Lean and agile management philosophy

Projects and project management approaches evolved through the years and as a new industrial revolution is set to begin, it is natural to expect that the above-mentioned triggers will further sustain the evolution. According to Xu et al. (2018) the Industry 4.0 transformations not only require new information and communications technologies but also new business models and processes at intra- and inter-organizational levels. Even though there is great interest in the literature on the topic of Industry 4.0, there are very few studies about the projects and project management during 4th industrial revolution, and the ones that touched on the subject mention the need for new skills for project teams and managers in Industry 4.0 environment (Cerezo-Narvaez et al., 2017) or the new organizational patterns and designs to deal with increased complexity (Semolic and Steyn, 2017).

This chapter contributes the already scarce literature on Industry 4.0 project management by exploring how industry 4.0 environment will likely affect the projects and project management approaches using the empirical research on project management styles, project complexity and their alignment by Camci (2006) as a starting point. Camci (2006) proposes models for project complexity and project management styles and hypothesizes that as alignment of these two constructs improves project performance as seen in Figure 1. This chapter further explores how the model proposed by Camci (2006) would explain the evolution of Agile methods in the Industry 4.0 era.

BACKGROUND

Even though the managing projects has been part of human experience since the beginning of history and project management has been evolving in to a major management discipline with academic programs and professional organizations since 1950s, project failure has been a recurring topic in project management literature (Morris, 1994, Johnson, 2001, Antony & Gupta 2018). According Morris (1994) only 12 projects out of 1449 found in the public record in early 1980s were on or below the budget. In 2000s, a survey of prominent public sector and defense projects showed that some projects exceeded their early cost estimates by several orders of magnitude and some of them cancelled even after spending large budgets (Edwards, 2003). Standish Group's "Chaos Study", which is one of the most cited studies on project failures, reports that in average between 1994 and 2015, of all IT and software development projects 24.30% failed before completion, 47.50% completed but failed to achieve at least one main project objectives and only 28.20% became successful (Sirisomboonsuk et al., 2017). Although the credibility of Standish Group's "Chaos Study" figures have been challenged in literature (e.g. Eveleens, Verhoef, 2009), the above-mentioned project management failures in the literature at least supports the idea that projects are complex endeavors and outcomes are not certain.

Pinto and Mantel (1990) offer a classification of causes of project failures based on a project's life cycle stage; in the strategic or planning stage, the main factors are the project's mission or the initial goals and acceptance of the client, in the tactical or implementation stage the main failure factors in addition to client acceptance are ability to troubleshooting the plan, quality of the project team, availability of the required technology and expertise to accomplish the planned tasks and a detailed project plan for implementation. Poulymenakou and Holmes (1996) outline the factors affecting project failure as macro (organizational) level and micro (project) level factors; organizational factors are culture, planning, accountability, irrationality and evaluation and project factors are power and politics, user resistance to change and development methods. Using a similar but more detailed classification Butler and Fitzgerald (2001) proposes a model consisting of following factors: institutional context, project-related factors, process-related factors, user (customer) related factors. Scott and Vessey (2002) add external business environment as another failure factor dimension. Writing about software development projects, McLeod and MacDonnel (2011) propose a model with project content, development processes, institutional context and finally people and action as its main factors. Project content includes project characteristics, project scope, goals, and objectives, resources and technology, development process includes steps in managing the project and involvement of customer people, institutional context outlines the environmental and organizational properties, people and action category includes all the stakeholders and their interactions. And finally, further analyzing the model by McLeod and MacDonnel (2011), Lehtinen et al. (2014) conclude that the interaction of the four main factors mentioned above is also plays an important role in project failures.

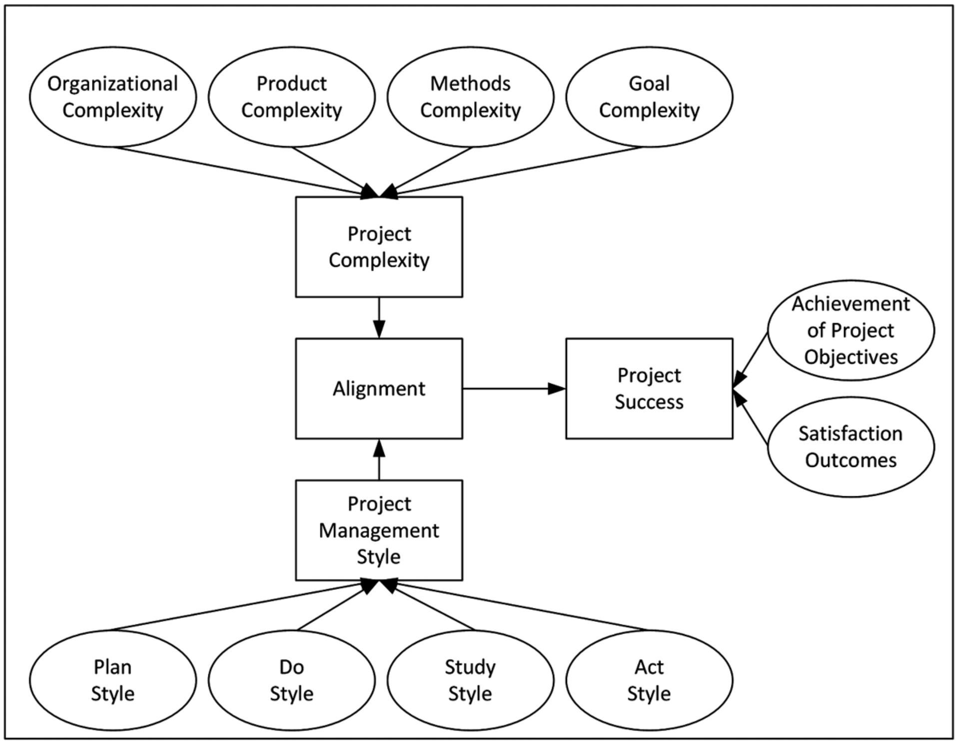
The models mentioned above incorporate project characteristics (organization, technology and goals) and how the project is managed in different failure factors. This chapter is based on the empirical research by Camci (2006). Camci (2006) posits that project characteristics (complexity) and how projects are managed (style) are two independent factors alignment of which leads to better project performance as shown in the research model shown in Figure 1. Camci (2006) hypothesized that as alignment improves, project performance also improves. After explaining the theoretical model for this research chapter further discusses the implications of this research for the new complexities of Industry 4.0 era.

PROJECT COMPLEXITY

Based on definitions of complexity by Fioretti and Visser (2004) and Baccarini (1996), Camci (2006) proposes a model for project complexity with four distinct sub-constructs: organizational, product, goal, and methods complexities. The main characteristics of each sub-construct are given as follows (Camci, 2006):

- **Organizational Complexity:** Camci (2006) outlines the main elements of organizational complexity summarized as:
- Size of the project: (McFarlan, 1981 (Baccarini, 1996)
- Number of the vendors/subcontractors (Baccarini, 1996)
- Number of units within an organization involved in the project (Baccarini, 1996)
- Number of dependent projects (Baccarini, 1996, Shenhar and Dvir, 2004)

Figure 1. Research model for alignment between project complexity and project management style (Camci, 2006)



- **Product Complexity:** Product complexity is the complexity related to the product that the project is supposed to deliver and conceptualized as consisting the following factors (Camci, 2006):
- Product novelty/newness (Clark and Wheelwright,1993; Shenhar and Dvir,2004).
- Number of product subassemblies (Baccarini, 1996; Tatikonda, 1999).
- Impact of change in design of a subassembly on to another subassembly (Tatikonda,1999).
- **Methods Complexity:** Similar to product complexity, methods complexity is the complexity related to the method that the project utilizes to produce its final product and conceptualized as consisting the following factors (Camci, 2006):
- Production technologies' novelty/newness (Shenhar and Dvir,2004, Tatikonda,1999)
- Number of production processes (Tatikonda,1999)
- Impact of a change in a production process on to another processes (Tatikonda,1999)
- **Goal Complexity:** Camci (2006) defines goal complexity as the complexity related to the goals of the project and conceptualizes as consisting fallowing elements:
- Number of the requirement changes (Turner and Cochrane, 1993),
- Potential impact of a requirement change on other requirements (Williams, 1993)
- Impact of not realizing the project's goals on the organization (Williams, 1993)

PROJECT MANAGEMENT STYLE

Adapting the definition by Rowe and Mason (1987), Camci (2006) defines management style as a paradigm that a manager uses when observing, understanding and responding to outside events and implementing their decisions. According to Kuhn (1962) paradigms provide templates and coordinate intellectual processes in problem solving. Camci (2006) proposes a project management style model with two main scientific paradigms of modern age, Newtonian and complexity paradigms, affecting the management of different phases of the project management defined by the plan-do-study-act (PDSA) cycle proposed by (Kotnour,1999).

As other management disciplines, early project management has its roots in the scientific management theories which are based on the deterministic Newtonian paradigm (Koskela and Howell, 2002; Wheatley, 1999), which has been the dominant scientific paradigm since Newton and Descartes (Wheatley, 1999). Project management concepts like work breakdown structure, discrete task that make up larger project deliverables and their linear relationships are all signs of Newtonian paradigm (Singh & Singh, 2002). The Newtonian paradigm views projects and its constituents as a machine and believes that studying the parts of this machine is essential to comprehend the whole (Brown and Eisenhardt, 1998). This mechanistic view ignores the projects' social and human aspects (Winter et al., 2006). Some of the key points of the Newtonian paradigm are as follows (Prigogine and Stengers, 1984, Dooley et al., 1995, Wheatley, 1999, Ottosson, 2003):

- **Deterministic:** Any future state of a system can be calculated by knowing the forces acting on the system and the initial conditions of the system.
- **Equilibrium and Control:** A system is supposed to be in an equilibrium state and to ensure this mechanism of control plays an important role.
- **Closed, Linear:** Newtonian systems are considered to be isolated from their environments and being linear, outputs are linear functions of inputs thus in a project one best solution can be achieved through planning and using right tools and techniques.
- **Reductionist:** Newtonian systems can be broken down into parts that can be worked on separately and put together afterwards to form the whole system again. The whole is the sum of its parts.

When the Newtonian Paradigm fails to deal with the increased complexity of physical systems (Mandelbrot, 1983, Maturana & Varela, 1987, Kauffman, 1995, Prigogine, 1996), the complexity paradigm emerged. Evidence of ever-increasing complexity of projects, sparked an interest in project management researchers and practitioners to apply the concepts of complexity paradigm to project management (Kiridena & Sense, 2016). In practice, the gradual transition to sequential to iterative project management approaches is a proof of acceptance of complexity paradigm in project management.

Main determinants of complexity paradigm can be identified as the nonlinear dynamic systems, the chaos theory and the complex adaptive systems. The combined influences of these three knowledge areas manifest themselves in the following key points pertaining to projects and project management:

- **Nonlinear Dynamic:** In nonlinear dynamic systems, there is no linear relationship between the inputs and the outputs thus outcomes are always unpredictable and systems are always changing (Lewin, 1992). Organizational systems exhibit main characteristics of the nonlinear dynamic systems (Millett, 1998).

- **Chaotic:** System outputs are highly sensitive to initial conditions (butterfly effect) and exhibit unpredictability over time, thus, long-term planning is very difficult. But in chaotic systems, pattern prediction is possible. Also, dramatic change can occur any time without warning.
- **Complex Adaptive:** Components of complex adaptive systems interact with each other in order to enhance their performance and the performance of the system of which they are a part of, in accordance with rules called schemas Stacey (1996). Organizations can be regarded as complex adaptive systems are learning organizations where the organizations get information and resources from the environment in order to survive (Dooley et al., 1995).

Camci (2006) conceptualized project management style as approaches to management of different phases of the project management characterized by the plan-do-study-act (PDSA) cycle (Kotnour,1999). In this mode Management styles of each phase of plan-do-study cycle are conceptualized as a continuum with the Newtonian paradigm and the complexity paradigm at its extremes Camci (2006).

Plan Phase:

- **Solution:** In Newtonian project management, a detailed final solution is possible, achieved through smaller transformations (Bardyn and Fitzgerald, 1999, Koskela and Howell, 2002, Herroelen and Leus, 2004). On the other hand, complexity paradigm threats projects as chaotic systems and rejects long term planning, thus initially a simple basic solution is developed and then modified during the project's life in iterations (Levy, 1994, Dooley et al., 1995, Bardyn and Fitzgerald, 1999, Schwaber and Beedle, 2002).
- **Involvement of the Customer:** In Newtonian project management the customer is not involved in the project after the requirements are established, on the other hand to mitigate the changes in the initial conditions, the customer is involved in the project through direct communications throughout project's life (Camci, 2006).
- **Project Plans:** Similar to the solution, in Newtonian paradigm projects are not revised once completed and agreed upon, where as in complexity paradigm project plans are revised iteratively (Bardyn and Fitzgerald, 1999, Schwaber and Beedle, 2002).

Do Phase:

- **Assignment of Tasks:** In Newtonian projects a central authority usually project manager assign tasks to team members, in a complexity paradigm project, project team collaborating with project manager determine which tasks they will undertake (Koskela and Howell,2002, Schawaber and Beedle, 2002).
- **Information Flow:** Newtonian project management periodically collects information on a limited number of project variables, whereas complexity paradigm requires just-in time information about the progress of the project (Bardyn and Fitzgerald, 1999, Koskela and Howel 2002, Schawaber and Beedle, 2002).
- **Execution:** In Newtonian projects, the main task of the project manager is to direct the project team members and ensure that their assigned tasks are completed as planned. Complexity paradigm project managers work with the top management, customer and the project team in order to eliminate any impediments to the project's progress, instead of directing the team members (Koskela and Howell, 2002, Schawaber and Beedle, 2002).

Study Phase:

- **Monitor:** In Newtonian projects project management collects the status reports from the team members. In complexity project management, team members report the status of their tasks continuously (Koskela and Howell, 2002, Schawaber and Beedle, 2002).
- **Analysis:** Newtonian project team members do not scrutinize the causes for failures to accomplish their tasks. Complexity project team members analyze and report the causes for failures (Bardyn and Fitzgerald, 1999).
- **Communication:** Newtonian project management does not require the project team share information about the progress of the project with the organization and the customer unless being asked to do so. Complexity project management on the other hand requires the project team regularly report the progress of the project to the organization and the customer. (Schawaber and Beedle, 2002)

Act Phase:

- **Plan Revision:** Since Newtonian project management is deterministic, the project plans are seldom changed after set, thus lessons learned during the project have no effects on the project plans and any deviations from the initial plans are fixed with additional resources. Complexity project management is complex adaptive, so lessons learned during the projects life regularly incorporated in the revised plans. Schwaber and Beedle, (2002)
- **Project Team:** Once set project team structure and roles of the project team do not change in a Newtonian the project. Conversely, complexity project management allows the project team to change its structure and the roles to adapt to the changing project conditions (Schwaber and Beedle, 2002).
- **Lessons Learned:** Newtonian project management does not require the organization document, keep and share the lessons learned during the project. Complexity project organizations are learning organizations and should document, keep and share the lessons learned within the organization (Dooley et al., 2002; Harkema, 2003).

EVOLUTION OF PROJECT MANAGEMENT FROM NEWTONIAN TO COMPLEXITY PARADIGM

From its start as a management discipline in 1950s till 1980s the dominant paradigm in Project management discipline has been the Newtonian paradigm and its most evident in the primary tools used in the discipline. The first and most popular project management tool, the Gant Chart, developed by Henry Gantt in 1910s, is basically a deterministic view of the whole project plan and assumes the information to be complete and the outcomes can be predicted from this information. Based on the same assumptions, the CPM method and project network diagrams are also deterministic tools is used in project planning. The first deviation from the deterministic model in this era is the PERT method which incorporates the uncertainty in the form of variation in the project planning. In PERT method each task is assigned an optimistic, a pessimistic and a most likely time duration and using these three different time estimates for each task in the schedule the method calculates an expected duration and the standard deviation for the project. The main drawback of PERT method is that it only deals with variation in schedule but not higher-level uncertainties like risks and unforeseen events. Mechanistic models accept variation in the system where they simply use negative feedback to control the system (e.g. thermostat). Thus, PERT by its nature is mechanistic and Newtonian. The final Newtonian tool from the early days of project management is the work breakdown structure (WBS). WBS is truly mechanistic and reductionist as it divides the whole into manageable portions where the sum of the parts is equal to the whole of the system (Milosevic, 2003, Singh and Singh, 2002). This deterministic view persisted till the end of the century and waterfall method, emerged during 1980s, is also another example, for it uses a linear approach for developing software projects. Waterfall method assumes a linear non-reversible development process in stages where once a stage is finished its outcomes become fixed and next stage is based on these outcomes. Any unforeseen changes in these outcomes require costly reworks.

1980s also witnessed the start of the shift from Newtonian paradigm for project management discipline. By this time, it has become evident that traditional Newtonian project management tools cannot model the dynamic unpredictable nature of projects. The first tool emerged based on this premise was Earned Value Management (EVM). EVM uses the structures provided by the previous Newtonian tools but uses dynamic monitoring of the project schedule performance to predict the outcomes. This tool, still deterministic, manifest that the projects are dynamic, and prediction using, initial estimates are impossible. Another method using a dynamic approach on a Newtonian system is the Critical Chain Project Management methodology which employs buffers to accommodate the variation and uncertainty in the project plan. The method requires the dynamic monitoring of the buffers rather than the tasks as done in EVM.

All the methods mentioned above exhibit the main characteristics of Newtonian paradigm; linear (sequential), deterministic and reductionist. Based on this knowledge base, the standards of project management (PMI, PRINCE) were established. But the main shift to complexity paradigm started in 1990s with the introduction of agile methodologies in software development. The complexity paradigm characteristics that set the agile methods separate from the Newtonian methods are as follows;

- Agile methods are iterative, thus incorporating non-linearity. In nonlinear systems it is easier to predict short time horizons than the long ones.
- Another consequence of being iterative and learning from each iteration is a sign of complex adaptive systems.
- Agile methods take an open-systems view thus including customers and other stakeholders is crucial for the success of the project.

ALIGNMENT AND PROJECT PERFORMANCE

According to DeMeyer et al. (2002), project managers should align their management styles to different levels of project complexities, balancing between planning (Newtonian paradigm) and learning and adapting (complexity paradigm). Camci (2006) defines organizational alignment as arranging at least two organizational dimensions relative to each other, such that these dimensions will work together harmoniously and accomplish perfect results. Camci (2006) investigated the alignment between project management style and project complexity using the matching perspective according to which alignment is achieved when the research variables match with each other (Venkatraman, 1989). In this model

Camci (2006) conceptualizes alignment as a separate variable as a function of project complexity and project management style, as the absolute difference between these two variables gets smaller alignment increases and vice versa.

Camci (2006) developed new measures for project complexity and project management style in order to test the research hypothesis;

Alignment of project management style to project complexity leads to increased project performance (Camci, 2006, p 79).

According to this hypothesis, in order to achieve higher performance Newtonian project management style should be limited to low complexity projects and for high complexity projects, the best approach is complexity project management style (Camci, 2006). Correlation analysis reveals that there are significant positive correlations between alignment and project performance. Thus, the research hypothesis was supported (Camci, 2006).

SOLUTIONS AND RECOMMENDATIONS

The research by Camci (2006) is relevant for project management discipline during the fourth industrial revolution, as the business and project environments are going through a big transformation as it is often referred to as "digital transformation". First of all, almost all industrial organizations will have to go through this transformation in order to stay competitive and participate in this environment. This means, there will be large number of transformation project of any sizes and will require knowledge and skills unique to this era.

This transformation will have profound effects on both projects in terms of complexity and the way they are managed. In terms of complexity, Industry 4.0 technologies and trends will likely to influence the project complexities as follows,

- **Organizational Complexity:** One of the key concepts of Industry 4.0 is integration in value creating networks (Lasi et al., 2014), connecting suppliers and customers with in a supply chain. This integration will get different organizations work on a single project or a series of projects which can be very small and very large, involve many organizations act as suppliers or vendors and also customers, and many organizational units.
- **Product Complexity:** During Industry 4.0 transformation the time to market products will be short, which means companies will have to develop new products faster and more frequently. Coupled with the transition to smart products, cyber physical systems and integration the product complexities will most likely be higher.
- **Methods Complexity:** Industry 4.0 require real time data collection and analysis through smart sensors, internet of things and artificial intelligence. These technologies will make processes simpler and easier to monitor. Because that artificial intelligence will eliminate many repetitive and routine jobs, those processes will not add to the overall methods complexity.
- **Goal Complexity:** As the number of project stakeholders due to the integration of companies will increase, number of in requirement changes and their effects on each other will also increase. This

couples with the impact of a failed project on one or more organization will likely make the goal complexities higher.

In terms of how projects will be managed, Camci (2006) showed that, in such a complex environment, successful project delivery using classical project management methods that are based on mechanistic and deterministic Newtonian Paradigm is not very likely. Based on the project management style construct by Camci (2006), the main recommendations for project managers in Industry 4.0 era are as follows:

- Instead of a detailed final solution to be implemented in a single step, a simple basic solution should be developed and later be modified in iterations during the project's life. Iterative development has been the main characteristic of agile methods, so this development philosophy will likely to continue in the new era. Comparing the recommendations by Camci(2006) to the original 12 principles laid out by Agile Manifesto by (Beck et al., 2001), one can see that in principle they are very similar, only difference is that, main focus of the Agile Manifesto is a small project team delivering a single software project team. Early agile methods were intended for small projects, but as the advantages of agile systems became widely recognized, new methods are being developed for larger scale projects like Large Scale Scrum (LeSS) or Scaled Agile Framework (SAFe) (Vaidya, 2014). Therefore, as the complexities of Industry 4.0 era became more apparent, new agile approaches will gain more acceptance.
- The customers should be involved in the project throughout its life. Customer involvement and taking customer change requests even in the late stages of project development is a crucial part of agile method (Beck et al., 2001). As the customers and suppliers or contractors will be in an integrated relationship through IoT and cyber physical systems, the involvement of customers will be increased to a point where customers will be part of the project teams to deliver successful products.
- In parallel to developing solutions in iterations, project plans should be revised continuously. As agile accepts the requirement changes, these changes should be incorporated in plans, and plans should be revised in each iteration.
- Instead of a single authority, project team should decide which tasks each team member they will complete. Agile project management promotes self-organizing teams and trust for project team members. Self -organizing and complex adaptive characteristics will be central to industry 4.0 project teams.
- Project leadership should receive continuous data and information from the project team about the status of their tasks. Face-to-face communication with in a project team is the norm in agile project management. This hold true for small projects. But as the projects gets bigger, Industry 4.0 technologies like IoT, clout base computing and AI will enable project teams share information both with in their respective teams and with other teams in the project.
- Instead of directing the project team and check if their tasks are completed, project managers should work with customers and stakeholders to remove any problems that might adversely affect the progress of the project. Customer collaboration instead of contract negotiations and individual interactions are important pillars of agile manifesto (Beck et al., 2001). Thus, from the start, agile values the collaboration and interaction over a directive type of leadership.
- Project leadership should receive real time information about the progress of the project. Responding change is another pillar of agile manifesto (Beck et al., 2001). In order to respond

change, project leadership should receive timely, continuous information from project team members. Industry 4.0 technologies like IoT, cloud computing, data analytics and AI are some of the industry 4.0 technologies that will enable team share real time information with leadership.

- Project team members should analyze and report the causes for the failures to achieve their assigned tasks. Being a part of learning and adapting organizations, project team members should be the first line in analyzing failures. Failures are learning opportunities that learnings of which will help project achieve better results in the subsequent iterations or individual projects. Cloud computing and big data analytics can provide capture and store information and AI can help analyze the causes of problems.
- The project team should regularly report the progress of their project to the customers and stakeholders. As part of the collaboration and being in an open integrated system, project team will have to share information about the progress of the project with customers and other stakeholders based on their access rights to the information. Cloud technologies, especially Blockchain will play an important role sharing secure data with the project stakeholders.
- The lessons learned during the project should be used in revising the project plans. One of the 12 principles of agile manifest to requires project teams to reflect upon the learnings to become more effective and adjust behavior (Beck et al., 2001). This will still be an important principle in the Industry 4.0.
- Project team should be able to change its structure and the roles to adapt to the changing project conditions. This recommendation is directly parallel to the self-organizing teams principle of the agile manifesto (Beck et al., 2001) and will still be a fundamental principle in Industry 4.0 era, albeit in larger scales when the scopes of projects get bigger.
- The lessons learned during the project should be documented, kept and shared within the organization. In agile projects, lessons learned are shared through agile retrospectives (Dingsøyr et al. 2018). But mostly face-to-face nature of this knowledge sharing can cause problems in keeping the knowledge within organizations (Dingsøyr et al. 2018). For small scale projects this problem may not be severe, but in Industry 4.0 environment, large scale projects will need more structured way of keeping and documenting retrospectives. AI tools like virtual assistants can handle this chore with minimal time commitment from project team members.

FUTURE RESEARCH DIRECTIONS

The aforementioned research by Camci (2006) provides starting points for future researchers in two tracts. One is the project management style construct, which will enable researchers to test theories on current and future project management methodologies like Scrum and Agile for the changing project management environment. Future researchers can expand the scope of the Style construct as the science involving complexity theories also evolves and add more dimensions to it or alter the construct structure altogether. Using project management style construct as a template, new project management tools and techniques can be developed incorporating Industry 4.0 technologies.

The second track is the research on project complexity. As the boundaries of project management expands with the new industrial revolution, so does the complexities associated with it. So, future research should take into account all the changes the Industry 4.0 brings into project management and reevaluate the construct based on these changes. For example, Industry 4.0 involves integration of companies at different stages of a supply chain, adding more levels in in organizational and goal complexities. Also, as a natural result of technological advancements process and methods complexities will be affected as well.

CONCLUSION

In the fourth industrial revolution or Industry 4.0, as we learned from the previous revolutions, projects complexities due to technological and organizational transformation will increase considerably. In order to deal with this new and extensive complexities project organizations should adapt more dynamic management styles as suggested by Camci (2006). Agile methods emerged during the last decades of the third revolution are good candidates for dealing with these complexities, but they were originally designed to handle small software projects involving small teams. As the numbers and the complexities of Industry 4.0 project increase, agile methods also have to evolve to accommodate the new realities. The already available and developing Industry 4.0 technologies like IoT, sensor technologies, cloud computing, AI, Blockchain, etc. will be very valuable to in developing new agile methods.

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Chapter 3
Industry 4.0 Technologies Used in Project Management

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ABSTRACT

Advancements in technology, especially ICTs, has caused a revolutionary change in every aspect of life. The reflection of these advancements on manufacturing industry is named "The Industrial Internet," or "Industry 4.0." New generation factories are to be equipped with cyber-physical systems. Teams integrating physical industrial components, and advanced modern sensing and networking technologies to form new smart systems. These systems will have more capabilities than the systems which are already in use. These winds of change will also affect projects and project management. Clearly, success in agile project management will become more crucial. At this point, technologies enabling Industry 4.0 will help project managers. Project organizations have the flexibility to get adapted to new situations fast. In this chapter, benefits of the technologies enabling Industry 4.0 in project management are introduced.

INTRODUCTION

Advancements in technology, especially ICTs, have given pace to a revolutionary change in every aspect of life. The reflection of these advancements on manufacturing industry is named "The Industrial Internet", or "Industry 4.0". New-generation factories or, with its commonly used name, "Future Factories" are projected to be equipped with cyber-physical systems. Project teams are integrating physical industrial components, machines, fleets, factories, artificial intelligence, advanced modern sensing and networking technologies to form new smart systems. These systems are designed to have more capabilities than the systems, which are already in use (PriceWaterHouse Coopers, 2016).

Evidently, the realm of project management would change considerably in such a wind of change. (Roblek, Meško, & Krapež, 2016; Thiry, 2013). The assumptions of mainstream project management approaches are very hard to maintain. Deterministic approaches are not applicable in highly volatile environments especially for complex projects with long durations. All critics of classical project management signify the importance of "learning-emerging" approaches, in other words, "agile" project management (Pajares, Poza, Villafañez, & López-Paredes, 2017; Whitney & Daniels, 2013).

DOI: 10.4018/978-1-5225-7865-9.ch003

Success in agile project management is crucial and would become more crucial in the future. Technologies, which form the basis to develop Industry 4.0, have the potential to create a productive environment for agile project management. This chapter intends to introduce how industry 4.0 technologies reshape project management practices and support the efforts of project teams becoming "agile" with examples from different industries. In the first section of the chapter, Agility in project management is presented briefly. In the second section, the introduction of technologies enabling Industry 4.0 exist. Examples for the use of each specific technology follow these introductions. The last section is the conclusion part where the author underlines the criticality of technology use in project management.

AGILITY

Before deepening the discussion on advanced technologies and their potential for improving agility in project management, the concept of "Agility" is revisited. Agile is defined as "ability to move quickly and easily" in dictionaries (agile definition Oxford Dictionaries, n.d.), it is "a time-boxed, iterative approach to software delivery that builds software incrementally from the start of the project, instead of trying to deliver it all at once near the end" in software industry (Rasmusson, 2018). The "Agile" adventure of the business world started with Agile Manifesto in 2001(Larson & Chang, 2016). Thus, it is better to keep in mind what Agile Manifesto tells us. If you visit the website http://agilemanifesto.org/, the message will see is given in Figure 1.

Authors of Agile Manifesto target software industry, yet their manifesto and the twelve principles behind it are very valuable for all other project-oriented industries. The importance of success in project management has already absorbed by the business environment. Yet failure rates are at still significant levels (Serrador & Pinto, 2015). When complexity, uncertainty, and time constraints are tight in projects, classical approaches fail, and projects end up with overruns. Projects need flexibility to be adapted to their ever-changing ecosystem and to cope with trouble (Alami, 2016). Inflexible project environment creates a chain of failure causes. Hence, identifying one simple specific cause of failure for any failed project is nothing more than looking for a scapegoat (Lehtinen, Mäntylä, Vanhanen, Itkonen, & Lassenius, 2014).

Figure 1. Agile Manifesto

Manifesto for Agile Software Development

We are uncovering better ways of developing
software by doing it and helping others do it.
Through this work we have come to value:

Individuals and interactions over processes and tools
Working software over comprehensive documentation
Customer collaboration over contract negotiation
Responding to change over following a plan

That is, while there is value in the items on
the right, we value the items on the left more.

Most of the causes of project failures are hidden in unfitting management approaches with project characteristics. In project management, the main question to be answered is "what is right management" rather than the misleading question "what is good management" (Sauser, Reilly, & Shenhar, 2009). The complexity and the scope of a project determines the typology. Management style coherent with the project typology leads to success (Shenhar, 2001).

Under these constraints "emerging" projects have more chance to succeed than "preplanned" projects (Williams, 2005). Therefore, managers from various industries are still in a search for better and "lighter" project management methodologies, which enhance customer satisfaction, efficiency, and overall project performance (Serrador & Pinto, 2015).

Agile project management deploys an iterative approach to product or service development providing some flexibility to the project team. Thus, during these iterations project team learns while the product emerges (Pajares et al., 2017). Rigid plans do not support learning in a project environment. Thus, practitioners generally prefer flexible scheduling approaches such as emergent planning, staged releases with the least possible in early stages, competing experiments, and alternate control in dynamic project environments (Song, Kim, Yu, Lee, & Lee, 2010). In projects with high complexity, adhering to initial project plan is riskier than being brave enough to change it in accordance with shifting conditions (Grove, 2001).

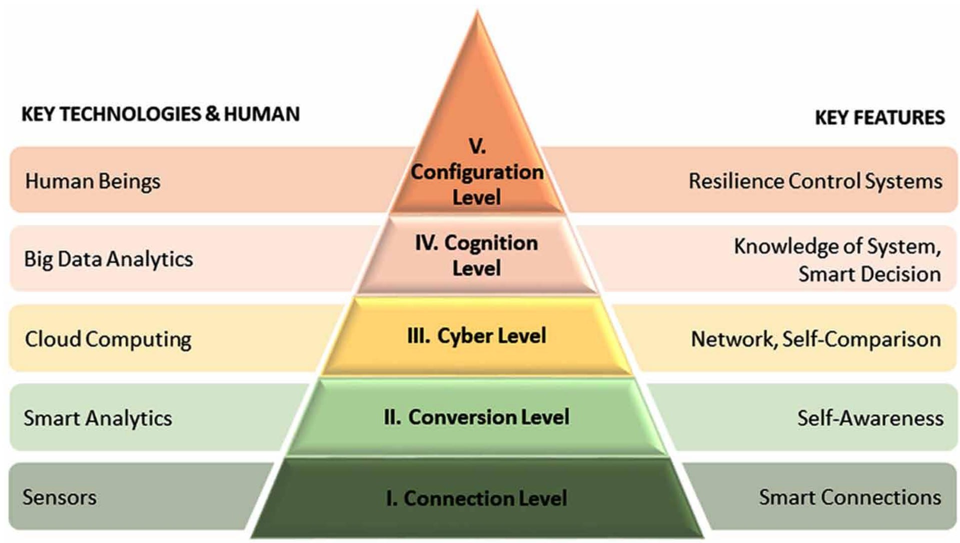
INDUSTRY 4.0 AND ENABLING TECHNOLOGIES

Industry 4.0 is the reformation of traditional industries by embedding advanced internet and communication technologies, and the creation of networks of machinery. The integration of artificial ability to sense into every aspect of life breeds accumulation of enormous data that is far beyond organizations can collect with classical tools (Li et al., 2017). Availability of huge amount of data empowers serious improvements in data analytics. New methodologies, which cannot work for small data sets are introduced to deal with big datasets. These improvements triggered the search for smart production systems (Roblek et al., 2016; Schmidt et al., 2015).

Industry 4.0 production systems are the products of technology intense projects. Project teams create these systems by bringing together a set of technologies. The technologies that industry 4.0 depends on are named as key enablers. These are big data, cloud computing, data analytics, internet of things (IoT) and augmented reality (AR) technologies (Li et al., 2017). Improvements in sensor technology, information and communication technologies, robotics, new materials, three dimensional (3D) printing, biotechnology are components of enabling technologies of Industry 4.0 (Pajares et al., 2017).

Accumulation of several innovations since the electrical revolution created feasible conditions for the realization of industry 4.0. RFID was first introduced in the 1940s. Innovations in artificial intelligence and digitization followed RFID in the 1950s. Until 2000s machine learning, the first generation of the sensor networks, 3D printing and the Internet of Things (IoT) were innovated. Since the early 2000s, we have witnessed improvements in cyber-physical systems, big data, and finally industry 4.0 (Li et al., 2017). Creating systems by integrating so many technologies is not a simple work. Similar to many IT systems, Industry 4.0 has its own architecture which is explained at five levels; in a bottom-up manner, these levels are "Connection", "Conversion", "Cyber", "Cognition", and "Configuration" levels (Lee, Bagheri, & Kao, 2015; Li et al., 2017).

Figure 2. The 5C architecture of the Industrial Internet
(Lee et al., 2015; Li et al., 2017)



Technologies and their use in project settings are introduced in the same order with the architectural levels of Industry 4.0.

Sensor Technology and Sensor Networks

In large project fields such as construction fields, monitoring outdoor activities is a serious problem. Successful applications enabled by RFID technology have created an expectation that the aforementioned problem can be solved. The RFID technology is capable of tracking objects, humans or animals within well-defined boundaries. But infrastructure investment of RFID is costly, therefore, its use in dynamic and temporary work settings is infeasible. A network of the smart object is an alternative to RFID system with lower investment and similar capabilities.

Any object can be converted into a smart object by embedding sensors and wireless capabilities in the object. These smart items can collect data from their local environment, process it, and react to it. They can exchange data with other smart devices or other IT systems through wireless capabilities. They enable a flexible system with enhanced capabilities (Kortuem, Kawsar, Fitton, & Sundramoorthy, 2010).

Both Wireless Sensor Networks (WSN) and the Internet of Things (IoT) are created by integrating the smart objects. IoT concept mainly refers to internet-connected objects. It covers devices, systems, and people. It forms the interface between the information system and the physical environment. It collects real-time data on events (Ghimire, Luis-Ferreira, Nodehi, & Jardim-Goncalves, 2017). Although WSN is referred to a network, it is not obligatory to be connected to the internet. The nodes, which refer as the sensors in the WSN are connected to each other. They sense, compute and send data for a specific purpose to a central server with low power. These nodes do not have an internet connection. In WSN, internet connection is used to gather collected information from the central server for further purposes. Applications are defined as IoT or WSN depending on whether the central server is connected to the Internet (Kocakulak & Butun, 2017; Manrique, Rueda-Rueda, & Portocarrero, 2016).

WSN and IoT systems are used in monitoring projects, and sensor technology stands at the heart of these systems. Sensors monitor our world, collect data in huge volumes, and enable connection between the physical world and the digital world. In general, size, power consumption, and cost of sensors have shrunk enough to embed sensors to everything that you can think of. Medical and healthcare, production industry, environment, wildlife, agriculture, logistics, household are some of the areas sensor technology is used intensively (Ayaz, Ammadu Din, Baig, & Aggoune, 2017).

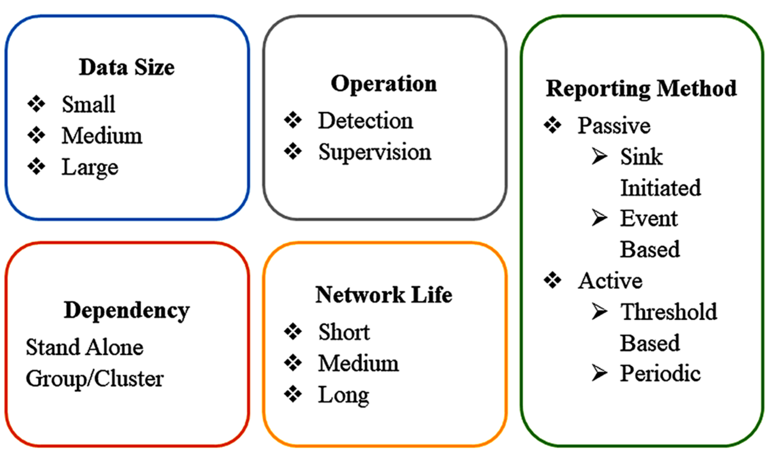
Sensors can be used in tracking all physical systems, but data requirements vary significantly according to the system behavior under consideration. There are different types of sensors available on the market. In Figure 3, the classification of wireless sensor applications is demonstrated (Ayaz et al. 2017; Introduction to Transducers, Sensors, and Actuators, 2009)

Project teams need to track the environment where their projects take place. WSN based solutions are commonly proposed for data collection purposes in outdoor projects. Construction projects and disaster management projects such as earthquakes, pollution, landslides, and forest fires demonstrate some examples of WSN based solutions.

Tracing the environmental parameter helps to reduce or remove the effects of disasters on the environment and the living things by providing on-time data to responders (Benkhelifa, Nouali-Taboudjemat, and Moussaoui, 2014). Disasters create highly dynamic and volatile environmental conditions. Predicting them early enough to prevent all of their devastating consequences is hard. In most cases, damages occur in infrastructure-based communication systems and deteriorate the existing situation. In such cases, wireless systems are more reliable in coordinating and management rescue efforts (Khalil, Khreishah, Ahmed, & Shuaib, 2014).

Time is crucial in the rescue and relief efforts. In highly populated areas, intense rescue efforts start right after the occurrence of a disaster. Availability of adequate information improves rescue capabilities. For example, in a water flooding incident data related to meteorology, topography, soil characteristics, vegetation, hydrology, settlements, infrastructure, transportation, and population are needed to take effective action. With the integration of data from different sources in a timely manner, the workflow can be organized dynamically, and reliable rescue and relief service can be provided (Liu, Webster, Xu, &

Figure 3. Classification of wireless sensor application
(Ayaz et al., 2017)



Wu, 2010). SENDROM (Cayirci & Coplu, 2007), SENEKA (Helge-Björn Kuntze, 2014), and INSYEME projects are proposed to improve the efficiency of post-disaster operations.

Sensor technology is used in the development of early warning systems as well. The WINSOC project aims to predict landslides during or after heavy rain. USN4D is developed to detect air pollution and provide early warning (Benkhelifa et al., 2014).

In construction projects, it is generally difficult to keep large-scale construction projects under control. Tracking project progress manually is time-consuming, and error-prone. It provides approximate results with a time lag (Ibrahim & Moselhi, 2014). Deploying sensor technology to construction side would provide an on-time tracking and accurate measures. Vehicles and supplies equipped with sensors collect real-time data from the construction site and track excessive vibrations, temperature fluctuations, and other potential maintenance indicators. Computer-based real-time monitoring of construction site allows more accurate cost control and tracks resource utilization while reducing waste (Lavelanet, 2017). Under the Smart Analytic title, how sensor data is used for tracking construction projects is exemplified.

Sensors contribute to scientific research as well. Information management is a critical component of research projects. As an example, North Temperate Lakes Long-term Ecological Research (NTL LTER) program has been going on for more than 30 years. Since its beginning, advanced technologies have been deployed to facilitate better information management practices, and data management processes have become as automated as possible within the capabilities of available technologies. Investments in sensor technology have enabled access to long-term, sensor data available online. Data is available to multiple groups for research and education purposes. This easy access to high-quality data helps researchers to develop new analytical tools, and R packages (Gries, Gahler, Hanson, Kratz, & Stanley, 2016).

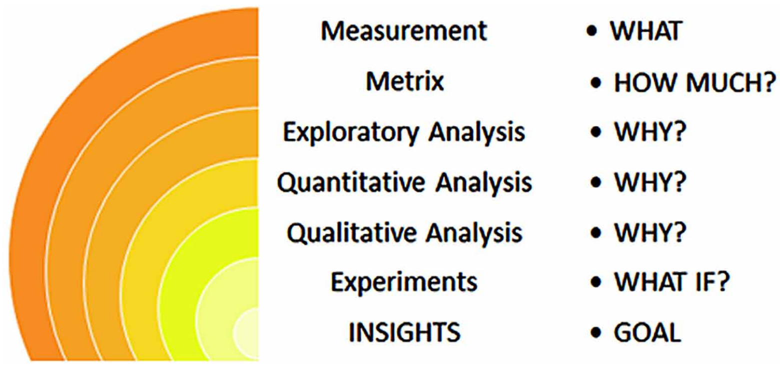
Smart Analytics

Data Analytics is described as “the systematic quantitative analysis of data or statistics to obtain meaningful information for better decision-making”. Notably statistical methodologies, operational research methodologies, Lean Six Sigma, and software programming form the basis of data analytics with other tools. Although data analytics sounds very similar to data analysis, these two terms have different meanings. Data analysis targets the status quo whereas data analytics is future-oriented. Data analytic tools are used in predictions or forecasts of an impending outcome. It helps project managers to make data-driven decisions (Singh, 2016).

Simple measurements do not provide much information to take action. In Figure 4, steps from measurement to insights are given. Yet, neither measurement nor data analytics provide the required insights. Project managers need to have the domain knowledge to interpret the results of data analytics. The managers who can use data analytics tool can derive the insights fast and easily (Buse & Zimmermann, 2011).

Singh lists the areas that data analytics can provide insights as feasibility analysis, project selection and prioritization, stakeholder management, schedule and cost follow-ups, risk management, and process improvement (2016). Additional to Singh’s list, Buse and Zimmermann define “evaluation of past decisions”, “the anticipation of changes”, and “tracking effectiveness of changes in process” as benefits of data analytics (2011). As it is detailed under Big Data title, handling huge amount of data is a problem for professionals who are not familiar with big data analytics. Smart analytic tools help project managers to manage the data they have, and dashboard applications demonstrate the big picture.

Figure 4. Paradigm of Analytics
(Buse & Zimmermann, 2011)



The complexity of data analytics may vary depending on insights to be derived, and volume and variety of data. The computational complexity of Big Data Analytics can be considered as the highest level (Singh, 2016). Nevertheless, the benefits that big data analytics may make it worth to deal with. Companies using big data analytics have already started to share their success stories.

Before continuing with the large data analysis in project management, Earned Value Analysis (EVA) supported by data analysis is discussed. EVA is a frequently used tool in project management for project monitoring and control. In EVA, actual progress is compared with project plan in terms of time and cost. Deviations from the plan are identified, and the completion time and the total cost of the project are predicted. It tracks the physical completion of projects. Unfortunately, EVA does not provide perfect predictions without accurate data. Assumptions replace reality and lead to unreliable results (Hazır, 2015; Meredith & Mantel, 2010). Smart data analytics overcome this problem of EVA.

Construction industry seems to be the pioneer industry that benefits from EVA supported by data analytics. In the construction industry, the Building Information Model (BIM) is used in automating project management. BIM has the capability to store data related to cost and quantity, and provide it to project participants. The software compares 3D geometries of the component with their design specifications and catches nonconformities. Feeding BIM with real-world data enhances its capabilities while simplifying project monitoring (Pazhoohesh & Zhang, 2015).

Use of digital twin is not limited to the construction industry. It is a new tool for product lifecycle management. Advanced digital twins let developers experiment the whole lifecycle of a real-world object (Devlin, 2018). Team Penke a professional car racing squad uses a digital twin of their racecar to innovate. They use sensor data to develop the digital twin so that the digital twin behaves as much similar to the racecar as possible. They try scenarios on the digital twin for justifying proposed improvement or innovation (Michael, 2018).

Artificial Intelligence

Since the first computer program, which solved calculus exam of MIT in the late 1950s, expectations from Artificial intelligence (AI) has never deteriorated. In the 1950s, people were imagining breakthrough technologies replacing human intelligence (Munakata, 2008), today they are worried about whether AI is going to surpass the capabilities of human beings (Keating & Nourbakhsh, 2018). None has happened yet, but clearly, AI is a promising research area and it has never lost its popularity. In the 1980s, it gained pace, and in 1990s early industrial applications were launched (Munakata, 2008). Scientists still spend their time to provide solutions for complicated real-world problems by developing and applying different AI methodologies. Thus, it is impossible to fully cover the AI subject in this chapter. The aim is to create an understanding of AI, and provide some examples of how it can assist project managers.

Before diving into AI solutions in project management, it is better to clarify what AI is. There are two commonly used concepts; computation intelligence (CI) and AI. These concepts may be confusing for beginners. Unfortunately, none of them has a generally accepted definition. Some experts are claiming that there is no difference but just a nuance. From this point of view, AI is a broader term, which consists of not only algorithms but also expert systems and formal logic; it is a search for neat solutions whereas CI covers the subjects Artificial Neural Networks, Evolutionary Computation, and Fuzzy Logic. These definitions are provided by IEEE (Kuhn, 2016).

Yet there are other definitions. Munakata categorizes approaches in AI as "traditional approaches" and "new approaches." According to the category definitions, the traditional approaches are symbolic in nature. High level of abstraction and a macroscopic view are the main characteristics of it. Knowledge-based systems, logical reasoning, symbolic machine learning, search techniques, and natural language processing are all categorized as traditional AI. In contrast, new approaches cover neural networks, genetic algorithms or evolutionary computing, fuzzy systems, rough set theory, and chaos. Low level, microscopic models form the basis for this second approach. The researcher does not give a definition for CI although he cited publications on computational intelligence in his paper (2008).

Xing and Gao use three characteristics to clearly separate AI and CI. From their perspective, AI deals with symbolic knowledge, uses high-level cognitive functions, and has a top-down operating manner while CI uses a numeric representation of information, and low-level cognitive function. It operates bottom-up manner. After this distinction, Xing and Bao split CI algorithms into two groups according to their level of acceptance. Well-known CI algorithms are gathered as conventional CI whereas relatively new and less-known algorithms are grouped as innovative CI (see Table 1). Innovative CI methodologies mainly address where conventional AI falls short (2017). Although researchers in this area use different terminologies, their classifications criteria, and the provided definitions are very similar to each other. Therefore, there is no need to feel bad or to get confused. Obviously, scientists need some time to reach a consensus about the terms. In the rest of the chapter, CI is not used, and definitions by IEEE are adopted.

Table 1. Computational Intelligence Paradigm

Computational Intelligence	
Conventional Artificial Intelligence • Artificial Neural Networks • Genetic Algorithm • Evolution Strategy • … • Multi-Agent System • Ant Colony Optimization • Particle Swarm Optimization	Innovative Artificial Intelligence • Teaching-Learning Based Optimization • Firefly Algorithm • Cuckoo Search • … • Gravitation Search Algorithm • Biogeography-based Optimization • Bat Algorithm

(Xing & Gao, 2017)

AI has the capability to mimic an analytic yet uncodified process after a sufficient amount of training. The advantage of applying AI in different areas originates from its ability to handle imprecise information, partial truth, and uncertainty (National Academy of Science, 1997; Xing & Gao, 2017). The intention of the development of artificial intelligence is to assist its users to perceive, reason, and act. Thus, it is such a large umbrella that covers many algorithms and addresses different real-world problems.

The techniques used in AI can be listed as artificial neural networks, evolutionary algorithms, fuzzy systems, multi-agent systems, and swarm intelligence. It is important to note that these techniques cover a number of algorithms thus the number of sub-categories of AI can be raised depending on categorization criteria (Xing & Gao, 2017).

The biggest issues in AI research are creativity. After sixty years of research, researchers in the area of AI still could not find a way to overcome the creativity problem of AI. The creativity that human intelligence has is the main distinguishing feature of it. Creativity does not belong to an elite group of people. All people are creative to some degree, and some of us are luckier than the rest (Boden, 1998). On the other hand, a creative artificial intelligence application has not been developed yet.

In near future, it is not expected AI to become creative, yet it has already started to assist human creativity in different ways (IBM, 2017). Here is an example from Century Fox. Selection of appealing scenes from a complete movie to patch a trailer is a long process; sometimes the selection process can take weeks. In 2016, IBM created a trailer for 20th Century Fox's horror flick, Morgan, by applying AI. The visuals, sound, and composition of hundreds of existing horror film trailers are used in the training process, and then AI chose scenes from the completed Morgan movie to be used in the trailer. With the assistance of AI, this long scene selection process is shortened to one day (IBM, 2017).

Another use of AI in project management is forecasting. Companies fail to get expected return on new product development projects due to unrealistic forecasts about duration and cost. In fact, classical scheduling techniques such as Critical Path Method (CPM) are deterministic methodologies and cover forecasting of neither activity duration nor cost. This approach fails to provide enough information on the profitability of projects. Intelligent systems are developed to fulfill this gap by using existing data to forecast activity time and cost (Relich & Muszyński, 2014).

Use of AI in a project environment has numerous application that this field of research is too large to summarize in one chapter. In this chapter, some examples are provided to be introductive more than informative.

Cloud Computing

Big data is just raw material. It becomes valuable when insights are derived by means of data analytics. Data analytics usually require a large amount of computing power. However, small-scale organizations do not have as much resource to dedicate to computing power that big data analytics necessitates. Even the companies that have enough resources to invest face technical problems due to technological constraints. Cloud computing provides the required computational power, and data storage capacity on-demand, which is affordable for all organizations (Marston, Li, Bandyopadhyay, Zhang, & Ghalsasi, 2011).

As a non-technical definition, cloud computing is "the ability to provide services on the internet". Internet services are replacing software running on personal computers. Users of cloud services access their data and the applications that they need as long as they have access to the internet; they do not need to store their data on their computer and to install any application that they use. Accordingly, cloud services eliminate the risks originated from hardware failures or breakages (Chovancová, Vokorokos, and Chovanec, 2015).

From a technical perspective, cloud computing is "a large-scale distributed computing paradigm driven by economies of scale, in which a pool of abstracted, virtualized, dynamically-scalable, highly available, and configurable and reconfigurable computing resources can be rapidly provisioned and released with minimal management effort in the data centers" (Sun, Chang, Sun, & Wang, 2011). Computer scientists have been working on distributed systems, grid computing, and parallelized programming longer than cloud computing exists. However, virtualization technology, which enables to run multiple virtual machines on a single physically-existing machine, enabled cloud-based business models. Running multiple virtual machines maximizes the utilization of hardware and flexibility, and accordingly increases the return on investment (Driscoll, Daugelaite, & Sleator, 2013).

Hashem et. al. defines the relationship of big data with cloud computing as "conjoint". Companies that use big data analytics gain competitive advantages. However, processing huge and heterogeneous data sets on personal computers is not possible; at least for today. Cloud computing provides a distributed data processing platform to process big data. Traditional storage systems such as hard drive, solid-state memory, object storage, and optical storage have scalability, expandability, and upgradeability problems. Cloud service provides scalable, expandable, upgradeable and affordable data storage on-demand (Hashem et al., 2015).

Cloud computing improves the manageability of large-scale, geographically distributed projects with complex organizational structure. The Adolescent Brain Cognitive Development (ABCD) study is the largest study of brain development and child health in the United States. The main goal of the project is stated as "integrate structural and functional brain imaging with genetics, neuropsychological, behavioral, and other health assessments to increase our understanding of the numerous facets of brain, cognitive, social, emotional, and physical development during adolescence". Another goal of the project is to provide valuable and reliable data to the research community. A consortium was formed to achieve the project goals and data collection process. Data gathering took ten years. During this period, professionals assessed 11.500 children from different sites of USA. During the project, this platform brought together more than 400 professionals from different disciplines such as child development, psychiatry, neuroscience, genetics, and public health. The ABCD study is an excellent example to demonstrate the place of cloud computing in a project environment. All the collaborators of the consortium are listed in Table 2.

Storage is not the only solution within the cloud environment. Providers deploy different service models to satisfy their customers. Most common models are infrastructure (IaaS), platform (PaaS), and software (SaaS) services. Customers rent processing, storage, networks, and other resources in the IaaS model. Customers build applications on existing libraries or development platforms when they rent a platform as a service. In the SaaS model, vendors provide applications such as e-mail service to customers, and customers use these applications online (Hwang, Kulkarni, & Hu, 2009; Khalid, 2010).

Cloud computing provides high computing power as well. Google is one of the companies that had to face big data challenges. The company had to find a way to handle big data, and in 2004, it introduced MapReduce framework to use existing computation power in a collaborative manner in order to take the advantage of existing computational capacity. Hadoop by Apache is an implementation of MapReduce framework. Apachi.org explains MapReduce/Hadoop framework as "a framework for easily writing applications which process vast amounts of data (multi-terabyte data-sets) in-parallel on large clusters (thousands of nodes) of commodity hardware in a reliable, fault-tolerant manner" (Driscoll et al., 2013; MapReduce Tutorial, n.d.)

Table 2. The participating organizations of the consortium

Directly Funded Sites	Data Analysis & Informatics Center	Federal Collaborators
University of Maryland SRI International University Minnesota Florida International University University of Pittsburg Medical University of South Carolina University of Wisconsin-Milwaukee Children's Hospital Los Angeles Oregon Health & Science University University of Utah University of California Yale University University of Michigan	University of California, San Diego **Coordinating Center** University of California, San Diego **Subcontracted Sites** University of Colorado Virginia Commonwealth University Washington University University of Florida University of Rochester Laureate Institute of Brain Research University of California, Los Angeles University of Vermont	National Institute on Drug Abuse National Institute on Alcohol Abuse and Alcoholism National Cancer Institute Eunice Kennedy Shriver Nation Institute of Child Health and Development National Institute of Mental Health National Institute of Minority Health and Health Disparities Nation Institute of Neurological Disorders and Stroke NIH Office of Behavioral and Social Sciences Research NIH Office of Research on Women's Health Centers for Disease Control and Prevention National Institute of Justice National Endowment for the Arts National Science Foundation

(Adopted from Auchter et al., 2018)

**For a more accurate representation see the electronic version.*

Hadoop is the most popular implementation of MapReduce framework, and it is an open source. It gained attention with the accomplishment in 2009; a petabyte of data and a terabyte of data are sorted in 16.25 hours and in 62 seconds respectively by using Hadoop, and this success was the new world record (Gupta, Gupta, and Mohania, 2012; Driscoll, Daugelaite and Sleator, 2013). Efforts to develop systems that are more efficient still goes on. At this point, in accordance with the goal of this chapter, it is more important to understand that cloud computing enables effective use of the computational power of multiple machines. Ability to process big data has made many research projects feasible that could not be realized without cloud computing and big data analytics (Driscoll et al., 2013).

Cloud computing enables collaboration among colleagues. Sharing documents and reflecting updates on time help multiple users to collaborate on the documents. This way of collaboration converts sequential processing to collaborative processes (Miller, 2009). Project management applications have moved to cloud as other desktop applications. With a simple internet search, you can find a number of cloud-based project management tools. Some of them have free versions letting limited budget projects benefit from advantageous of cloud-based services.

There are some cons of cloud computing as it has pros. Renting data storage is more advantageous than investing in hardware, yet it creates some risks. Different cloud architectures have different levels of risk depending on the structure of cloud-ownership. Security, lack of control, and reliability are serious issues to be addressed when choosing the cloud vendor and the cloud architecture. Private cloud architecture provides full control over the cloud as it is dedicated to only one customer. It minimizes the aforementioned risks but increases the cost. Companies can choose to host the cloud internally or externally. When the control and the use of cloud are shared by multiple organizations, it is named as community cloud. Public clouds are open to everyone who is interested in, and it is the most cost-effective cloud architecture from customers' point of view. In some cases, organizations prefer to combine these architectures to optimize the cost and the control and create a hybrid solution, which is named as "hybrid cloud" (Marston et al., 2011; Chovancová, Vokorokos, and Chovanec, 2015). Thus, the cost of cloud-based solutions decreases for companies as long as they are open to using shared resources. Companies, which benefits from cloud-based solutions, choose the providers that they trust to avoid the risks (Burda & Teuteberg, 2014).

Big Data and Big Data Analytics

Business intelligence (BI) is a data-driven process, which uses IT infrastructure and creates value by supporting decision-making in a way that regular reports cannot achieve. The value created by BI is hidden in the methodologies, which integrate and transform various type of data into information (Larson & Chang, 2016).

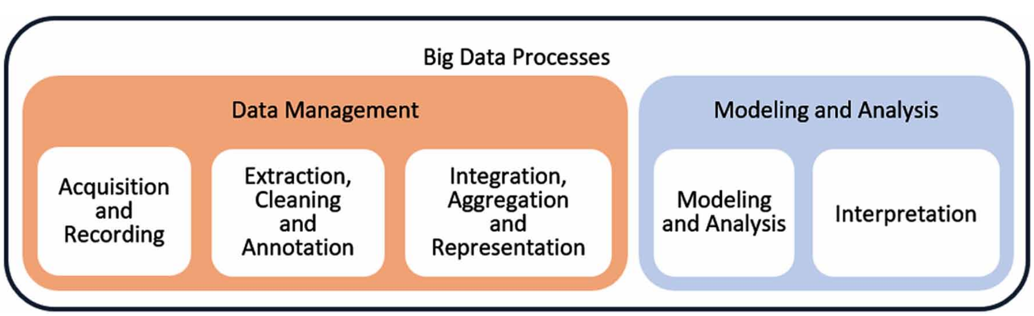
The Data Warehouse Ins. published a guide to instruct how to define the requirement in BI development projects by representing techniques to derive business insights. The guide also pointed out some common issues such as data reliability, and delays in reporting processes (The Data Warehouse Institute, 2009). Big data seems to overcome these two issues while opening doors to success opportunities for businesses (Xu, Frankwick, & Ramirez, 2016).

Big data is a kind of a buzzword; its boundaries are still ambiguous. Mainly five characteristics draw the line between data and big data; these are volume, velocity, variety, veracity, and value. Veracity is the latest characteristic means data assurance. It ensures the credibility of outcomes. Unlike the first three characteristics, value and veracity are results that are desired to be actualized (Demchenko, Laat, & Membrey, 2014; Raghupathi & Raghupathi, 2014).

Big data analytics is processing big data to uncover beneficial information and make data-driven decisions (Rouse, 2017). As the raw data is unstructured, big data analytics require a few more steps than the analysis of structured data. In Figure 5, steps from raw data to valuable insights are demonstrated (Gandomi & Haider, 2015).

Big data is valuable for the areas where the future is unknown and prediction is necessary, in other words, it works in every area. However, its effects on some areas are revolutionary. One area that big data revolutionized is marketing research. Here are the stories of two companies using big data analytics effectively in new product development.

Figure 5. Big Data Processes
(Gandomi & Haider, 2015)



Netflix is not only famous for its series but also its capabilities in applying big data analytics in innovative ways. For instance, Netflix forecasts whether a new pilot would be successful by analyzing real-time data from its viewers, and improves its creativity by using big data analytics. By collecting data of measurable attributes, they can provide personalized suggestions and content for their customer (Orcan Intelligence, 2012; Xu et al., 2016). The company tracks its viewers, understands their behaviors, and defines what characteristics of shows are attractive to its customers. They record customer logs that is a large amount of data such as how much time customers spend for selecting movies, who watches which shows, how often viewers stop playback, when they turned it off, who they want to see on their screens, which device they use etc. Therefore, their data is ready to tell what taste their customers are looking for. Accordingly, what attracts the customers is the product of these efforts (Atchison & Burby, 2016; Orcan Intelligence, 2012).

Speaking of Netflix, we should not skip the popular series on Netflix, "House of Cards". It is an extraordinary example enabled by big data technologies. What Netflix already knew was that people like Kevin Spacey, enjoy works of David Fincher, and were keen on the British version of House of Cards. Thus, they were ready to enjoy the combination of these three (Atchison & Burby, 2016). The success of "House of Cards" was not a chance, but it was an expected result supported by big data analytics.

Procter & Gamble, P&G in short form, is another company that aims to be "the most technologically enabled business in the World". P&G has 5 billion customers in total and it operates in more than 180 countries. The company uses the data from all these sources to improve its products and to optimize its operations (Rijmenam, 2013). A system developed by the company, they call it "Consumer Pulse", helps P&G employees to react to consumer comments in a timely manner. The system scans the universe of consumer comments, uses a methodology based on Bayesian Approach to sort the comments according to brand names, and delivers these comments to the relevant employee. A similar approach is used in product innovations as well. Robert McDonalds, ex-CEO of P&G, explains how P&G uses big data analytics in new product development. Reaching to customers with the desired demographic characteristics and setting up a consumer panel can be a costly and time-consuming task with classical marketing research methodologies. With big data, sample data sets, in other words, feedback or insights from the representative groups, is always available. Thus, consumer panels have become redundant for P&G.

The company shortens the design process by applying predictive analytics and simulations. Design of a disposable diaper costs thousand dollars when classical prototyping processes are executed. Instead of prototyping the designed product physically, P&G runs thousands of simulation iterations in a few seconds with considerably low cost. After introducing the scale of the company, McDonald states: "… Imagine all those data points. We can literally fit any virtual diaper to any baby anywhere in the world" (Chui & Fleming, 2011).

Another revolutionized area by big data is "Change Management". Companies such as Airbus and CERN use big data technologies in configuration management intensively. The complexity of products and long development periods of new designs obligate effective configuration management in both organizations. Airbus provides an opportunity to choose any variant of options to its customers. Moreover, the industry is highly regulated, and regulations keep changing. Thus, Airbus does not produce two identical aircraft; each aircraft is unique. For Airbus, developing a new design ends more than ten years; three years of this period is generally spent on congruence process. Each aircraft has millions of parts. A large number of suppliers and employee are involving in design processes. As an example, the A380 plane has nearly 2.5 million parts provided by 1.500 suppliers from 30 countries. Even these numbers demonstrate the complexity Airbus deals with (Whyte, Stasis, & Lindkvist, 2016).

CERN is using the largest and the most complex scientific instruments of our planet to search the fundamental structure of the universe. Besides scientific projects going on, installation of particle accelerator requires advanced project management skills. CERN is considered as a company in the nuclear industry. Therefore, it has to fulfill the obligations of nuclear installations. On the other hand, designing a particle accelerator is not a simple work. The design phase of The Large Hadron Collider (LHC) took nearly 20 years. Collaborators from 80 countries involved in this process. In the design and installation phases, the data flows from a large number of sources. Specifications cover physics parameters, technical specifications, layouts and equipment codes. The design team generates data by running simulations or creating documents such as a bill of materials, drawings etc. Data related to manufacturing processes, test procedures, and results come from manufacturing. During installation and safety procedures, "as-installed" documents are created. Dismantling is a highly regulated process and detailed documentation is required. Radiation measurements, material composition, recycling procedures, and waste management data are collected in the dismantling process. In short, both CERN and Airbus have to manage high volume and high variety data as well. Both of these companies use big data technologies to keep records and make product information available (Whyte et al., 2016).

Some spectacular examples that demonstrate the value of big data in project management, are shared in here. Of course, the number of examples can be enhanced. Nevertheless, it is more important to catch the main idea, and the main idea is project managers gain strength with big data. They monitor their system, fix the issues on time, predict the future, and behave proactively.

3D Printing

Additive manufacturing or 3D printing is accepted as a revolutionary technology in manufacturing. Instead of caving out of raw material or molding, 3D printers transform digital designs into real objects by adding successive layers on each other of a specific material. It improves design flexibility, mass customization, waste minimization, and manufacturability of complex structures. These abilities change the processes of manufacturing and logistics significantly. Therefore, 3D printing overcomes the constraints of subtractive manufacturing and outperforms it in many areas (Ngo, Kashani, Imbalzano, Nguyen, & Hui, 2018; Rayna & Striukova, 2016).

The technology changes the way of manufacturing radically. The range of materials that can be used for printing is already very large and continues to grow. Currently, printers printing plastics, nylon, metal alloys, ceramics, food, paper, and wood are available. Silicone, graphene, biomaterials, electrically conductive materials can be listed as emerging materials. Richness in materials, investments of large companies, and software availability facilitate the adoption of 3D printers. It is projected that 3D printing would disrupt many technologies and industries in near future. It would change business models, even lending and borrowing behavior (Patwardhan, 2017).

Unlike the other technologies discussed up to this point, 3D printing is firstly used in projects for rapid prototyping. Advancements in 3D printing technology let professionals use 3D printers for producing manufacturing tools and molds. For some cases, even producing the final product is feasible. With the launch of personal 3D printers producing products at home and avoiding delivery is possible to some extent (Rayna & Striukova, 2016).

The ultimate point of 3D printer technology is far beyond manufacturing. 3D printers have reformed many industries. One of these industries is the medical industry. From the point of healthcare professionals' view, each patient is a project with unique needs. 3D printing helps to satisfy these unique needs. Professionals print customized medical tools, surgical templates, pharmaceutical products, orthopedic grafts, even living tissues with viable blood-carrying capillaries (Roopavath & Kalaskar, 2017; Szondy, 2018).

Gluten Free Corner Project (GFCP) is enabled by food printing. Normally, it is risky to produce both gluten-free and ordinary foods in the same kitchen. Sharing the tools, appliances, and space increases the risk of contamination. Using 3D printers dedicated to celiac foods annihilate the risk of contamination (Francesca, 2017).

The aerospace industry is another example where 3D printing improves both project management and Product Lifecycle Management (PLM). Airbus example has verified the complexity of project management in the aerospace industry. Figure 6 (Romero-Torres & Vieira, 2016) demonstrates the place of additive manufacturing in PLM.

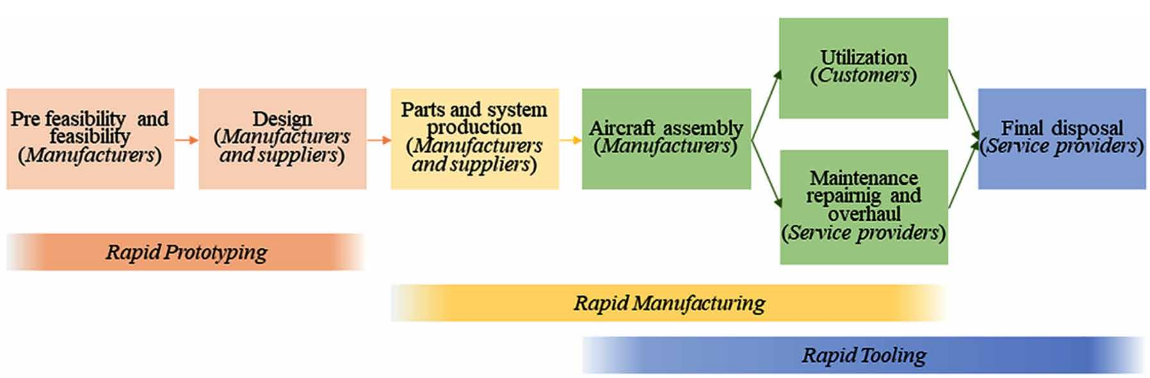
3D printers are used in the production of prototypes, hearing aids, dental implants, architectural models, educational objects, prosthetics and surgical guides, final parts, jewelry, customized objects, tissues, body parts for replacement, printed food, construction, 3D printed pills, and electronic circuits although the maturity levels of these applications vary significantly (Patwardhan, 2017). Thus, project teams may enjoy the advantages of 3D printing in different ways.

FUTURE RESEARCH DIRECTIONS

Project management has existed as a research area since the 1970s. Professionals in the area have accepted the cost, quality, and time as The Iron Triangle or in other words Triple Constraint of project success since then. However, the focal point of discussions around these concepts changes in time. For instance, discussions on planning and control have shrunk while project progress has gained importance. Consequently, decision-making and decision support have caught the attention of the professionals in the field (Pollack, Helm, & Adler, 2018). Thus, efforts to become "agile" in project management can be traceable in the scientific literature.

Project teams of today and future have to work in unstable environments. High competition, constrained resources, and many other factors make their life difficult. Under these conditions, they have to improve their capabilities to stay competitive. Using technology wisely is a way to improve agility, thus they should search for new ways to benefit from technology.

Figure 6. Aircraft PLM
(Romero-Torres & Vieira, 2016)



CONCLUSION

In this chapter, it is aimed to look at project management from a technology perspective. Experts developing systems based on advanced technologies are already aware of the significance of agility in the project environment. These people not only use technology to develop technological products or advanced production systems, but they also take advantage of technology to become agile. In this chapter, it is aimed to collect inspiring examples of the use of advanced technologies in project management. As the audiences of the chapter, do not necessarily have to have an engineering background, some introductive information on the technologies is also added.

The author wants to draw your attention to two concepts that are always popular in industry 4.0 discussions but not discussed in the chapter, ICT and Cyber-Physical Systems. ICT is a broader concept that covers more technologies than the ones discussed in this chapter (Lin, Lin, and Tung, 2016). Cyber-physical systems (CPS) enables connection between physical assets and computational capabilities by fulfilling two main functionalities, which are real-time data acquisition and data analytics (Lee et al., 2015) As long as you are in interaction with a computer, you are a part of a cyber-physical system. Thus, having two more subtitles, namely ICT and Cyber-Physical Systems, do not make much sense. All the technologies that are discussed in the chapter are a part of both ICT and cyber-physical systems.

Shortly sensors watch your project. They generate big data with all other data sources. Cloud is used for storing big data and processing it with data analytics. It is the infrastructure needed to benefit from big data and data analytics. Analytical tools let the project team understand their environment and stakeholders. With the integration of domain knowledge, organizations can execute the fruitful project. Use of AI in project management is limited to the creativity of project teams. Although AI does not have creativity, creative project teams can use it for different purposes.

Moreover, all the technologies in the chapter are dependent on each other. The interaction of the technologies makes it very difficult to organize the chapter. It is hard to develop a logical order that enables an uninterrupted flow. Thus, following the order of the industrial internet layers as much as possible is preferred.

Technologies enabling industry 4.0 are very advantageous in project management as well. They mainly improve information and knowledge management processes in projects. Project teams access to the information in the time of need. Understanding the customer expectations, improving user experience, and minimizing waste of time and resources are easier to realize in case accurate and timely information is available. Project teams can behave proactively by means of predictive analytics. Advancements in ICT annihilate the constraints rooted from the distances among the contributors of projects. Knowledge sharing has never been as simple as it is today. On-time updates keep every member of project teams on the same page. 3D printing accelerates the production of prototypes, customized parts, and components. In short, the technologies not only enables Industry 4.0, but they also enhance the practices of Agile Project Management (Memon et al., 2016).

ACKNOWLEDGMENT

The authors would like to Mustafa Volkan Güngör for supporting the author with his knowledge in ICT and helping her to understand the technological background of Industry 4.0.

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

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KEY TERMS AND DEFINITIONS

3D Printing: Transformation of digital designs into objects by adding successive layers on each other of a specific material.

Artificial Intelligence: AI is a term, which consists of not only algorithms but also expert systems and formal logic.

Big Data: Big and complex data sets that necessitates advanced processing software and hardware.

Cloud Computing: a large-scale distributed computing paradigm driven by economies of scale, in which a pool of abstracted, virtualized, dynamically-scalable, highly available, and configurable and reconfigurable computing resources can be rapidly provisioned and released with minimal management effort in the data centers.

Computational Intelligence: A branch of AI that covers the subjects Artificial Neural Networks, Evolutionary Computation, and Fuzzy Logic.

Digital Twin: Virtual representation of a real-world object

Industry 4.0: Deployment of advanced automation and data processing technologies in manufacturing systems.

Internet of Things: Internet connected objects.

Sensor: An electrical circuit that converts one type of energy to electrical signals.

Smart Analytics: Systematic quantitative analysis of data or statistics to obtain meaningful information for better decision-making.

Chapter 4
Project Cost Control in Industry 4.0

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ABSTRACT

During this fourth industrial revolution, the fundamental purpose of industrial transformations is to carry competitive edge of the companies to an upper level by increasing efficiency and effectiveness of sources and decreasing the operational costs. Therefore, the companies need to invest in the right project in the right time in order to provide a competitive edge against their competitors and to gain a desired level of profit. The aim of the project cost analysis is, in the simplest terms, to calculate optimal project costs and to consider if there is any difference between the planned budget and the optimal cost; and in case of a difference, to take necessary actions. The purpose of this chapter is, as a result of principles and conceptual framework of Industry 4.0, to describe how adaptive robotics, artificial intelligence, big data, augmented reality, additive manufacturing, internet of things, cloud computing and cyber security technologies, which are building blocks of Industry 4.0, changed the project cost analysis.

INTRODUCTION

The transformation taking place today, which is also called fourth industrial revolution, is a result of combination of numerous physical and digital technologies. Regardless of the triggering technological means, the fundamental purpose of industrial transformations is to carry competitive edge of the companies to an upper level by increasing efficiency and effectiveness of sources and decreasing the operational costs. The difference of this transformation that we are living in is not just to ensure the change in basic business processes, but also to offer to the business world the new service-based business models and projects by developing the smart and connected product concept. Therefore, during this fourth industrial revolution where technology develops rapidly and is used commonly, the companies need to invest in the right project in the right time in order to provide a competitive edge against their competitors and

DOI: 10.4018/978-1-5225-7865-9.ch004

to gain a desired level of profit. For accurate investments to be made by the companies, to carry out project cost analyses, where feasibility studies are at the forefront, and to create project plans are very critical in making correct decisions. Particularly, availability of different options (for example, choice between alternative business locations, alternative suppliers, alternative project proposals, etc.) makes the cost element a significant mean for decision making in the project management. Therefore, cost control is critical in the project management for an accurate business investment decision and selection. Cost control in the project management results in million-dollar, even billion-dollar investments to be made in most profitable way.

The wonder of Industry 4.0 was first said in 2011 in Germany as a proposition for the improvement of another idea of German monetary strategy in light of innovative methodologies (Mosconi, 2015). The idea has propelled the fourth innovative unrest, which depends on the ideas and advancements that incorporate digital physical frameworks, the Internet of things (IoT), and the Internet of administrations (IoS; Lasi, Fettke, Kemper, Feld, and Hoffmann 2014; Ning and Liu, 2015), in light of never-ending correspondence by means of Internet that permits a consistent association and trade of data not just between people (C2C) and human and machine (C2M) yet in addition between the machines themselves (M2M; Cooper and James, 2009). This communicational association impacts the foundation of information administration 4.0 (KM 4.0; Dominici, Roblek, Abbate, and Tani, 2016). On the off chance that the pattern of the social client relationship administration (CRM) coordinates established CRM and online life to offer some incentive included for associations and clients (Marolt, Pucihar, and Zimmermann, 2015; Roblek, Pejić Bach, Meško, and Bertoncelj, 2013; Rodriguez and Trainor, 2016), As the cutting edge for client relationship administration, Social CRM is picking up force. Conventional CRM procedure centers around administration answers for channels, for example, corporate Web locales, call focuses, and physical areas. With Social CRM, these methodologies currently consider the elements of the network based condition that characterizes online life – a domain in which control of the relationship has moved to the client, who has the ability to impact others in his or her informal community. (Heller Baird, and Parasnis, 2011) By all methods, at the organization level, the effect of this transformation on generation procedures won't just be restricted to mechanical and infrastructural angles. This change procedure will advance the improvement of new expert figures, new authoritative structures and the development of another style of administration. With computerized forms, enormous streams of correspondences and extensive measures of information to be handled, the tasks in Industry 4.0 will require administrative figures with various abilities and mentalities contrasted with the past. In any case, innovative advancement will even now be centered around people—their sanity, instincts and feelings. Hence, venture directors ought to end up the heroes of Industry 4.0 in controlling, spurring and enhancing change.

Businesses achieve breakthroughs with Industry 4.0 for a change in their projects and use Industry 4.0 approach in the project management to increase their efficiency. Tools which characterize the Industry 4.0 such as smart factories, internet of things and related applications, mobile internet network (5G), intelligent and collaborative robots (autonomous robots), sensors, big data and analytics, virtual reality, artificial intelligence, three-dimensional (3D) printers, embedded systems (smart central control units), wearable technology/tools, cyber security tools, cyber-physical systems/simulation, cloud computing, three-dimensional virtual environments, horizontal and vertical integration, digital planning and monitoring, building a good project team etc. are also a focal point in today's new projects that are open to change. Therefore, it is seen that large-scale companies focused on the concept of smart factory today have got acquainted with Industry 4.0, and they have started their production processes with project-based new generation lines, fully automated and comprising robotic processes.

There are lots of different aspects studied in the project management, such as risks, compliance with standards, legal considerations, organizational structures, cost analysis, profitability analysis, sales and/or demand forecasts, capital requirement and return of capital etc. However, besides quantitative data such as cost of the project to be realized as well as financial data, timeline, also qualitative data such as customer satisfaction, operational efficiency, are evaluated in the project management. The aim of the project cost analysis is, in the simplest term, to calculate optimal project costs and to consider if there is any difference between the planned budget and the optimal cost; and in case of a difference, to take necessary actions (for example, to try or pass to other options). Answer is sought for the question, how conducting a cost control analysis for any investment or project depending on the planned budget is changed during the fourth industrial revolution.

With the help of "Internet of Things-IoT" ecosystem and "Machine to Machine Communication-M2M" technologies which are outcomes of Industry 4.0, project cost control is aimed through monitoring these objects over the net. On the other hand, manufacture of tiny and low-cost detectors have been increased depending on developments in detection technologies. Detectors are devices, which are engineering marvels to detect and measure the physical properties and conditions, essential for next generation technology. Various sensors for temperature, pressure, vibration, sound, light, smell can be used in projects. Use of such sensors in projects empower and speed up the cost control by the help of internet of things, and accordingly, project management enhances.

BACKGROUND

Publicly first expressed at Hannover Messe (Hannover Fair) in Germany in 2011 (Qin, Liu, & Grosvenor, 2016), the foundations of 4th Industrial Revolution were laid at the end of 20th century doubtlessly, and it has continued to develop also in 21st century. Industry 1.0 used water and steam to make production, Industry 2.0 used electric energy to create mass production, Industry 3.0 used electronics and information technology to automate production, while Industry 4.0 which builds upon the digital revolution uses artificial intelligence approach [(Khan & Turowski, 2016), (Bake, Vinicius, Pessoa, & Becker, 2018)]. Even though calling the developments around the concept of Industry 4.0 as revolution is the most commonly shared opinion among many researchers and experts, some also argue that it may be too much to say that it is another industrial revolution, and they rather prefer to call it fourth major upheaval in modern manufacturing following the lean manufacturing in the 1970s, the outsourcing in the 1990s, and the automation in the 2000s (Baur & Wee, 2015). There are also other names given to this concept in the literature: "Industrie 4.0" which is the name of the German plan, "Industrie du future" which is used in France, "Industrial Internet" which is at the basis of the American idea of Industry 4.0 and first stated by General Electric almost at the same period with German plan (Polli, 2017). In USA and some other countries also use terms "fourth industrial revolution" or "next generation systems" (Khan & Turowski, 2016). Albeit such disagreements if this is a revolution or not, or regarding the owner, name, date and elements of it, the concept has gained too much attention both from governments and the private sector as well as the academia, and has become a hot issue which is being discussed from a point of view changing according to the position of the groups, sectors, and institutions addressing it.

What underlies Industry 4.0. is the realization of networked systems where people, machines, robotic equipment and products communicate with each other, and production is organized in this way (Gorecky, Schmitt, Loskyll, & Zühlke, 2014; Khan & Turowski, 2016; Bartevyan, 2015). In this industrial transformation process, while new business models, new approaches and tools are emerging, the established companies based on traditional business paradigm are being disrupted, and consequently, production, consumption, transportation, shipping systems and projects undergo restructuring (Ibarra, Ganzarain, & Igartua, 2018). On the other hand, during this change, the approach that sees nature as an instrument used by humanity gives way to a new perception of revitalization and protection of the natural environment (Erol, 2016). However, the fourth Industrial revolution also brings a new lifestyle. The core values that make up the classic industrial society are being replaced by a new system of values where various and renewable energy sources are used, smart factories have become more prevalent instead of the factories that workers lie at the heart, family structure has changed, a new living space called electronic house has become the center of social life and management techniques are changed (UNIDO, 2017; Kusmin, 2014; Semolic & Steyn, 2017). In this process, standardization, synchronization, centralized management units besides management techniques, where energy, money and power are concentrated in a single hand, are being discussed again. In this new industry structure, the manufacturing sector is gradually being filled by smart machines and the services sector is becoming the core of social life (Khan & Turowski, 2016; Semolic & Steyn, 2017). The social structure shaped around manual labor and dominance over energy sources is changing, and a whole new social relationship emerges around skilled professionals draw strength from knowledge (Bake et al., 2018).

APPLICATION-PULL AND TECHNOLOGY-PUSH AS DRIVING FORCES FOR THE FOURTH INDUSTRIAL REVOLUTION

Automation in mechanical engineering is understood as the motor of technological progress in our modern world. Therefore, modern Industry is the part of an economy that produces material goods which are final products of highly automated mass production processes. Ever since the dawn of industrialization, technological advancements have led to paradigm shifts which today are ex-post named “industrial revolutions”: in the field of mechanization (the alleged 1st industrial revolution), of the exhaustive use of electrical grid (the alleged 2nd industrial revolution), and of the widespread digitalization (presumed 3rd industrial revolution).

Based on a propelled digitalization inside processing plants, the blend of Internet Technologies and future-arranged advancements in the field of “smart” items (machines and products) appears to result in another major change in perspective in modern creation. The vision of future generation contains particular and reminiscence proficient assembling frameworks and describes situations in which items control their own particular assembling process. This is supposed to realize the manufacturing of individual products in a batch size of one while maintaining the economic conditions of mass production. Tempted by this future expectation, the term “Industry 4.0” was established extant for a planned “4th industrial revolution”, the term being a of software versioning. This should understand the assembling of individual items in a cluster size of one while keeping up the monetary states of large-scale manufacturing. Enticed by this future desire, the expression “Industry 4.0” was set up extant for an arranged “4th industrial revolution”, the term being a recollection of software versioning.

FUNDAMENTAL CONCEPTS OF INDUSTRY 4.0

The term Industry 4.0 all in all alludes to an extensive variety of current ideas, whose unmistakable characterization concerning a teach and in addition their exact qualification isn't conceivable in singular cases. In the following fundamental concepts are listed:

- **Smart Factory:** Manufacturing will totally be outfitted with sensors, on-screen characters, and self-governing frameworks. By utilizing "brilliant innovation" identified with comprehensively digitalized models of items and production lines (computerized industrial facility) and a use of different Technologies of Ubiquitous Computing, alleged "Savvy Factories" create which are self-controlled (Lucke et al., 2008).
- **Cyber-Physical Systems:** The physical and the computerized level consolidation. On the off chance that this covers the level of creation and additionally that of the items, frameworks rise whose physical and computerized portrayal can't be separated sensibly any longer. An illustration can be seen in the zone of preventive support: Process parameters (push, profitable time and so forth.) of mechanical segments basic a (physical) wear and tear are recorded carefully. The genuine state of the framework results from the physical question and its advanced procedure parameters.
- **Self-Association:** Existing assembling frameworks are winding up progressively decentralized. This joins a disintegration of great generation pecking order and a change towards decentralized self-association.
- **New Frameworks in Conveyance and Obtainment:** Distribution and acquirement will progressively be individualized. Associated procedures will be taken care of by utilizing different distinctive channels.
- **New Frameworks in the Advancement of Items and Administrations:** Product and administration improvement will be individualized. In this specific circumstance, methodologies of open advancement and item insight and item memory are of exceptional significance.
- **Adaptation to Human Needs:** New assembling frameworks ought to be intended to take after human needs rather than the invert.
- **Corporate Social Responsibility:** Sustainability and asset effectiveness are progressively in the focal point of the outline of modern assembling forms.

These elements are crucial structure conditions for succeeding products.

RELEVANCE FOR BUSINESS AND INFORMATION SYSTEMS ENGINEERING AND EXEMPLARY FIELDS OF APPLICATION

The methodologies and thoughts with regards to "Industry 4.0" are arranged at the interface of the disciplines electrical engineering, business administration, computer science, business and information systems engineering, and mechanical engineering as well as the participating and supplementary segments. The delineated parts of Industry 4.0 outcome when all is said in done fields of action, which are exceptionally compelling for the discipline of business and information systems engineering (BISE). A more critical take a gander at the primary territories of use and branches that were of enthusiasm for the train of BISE demonstrates that industry was regularly engaged (e.g., Hasenkamp and Stahlknecht, 2009, p. 16).

The field of BISE has to be sure opened itself up towards different branches and territories of utilization, anyway incorporated data frameworks and their demonstrating configuration still assume a focal part. As needs be, the field of BISE can expand upon built up results. For the discipline of BISE intriguing beginning stages emerge particularly concerning the territory of combination with regards to "Industry 4.0" (Fettke, 2013):

- **Integration of the Physical Fundamental Framework and the Product Framework:** New alternatives by utilizing constant data by means of RFID, sensors and so forth permit a propelled coordination in different application frameworks.
- **Integration With Different Branches and Monetary Segments:** Reflection on integrative ideas with different branches is important. Along these lines, particularly business coordination, yet in addition monetary administrations and other specialist organizations assume a focal part.
- **Integration With Different Ventures and Industry Composes:** Although the field of BISE knows distinctive sorts of plant, it stays vague how the change between various kinds of plant can be bolstered satisfactorily with data innovation.
- **Integration in Dynamic Value-Creation Networks:** Thought of value adding forms increases new perspectives with regards to Industry 4.0 if generation is done in powerful systems over the entire product-lifecycle (product service systems). Now it is fundamental to create sufficient ideas which consider generation under parts of reciprocal and substituting network partners.

Against this foundation, new issues concerning the discipline of BISE show up in the time of Industry 4.0 with respect to a proper level of combination, robotization and decentralization of big business data frameworks. Moreover, multifaceted territories of use concerning the discipline BISE have just appeared, some of which will be exemplarily laid out in the following:

- **Strategies for Demonstrating and Reference Models:** New ideas inside Industry 4.0 prompt a request concerning propelled techniques for displaying and specific reference models (Fettke and Loos, 2004). Imaginative MES/ERP approaches: Single logical investigations analyze creative ideas for Manufacturing Execution Systems (MES) and Enterprise Resource Planning Systems (ERP) (Klöpper et al., 2012; Koch et al., 2010).
- **Business Intelligence:** Based on the utilization of quantitative techniques for Business Intelligence, starting ideas and models have just been produced and assessed (Gronau, 2012; Lasi, 2012). Advanced item recollections: These frameworks take into consideration a gathering of information records in all periods of item lifecycle, they furthermore spare them and disperse them for investigation. This spreads information of individual generation, collecting, dissemination and so forth (Brandherm and Kröner, 2011).
- **Developing Technique:** In Industry 4.0 imaginative precise methodologies for arranging and advancement of assembling frameworks are required. For example, Pohlmann (2008) and Loskyll (2013) each portray specific systematic ideas for arranging, directing, and controlling administrations in an industrial facility, which meet the requests of the most up to date innovative potential outcomes and prerequisites.

- **Innovative Stage Designs:** Wahlster (2014) declares that future assembling frameworks will be founded on an imaginative platform that packs wise items, information, and administrations, and makes them reliably usable.
- **Data Models and Trade Groups:** New assembling advancements, for example, Additive Manufacturing lead to new prerequisites in the fields of information models and information trade positions (Lasi et al., 2014). This worries engineering oriented application frameworks and in addition application frameworks for business organization.

IMPACT OF INDUSTRY 4.0 ON PROJECT COST MANAGEMENT

Before addressing impact of Industry 4.0 on the project cost management, the better understanding of each tool of it is necessary.

- **IPv6:** IPv6, also called IPng (or IP Next Generation), is the next planned version of the IP address system. IPv6 uses 128-bit addresses, which increases the number of possible addresses by an exponential amount. Because IPv6 addresses are so complex, the new system also adds extra security to computers connected to the Internet (TechTerm, 2006).
- **Cloud Computing System:** Cloud computing is a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction (NIST, 2017).
- **Cyber-Physical System (CPS):** A system in which the link between the real world and the cyber world is highly interconnected (Erkki & Johnson, 2018). In cyber- physical systems, physical components, such as 3D printers and robots together with digital software components, such as data analytics and sensor technology, are aggregated into a network of interacting elements where the initial inputs and final outputs are customarily physical, information often transposes between physical and digital states during manufacturing process (Kusmin, 2014) .
- **Internet of Things (IoT):** It is used to describe a state of connectivity for things otherwise perceived as ordinary analogical where ordinary objects are made “smart” with connected sensors and standardized protocols (Erkki & Johnson, 2018)
- **Smart Factory:** Smart factories leverage on cyber-physical systems which permit automated systems and equipment, software, and supplies to be continuously interconnected (Polli, 2017). The intelligent and highly configurable machinery in these smart factories will allow more flexible production where it can be adapted customer needs simultaneously.
- **Intelligent & Collaborative Robots (Autonomous Robots):** These are new generation of robots which can be considered team partners of human workers and are not isolated in cages anymore (Polli, 2017).
- **Smart Sensors:** These incorporate their own smart logic and can reduce the data demand by providing only necessary information desired. The smart sensors may also assist in automatically reconfiguring the process, for example keeping the running production data within the packaging line for best efficiency (Johnson, G., 2016).

- **Big Data and Analytics:** Big Data is a term encompassing the use of techniques to capture, process, analyze and visualize potentially large datasets in a reasonable timeframe not accessible to standard IT technologies. By extension, the platform, tools and software used for this purpose are collectively called Big Data Technologies (Moorthy, Baby, & Senthamaraiselvi, 2014). With the ability to collect massive amounts of data from different systems, combine and analyze it, the emerging patterns can be used to predict future activities. For example, it is possible to model out different scenarios that might happen with the asset and how these events affect related elements in the cyber-physical system (Kusmin, 2014).
- **Virtual Reality (VR):** Due to sufficient computing power, virtual reality allows visualization of virtual objects in both professional and public spheres. With virtual reality, solving complex projects has become much easier, especially of those based on Industry 4.0 standards. Industry 4.0 projects require connection between all systems of modern machines (physical systems, embedded systems, sensors, actuators, electronic hardware, software etc.) via integrated data chains and these links are used, among other things, for monitoring operating conditions and share virtual models in the development cycle, both of which can be visualized via virtual reality (Kovar et al., 2016).
- **Artificial Intelligence (AI):** The theory and development of computer systems able to perform tasks normally requiring human intelligence, such as visual perception, speech recognition, decision-making, and translation between languages (The English Oxford Living Dictionary, 2018).
- **Three-Dimensional (3D) Printers (Additive Manufacturing):** Additive manufacturing (AM) is a method of fabricating parts through a three dimensional printer which usually uses powder to create a product "layer-by-layer" starting from a digital image realized with a three dimensional CAD Software.
- **Embedded Systems (Smart Central Control Units):** A microprocessor-based system that is built to control a (range of) function and is not designed to be programmed by the end user (Heath, 2003).
- **Mobile Internet Network (5G):** 5G is a new generation of mobile networks with low latency, high capacity and gigabit speeds for the potential of the fourth industrial revolution to be fulfilled, it's clear the network will play an important role (McCaskill, 2018).
- **Wearable Technology/Tools:** Wearable devices are a new type of computation that contains the features of computation miniaturization, customer mobility, and customization. To meet the requirements of high customer mobility, wearable devices have been developed to allow people to access the advantages of computation while moving. There are many types of wearable devices that can be worn on different parts of the human body (Huang, Cheng, & Tsai, 2017).
- **Machine Learning (ML):** Through different learning methods, computer algorithms generate latent solutions to complex problems (Erkki & Johnson, 2018).
- **Vertical integration of Smart Production Systems:** Even if smart factories are at the core of Industry 4.0, they cannot work alone. The Industrial Internet of Things (and so cyber-physical systems) enables the creation of networks that connect downstream distributors and upstream suppliers. These networks replicate the advantages of the smart factory at the supply chain level, thus further enhancing the possible benefits (Polli, 2017).
- **Horizontal Integration Through the Global Value Chain Networks:** This means that a company can make its partners connect with customers to improve services (Polli, 2017).

- **Through-Engineering Across the Entire Value Chain:** Including the whole value chain in the network permits to monitor and control the product and its parts during all their lifecycle (this activity is called "through-engineering"). This is particularly important for industrial components. A company like General Electrics, which produces engines for airplanes, has legit concerns about the quality of materials and parts it uses to realize its products (Polli, 2017).
- **Cyber Security:** The interconnected nature of Industry 4.0–driven operations and the pace of digital transformation mean that cyber-attacks can have far more extensive effects than ever before, and manufacturers and their supply networks may not be prepared for the risks. For cyber risk to be adequately addressed in the age of Industry 4.0, cybersecurity strategies should be secure, vigilant, and resilient, as well as fully integrated into organizational and information technology strategy from the start (Waslo, Lewis, Hajj, & Carton, 2017).

Evidence of Industry 4.0 can be seen by the fact that networks are growing, the internet is used as a major source of information and the most important means of communication, virtual representations of the real world are being created and used, and cyber systems are increasingly being developed, which act autonomously to a certain degree and are able to make their own decisions (IAPM, 2017). In the context of project management, there is ever-increasing pressure to deliver projects more quickly and efficiently, leading to the adoption of new technologies which will likely drive significant change to the structure and nature of project management, project teams and even projects themselves (Jordan, 2017). So it is true to say that there is a mutual interaction between developments of Industry 4.0 and project management. The transition to Industry 4.0 is itself a project which should be managed both at governmental level, sectorial level, organizational level and individual level. And it is inescapable that each step of this transition will have impact on every aspect of project management.

The subject of Industry 4.0 is ever-present in project management. First and foremost, project management is involved with companies that are going through digitalization and need to be able to manage this process. Project managers themselves are also affected by digitalization and increasingly organize their internal structures using digital products (IAPM, 2017).

The developments and progresses under Industry 4.0 will likely to result with delocalized project teams having higher skills than those required in the past, and where some team members will be virtual assistants –this means hybrid project teams, the innovative aspect of the projects will gain importance to ensure the best competitiveness and in turn this means smaller project teams focused on specific objectives (Rezzani, 2018). The other things to be changed in this era are automation of business tasks not requiring analytical and design skills, changing of corporate structures based on hierarchical functions with streamlined structures, the products and services that will be both mass produced and personalized, dramatically less time to market smart products which require flexible production processes (Rezzani, 2018), integration of supply chain and distribution channels with manufacturing processes (Polli, 2017), self-sufficient and self-deliverable projects for each individual working area, replacement of on-site data centers with cloud systems (Jordan, 2017) and so on. Changes to the value chain will require companies to embrace new business models and partner with other companies, including suppliers, technology companies and infrastructure suppliers to establish new regulatory frameworks, standards or training methods. Consequently, the companies will have to invest large sums into new machinery, software, business model development, employee competency models and training (Kusmin, 2014; Polli, 2017). Handling of each one requires a change management which should be carried out carefully and skillfully. It is evitable that these changes will cause reaction in people within the organization who have to change their way of doing things and thinking within very short period of times. One aspect of Industry 4.0 is the way it will change the workplace; intelligent machines are becoming smarter and cheaper, enabling human workforce to focus on less repetitive and more challenging tasks. Flexibility, work time, demographics as well as health and private life will all be impacted, besides essence of certain jobs and skills profiles. New organizational structures will require a socio-technical approach for decision making, coordination, control, and support across both virtual and physical machinery and factories which can be translated as higher demands towards the workforce (Kusmin, 2014). Also, security and safety issues can arise as data is collected throughout the supply chain in regard to data ownership, protection of data from their competitors, cyber-attacks against smart factories, how to ensure production facilities themselves do not pose a threat to humans or the surrounding environment, etc. And at product level, intellectual property rights belong to customized products, how to protect each stakeholder rights, what portion of data to consider as corporate data and personal data are among important issues to be solved which also lead the way to the standardization and interoperability problems (Kusmin, 2014).

PROJECT COST CONTROL'S STAGES ARE CHANGING DUE TO INDUSTRY 4.0

5-step approach towards successful Industry 4.0 projects offered by Bosch- a company based in Germany, initiator of Industry 4.0 discussions and developments- is given in this section. This is a proof of concept (POC) project offered by Bosh to showcase the possibilities of Industry 4.0 technology while incurring low risk along with manageable capital investments (Jakob, 2018), which is for enterprises in intention of initiating a transition project towards fourth industrial revolution. This example is preferred due to simplicity and clearness it offers for ones trying to figure out a way to start a change in their organization towards Industry 4.0 without allocating too much resources and undertaking too much risk at the beginning. This point is especially plays an important role in countries having emerging economies such as Turkey and small to medium size companies which have limited resources to use scrupulously. A summary of this project and its steps is given below.

Step 1 - Setting the Business Objectives: Industry 4.0 projects mostly start by operational managers trying to solve problems or improve their daily work on the shop floor in regard to operational issues they constantly face. So operational issues should be addressed by Industry 4.0, besides unique business objectives or client demands with stringent measurements. Then for comparison, clear metrics will be decided upon to serve as baselines.

Step 2 - Creating a Prototype: Formulation of a plan to execute a trial POC project with a limited budget aiming to achieve optimization through manual process improvements based on analysis results. The quantification of these gains is a key indicator in the validation phase whether if the trial should be expanded or not. Doing a trial with an Industry 4.0 cloud platform on a public cloud allows for a small deployment to be created within a short time span at minimal cost. This eliminates the need to invest in servers and equipment.

Step 3 - Validating the Findings: The second step is to quantify and validate the findings from the trial for management approval. Data collected by sensors from the pilot machinery is used for identifying inefficiencies as well as issues having potential to lead to more serious problems. Afterwards managers can apply this information to define process improvements and reduce waste which should be implemented on the shop floor for the next round of data collection and validation. By using the baseline defined at the beginning, teams can conduct a thorough analysis of the new status and situation compared to the benchmark.

Step 4 - Replicating Successful Use Cases: After the teams have verified the data and checked the use cases to consider the success of POC, which means that the system is workable for the pilot set of sensors and devices. The next step is to extend the project to apply more machines and lines. In this step, the scale of system complexity can increase dramatically because of the increasing number of data points, sensors, and connected machines, so the volume of data also grows drastically. At this stage it's important for the manufacturer to collaborate with a trusted Industry 4.0 partner to work with the manufacturer to craft a holistic Industry 4.0 implementation vision, designed to meet expanded objectives and metrics, and deployed in a phased approach so that operations are not interrupted. To use the cloud deployments to expand computing and storage capacity is a good solution but this also means tougher security measures to safeguard and protect data, a critical asset for any company, while ensuring that all the data is easily available to authorized personnel.

Step 5 - Conducting a Global Rollout: After devising and testing of the proof of concept, in the final step, the aim is to gain further efficiency and visibility by expanding connected Industry 4.0 systems outside the plant into the broader ecosystem.

SUMMARY AND EXPECTATIONS FROM INDUSTRY 4.0

In a nutshell, it very well may be reasoned that the expression "Industry 4.0" depicts diverse essentially IT driven – changes in manufacturing systems. These advancements do not just have innovative however moreover adaptable authoritative suggestions. Thus, a change from product- to service-orientation even in conventional ventures is normal. Second, an appearance of new kinds of ventures can be foreseen which receive new particular parts inside the manufacturing procedure resp. the value-creation networks (Scheer 2012). For example, it is conceivable that, similar to merchants and clearing-focuses in the branch of money related administrations, simple kinds of undertakings will likewise show up inside the industry. With the arranging, investigation, displaying, outline, usage and the support (in short: the advancement) of such exceedingly mind boggling, dynamic, and incorporated data frameworks, an appealing and in the meantime difficult assignment for the scholastic teach of BISE emerges, which can anchor and further build up the aggressiveness of industrial enterprises.

Large modern projects, such as construction of factories, power plants, airports, or railroad tunnels, incorporates many engineering disciplines and contains a large number of connected devices. In such projects the engineering quickly becomes a complex operation with the need to exchange data between different tools and data sources used by engineers from different disciplines (Carlsson, Vera & Delsing, 2016, p. 730).

Current developments in technology including industry 4.0 and Industrial/Internet of Things (IoT/IIoT) together with the global village concept (the world is contracting based on connectivity) have contributed to large international corporates demanding digital enablement. Growth of companies has surpassed geological boundaries with business optimization as the key driver in securing sustainability. Total business optimization must include, but not be limited to (all business functions), production, supply chain, human resources, finance, information management, sales and distribution research, maintenance, safety, environmental, security, design, project management together with all other business functionality. This has to be achieved on an international basis with a high level of repeatability and consistency, inclusive of all business functions (Telukdarie, Buhulaiga, Bag, Gupta & Luo, 2018, p. 317).

Industry 4.0 tools drive radical development of the productivity and efficiency of complex projects activities. Industry 4.0 concept integrates the three key lines: internet of things, internet of services and internet of people – networks objects, people and systems. Optimal combination of strategic pillars in the projects will combine best principles of the smart factory, business and social platforms. This combination guarantees the right functionality of project process initialization, planning and scheduling and controlling process realization with according to the effective and real-time necessary data exchange, safety and reliability (Chromjaková, 2017, p. 138).

Traditional project costs were accepted on a high cost because of controlling processes and long-term planning. But the modern project cost control appliances (e.g. IoT) have been cost reductions. Because compound effects may lead to cost reductions for all partners. Also, the coordination between partners is perceived to be both time and cost-intensive. During project automated communication and interactions, as proposed by Industry 4.0 in general, may lead to decreasing inspection costs and transaction costs, which in turn decreases coordination efforts. Additionally, resources may be provided to lower coordination costs for projects (Müller, Maier, Veile & Voigt, 2017, pp. 310-312).

Initiated with Industry 4.0 which is a German strategic initiative, Industry 4.0 or fourth industrial revolution has been a hot issue for more than half-decade. The researchers and company professionals both from developed countries as well as emerging economies try to suggest new insights and opportunities in relation to Industry 4.0 capabilities as well as trying to solve drawbacks of such a revolutionary transition from their standpoints. So, like the enormous size of the datasets to be analyzed in this coming era, the research areas related to Industry 4.0 is also vast. Industry 4.0 builds upon the digital revolution uses artificial intelligence approach and is characterized by some tools such as IPv6, cloud computing system, cyber-physical systems, internet of things, smart factories, intelligent and collaborative robots, smart sensors, big data and analytics, virtual reality, three dimensional printers, mobile internet network, embedded systems, wearable technology/tools, machine learning. These tools are also essential and significant for the technology-based project management where there is ever-increasing pressure to deliver projects more quickly and efficiently. Adoption of new technologies will force a change in the structure and nature of project management, project teams and even projects themselves. But there is a mutual interaction between Industry 4.0 and project management since transition to Industry 4.0 is itself a project to be managed successfully in skillful hands.

A generic approach created in this research relates to Industry 4.0 oriented projects development.

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Chapter 5
Adoption of Design Thinking in Industry 4.0 Project Management

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ABSTRACT

Management of Industry 4.0 projects needs to have a distinct discourse, be flexible, iterative and creative. These projects are tightly linked with the way people work which is directly related to both their capabilities and their ways of thinking. Challenging Industry 4.0 projects entail out-of-the-box thinking. The basic premise of this research is that the complex transformation accompanying Industry 4.0, which involves various dimensions, requires extensive and effective project management that can leverage novel approaches and techniques such as design thinking. This new approach may overcome the limitations of the dominant model of standard project management and has the potential to bridge the gap between a refreshed project management perspective and the tools/techniques in practical use. Deciding whether, and to what extent, design thinking needs to be adopted in practice in Industry 4.0 project management is a challenge. However, it is time to start exploring the challenges governing the interface between agile approaches such as design thinking and Industry 4.0 project management.

INTRODUCTION

In the last decade, society is increasingly surrounded by a socio-technical-digital ecosystem involving manufacturers, service providers, customers and users, in which more interactions occur between people, machines and digital technologies to meet the needs of society and deliver added value for all involved in the ecosystem. From an agriculture society through an industrial revolution towards a smart industrial and service driven society, the ecosystem represents an industrial structural transformation (Gerlitz, 2015).

DOI: 10.4018/978-1-5225-7865-9.ch005

The fourth industrial revolution, "Industry 4.0" initiated in Germany as a roadmap was later promoted in other countries (Brettel et al., 2014). The roadmap was designed by the German Ministry of Education and Research to promote the German high technology industry and its strategy.

Broadly, the linking of the virtual world with the physical world is associated with Industry 4.0. Intra-company linking of intelligent products and systems and their cross-company integration into industry value networks in manufacturing is referred to as Industry 4.0 (Kagermann, 2015). Many companies especially in the manufacturing industry (i.e. automotive, machine) compete on product quality, manufacturing costs and time to market performance. Offering customized products of remarkably high quality at competitive prices can be realized through intelligent automation and the rearrangement of people in manufacturing systems.

On one hand, Industry 4.0 facilitates increased flexibility, mass customization, acceleration, improved quality, and enhanced productivity in manufacturing, on the other hand it requires firms deal with various challenges such as individualized products, shortened lead time to market, and high product quality. For instance; typical issues for smart manufacturing system in Industry 4.0 involve complex problems of design, machining, monitoring, control, scheduling, industrial applications, sensor and actuator deployment, data collection, data analysis, and decision making (Zheng et al., 2018).

In manufacturing firms, increasing speed of technological capabilities, development and diffusion, in terms of robotics, advanced manufacturing technologies, integration of information and communication technologies (such as artificial intelligence, big data analytics, industrial Internet of Things) and sensors into the manufacturing process have high impacts on business/operations, people and culture. Indistinct boundaries of virtual and real worlds force manufacturing firms to master the cyber-physical interface. Shifting and accelerating customer preferences cause manufacturing firms to shift from being reactive to proactive (Roos, 2016). Shepherd and Ahmed (2000) introduce that manufacturers should evolve from product-driven to customer-driven approaches by moving from the conventional new-product business model to a solutions-innovation business model.

At various stages of product life cycle maturity, there are various manufacturing approaches to improve business performance. Supply chains are being forced to turn into supply networks which constitute concurrent processes necessitating higher levels of agility, flexibility and wide range of soft skills (interpersonal and communication) across the labor force. Higher levels of employee responsibility, autonomy and managerial delegation are demanded at all levels in the organization (Davis et al., 2012).

One of the key problems in Industry 4.0 projects is that, Industry 4.0 solutions require a comprehensive approach both on technical and on organizational/processual level. Due to required scope of the solution it is not possible for single manufacturing company to build new solutions due to knowledge and accessibility barriers on either technical or processual level (Albers et al., 2016). Projects become more complex and ambiguous in Industry 4.0. Project management becomes more challenging. Furthermore, projects are regarded as highly dependent on stakeholders but require cooperative processes among them. These project characteristics require special skills and competences in human.

In this context, inclusion of prospective innovative approaches in project management such as design thinking is likely to be underrepresented in the Industry 4.0 transformation. That is, researchers believe that the extent to which design thinking is adopted in Industry 4.0 project management is a relevant and persistent research issue. Referring to this research gap, through this chapter, the researchers expect to open a discussion on the conceptual and empirical basis of design thinking and project management within the Industry 4.0 context.

One of the key contributions of this chapter is to establish a basis for elaborating on how design thinking can provide project management with new perspectives for addressing Industry 4.0 challenges. We take into account both conceptual and empirical aspects of an evolving basis for this research issue. It requires a conceptual examination as three relevant notions (design thinking, project management, Industry 4.0) are intertwined. The empirical aspect is needed since we need to understand the very idea of design thinking in Industry 4.0 project management in a real-world context.

The chapter is organized as follows. The background section presents the key concepts of Industry 4.0, a refreshed perspective of project management, design thinking and its potential in the context of Industry 4.0 project management. The main focus of the chapter section is the display of the methodology of the research and case study in a nutshell. In the succeeding section called 'solutions and recommendations', the results from the case study are discussed. This section argues for a new perspective in Industry 4.0 project management. The chapter continues with future research directions and key observation-based implications and ends with the conclusion section.

BACKGROUND

Industry 4.0 has drawn considerable attention from academics and practitioners in recent years, but its basis is notably built on a technology push. However, it is hardly possible to execute it in "plug-and-play" mode. It necessitates complex and continuous transformation of different aspects including business/operations, technology/infrastructure, people, and culture. The transformation towards Industry 4.0 emerges as a continuous evolutionary process, integrating physical objects (technologies, machines and people) into the information network, connecting with intelligent machines, manufacturing systems, processes and people through the Internet, thus turning the real world into an information system (Gerlitz, 2015; Kagermann 2015). Through Industry 4.0, all productive units in an economy are linked and consistently digitalized thereby forming a sophisticated network (Blanchet et al., 2014).

New industrial concepts and policies encouraging social and technological innovation are changing the common understanding of many industries and manufacturing systems as well. Various digital maturity models apply to organizations. Schumacher et al. (2016) propose a maturity model for assessing Industry 4.0 readiness and maturity of manufacturing enterprises. Nine dimensions are categorized (strategy, leadership, customers, products, operations, culture, people, governance, technology) and exemplary maturity items are identified. Most of these maturity items overlap with the projects (i.e. digitalization of sales/products/services, individualization of products, interdisciplinary, interdepartmental collaboration, and open innovation, utilization of mobile devices and machine-to-machine communication).

Industry 4.0 research seems to be mostly technology-driven and appears to undervalue a managerial and human-centered perspective (Arnold et al., 2016). Schneider (2018) identifies 18 managerial challenges of Industry 4.0 categorized into six interrelated groups: strategy and analysis, planning and implementation, cooperation and networks, business models, human resources, and change and leadership. These challenges trigger organizational and cultural change and are governed by managers. Change is governed centrally from the top-down or horizontally from the bottom-up. Innovative projects are conducted by heterogeneous decentralized units facilitating the role of experimentation and iterative learning which are significant sources to deal with uncertainties accompanying the transformation. However, the knowledge penetration from these decentralized units may be difficult (Fleisch et al., 2014). Likewise, Bechtold et al. (2014) state that the uncoordinated array of bottom-up initiatives will block the path towards Industry 4.0 and emphasize the importance of a clear top-down governance.

Industry 4.0 transformation requires new employee level and company level capabilities. While simple and repetitive tasks are automated, new and more complex tasks emerge (Becker and Stern 2016). Due to task enrichment, managers and technical experts are supposed to have a T-shaped, interdisciplinary competence profile, rather than a specialized one, providing broader perspective across business models, processes, technologies and data-related procedures. There will be a demand for enhanced social and technical skills, and a shift toward design thinking instead of production thinking (Blanchet et al., 2014). Labor work will still remain permanent, but will change in context, needed to be skilled in decision-making and collaboration. The role of workers is changing towards becoming coordinators and problem-solvers when faced with unforeseen events (Brettel, 2014).

The basic premise of this research is that the complex transformation accompanying Industry 4.0 involving various dimensions requires extensive and effective project management that can leverage novel approaches or techniques such as design thinking. In real world practice, projects have been carried out using various approaches and techniques based on conventional (linear, plan-driven, predictive) or emerging paradigms (Design Thinking, Kanban, Agile, Lean) to address such transformations. One can argue that standard project management is inadequate for addressing changes in the environment or in business needs (Morris, 2013; Pajares et al., 2017). Projects with high uncertainty are referred to as exploration or soft projects (Lenfle, 2008; Atkinson et al., 2006) where technologies, market and customer requirements are unknown at the beginning or are constantly changing. These types of projects enable experimentation, exploration and knowledge creation. In a similar context, one of the key assumptions of standard project management is an act of optimizing (scope, time, cost, quality) and now substitutes a more creative and open-ended approach.

Shenhar & Dvir (2007) suggest a framework with four dimensions to manage complexity in projects; technology, novelty, complexity and pace. Novelty highlights the uncertainty in projects (goals, customer requirements, market etc.). Pace addresses the competitive pressure.

Rapid change, accelerated innovation, and rising complexity are characterizing today's world, and uncertain contexts are becoming the norm rather than the exception (Ben Mahmoud-Jouini et al., 2016; Hobday et al., 2012). Therefore, the usual, basic assumptions utilized in standard project management have become open to discussion. Consequently, three streams of work have emerged to reformulate project management in such a context focusing on; the importance of an exploration phase allowing requirements and specifications to emerge during the project life through trial-and-error and learning; the importance of stakeholders and the need to mobilize them to build the project context; and the need to link project management to strategizing at the firm level (Ben Mahmoud-Jouini et al., 2016). Particularly in the manufacturing industry, innovation-based competition increases the project management's significance as a strategic capability. However, when reviewed in such perspective, effective methodologies, tools and professional attitudes do not seem adequate to implement these three streams of recommendations. In this regard, the refreshed perspective of project management can get help from the field of design (Ben Mahmoud-Jouini et al., 2016; Lenfle, 2016; Lenfle et al., 2016). Designers deal with open and complex problems for many years. Studying the way designers work and borrowing some practices from the field could be interesting for organizations (Dorst, 2011). Today, design is untied from its domain and freely used in many fields such as business innovation as a complex thinking process for realizing new realities (Tschimmel, 2012).

Design is perceived as an activity and process, because it is managed towards product and service innovations in organizations. Because of its iterative nature, it is an activity to be developed further. It frames the problem space, at the same time receives potential emerging solutions gladly (De Blois & De Coninck, 2008). On the other hand, design is a strategic resource, an organization asset and information for competitive advantage. It is also knowledge, because it is used to create new forms and meanings. Similarly, design is understood as capability as well (Gerlitz, 2015). Amit & Schoemaker (1993) states that developing design capabilities is a long-term learning process requiring complex interaction between an organization's human capitals. Perceiving design as an activity, process, resource, asset, information, knowledge and capability shows appreciation of its value in smart and digitalized production and service development in Industry 4.0. In this light, design becomes an essential enabler for innovation within the dynamic emerging smart community and assures a playroom for creativity and its tangible/intangible outputs as products, services and processes (Gerlitz, 2015).

According to Brown (2008), design thinking is an approach to innovation. Le Masson et al. (2011) designate situations of ill-defined problems with high uncertainty related to either technology or markets (such as smart cities, electrical devices or complex machines) as "innovative design situations" requiring specific design processes that act as an interplay between the space of concepts (C) and the space of knowledge (K) (Hatchuel & Weil, 2009).

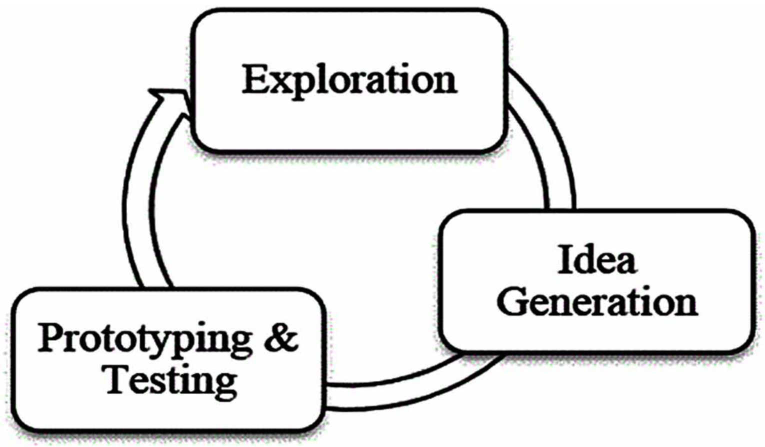
Design management and design thinking are intertwined approaches to innovation, which share the same conceptual base (Carlgren, 2013). Design thinking goes beyond the traditional problem-solving approach (linear and analytical) which lacks definitive solutions. In projects characterized by high uncertainty, understanding and defining the problem requires uncertainty reduction strategies through a learning-focused, hypothesis driven approach (Beckman & Barry, 2007; Owen, 2007). De Blois & De Coninck (2008) present the concept of a project as an organizing process ("organizing project") in which all actors and stakeholders play a primary role in contrast to the traditional perspective of "the organized project". A project is dependent on its context, rather than being a free object. The role of actor and stakeholder participation is highlighted both in the concept of the organizing project and thinking by design. Thinking by design revisits the problem space iteratively, whereas project management theory mostly ignores problem-setting activities assuming that project objectives will become clear in the feasibility phase (Dijksterhuis & Silvius, 2017). Therefore, the focus in project management is shifting towards the problem space from the solution space.

Design thinking involves three main phases with iterative cycles; the first phase of exploratory focusing on data gathering to identify user needs and define the problem, the second phase of idea generation and the final phase of prototyping and testing (Liedtka, 2015). Non-linear process structure of the phases in design thinking is presented visually in Figure 1.

Some specific examples from manufacturing industry can be found in Product-Service System (PSS) (Baines et al., 2007) design. Design thinking as a human-centered problem solving and need-discovery approach, is used with business analytics to build a profitable PSS (Scherer et al., 2016). Service-design thinking (Stickdorn et al., 2011) approach is adopted in a manufacturing firm to explore and create new integrated product-service solutions (Costa et al., 2015).

Management of Industry 4.0 projects needs to have a distinct discourse, be flexible and iterative and utilize a creative approach. These projects are tightly linked with the way people work which is directly related to both their capabilities and their ways of thinking. Challenging Industry 4.0 projects entail out-of-box thinking. Thus, there is a need to review tools and approaches. Common design thinking tools/techniques (visualization, storytelling, brainstorming, co-creation, prototyping, field experiments,

Figure 1. An exemplary three main iterative cycle of design thinking



observation and mind mapping) have potential to help surmount the challenges of Industry 4.0 projects. This new approach may overcome the limitations of the dominant model of standard project management and has potential to bridge the gap between a refreshed project management perspective and the tools/techniques in practical use.

In this research, the researchers examine to what extent a new approach (design thinking) can be embedded in project management in a manufacturing company which is subject to Industry 4.0 transformation and how design thinking has been adopted in practice.

MAIN FOCUS OF THE CHAPTER

Issues, Controversies, Problems

This chapter presents the preliminary investigations into research exploring new and promising approaches to better managing Industry 4.0 projects. Organizations require employees to accumulate generic capabilities to function in the 21st century knowledge economy (Benešová & Tupa, 2017; Marnewick et al., 2017; Pinzone et al., 2017). New approaches (i.e. design thinking) accompanying a refreshed perspective of project management provide accessibility to new knowledge and mindsets. Organizations that face the altered circumstances of Industry 4.0 may utilize new tools and techniques giving them the chance to develop new skills such as design thinking.

This section of the chapter displays the methodology of the research and case study in a nutshell.

Regarding impacts of Industry 4.0 on working life, Schneider (2018) proposes that in depth, qualitative case studies may improve our understanding of sociocultural aspects and the changing role of humans in manufacturing. As we adopted a similar logic of inquiry, we conduct an interpretative case study as a research method (Yin, 2013). The case organization is one of Europe's leading spare-part manufacturers with a history of operating in the manufacturing industry for almost 50 years. The organization has already initiated a strategy to cope with the challenges of Industry 4.0 and has demonstrated on-going efforts to survive in the competitive industry. It has adopted a corporate innovation system to improve creative and innovative outcomes and inquired into opportunities to become more flexible and responsive to changing industry dynamics. In addition, the organization has implemented lean production methods focusing on the creation of customer value through the elimination of production waste and reducing costs (Hannola et al., 2016; Lacerda et al., 2015), which has been used more frequently in discrete manufacturing than in the process sector (Abdulmalek and Rajgopal, 2007).

The organization's focus is on new product development with high health, safety and environmental standards. With this focus, its engineering base and its Research & Development Center, the company has been responding to the changing dynamics of the sector and specific customer demands. An Enterprise Resource Planning system, automated manufacturing lines, robotics and a computerized tracking system at each manufacturing point are part of the company's assets.

The researchers employed semi-structured qualitative methods so that the phenomenon under investigation (adoption of design thinking in Industry 4.0 project management) is explored from conceptual and empirical point of views. Collecting and analyzing data is decomposed into three rounds as seen in Figure 2. In the first round, researchers performed needs assessment and maturity level analysis to understand the organizational capabilities. The researchers synthetized core information about the organization, the plant in general and core processes of product development and project management at the company. The results are evaluated to propose a series of recommendations to the senior management to comply with the challenges of Industry 4.0 transformation. One of the recommendations relates to experimenting with convenient approaches to support the organization to go beyond the offerings of conventional project management in the fourth industrial age in manufacturing. In the second round, data is collected by conducting workshops, which enable observation and in-depth discussions with participants via focus groups. Two researchers' reflective notes are used to collect written observations of activities, experiences, thoughts and interactions in the workshops. In the third round, publicly available data and document analysis are employed (post-workshop reviews). The researchers examine all project deliverables / project artifacts of the groups (researchers' reflective notes, groups' project documents, prototypes and reflection papers of W1 participants). The transcribed verbal data and written data (project documents, reflection documents, and focus group notes) is thematically analyzed using open and axial coding (Baskerville & Pries-Heje, 1999). The unit of analysis is a group of practitioners at different organizational levels. Table 1 displays the characteristics of two workshops involving seven practitioner groups in total.

Two distinct entire-day intensive workshops (W1 & W2) were conducted with seven groups in the plant. The first workshop involved three groups of fifteen participants whereas the second workshop involved four groups of twenty participants. The participants chose to join one of the workshops which fit their schedules. The random composition of W1's participants are mostly the operational staff. W2 is incidentally balanced. On the other hand, W2's seniority seems to be relatively higher than W1's seniority. A diverse group of people were involved in both workshops including all types of staff (technicians, experts, engineers, marketing, sales and other administrative staff) and managers at different seniority levels. Seven cross-functional groups (each with five participants) were formed.

W1 groups were given a domain independent project with high uncertainty and complexity, and were invited to adopt design thinking in hands-on group projects. Domain knowledge was low due to the context unrelated project. W2 was conducted one week later. Meanwhile the organization's top management asked the researchers to work with a domain related project. Thus, the project of W2 groups involved medium uncertainty along with high complexity and domain knowledge. In addition, top management emphasized their preference for the immediate completion of a context related project applying conven-

Figure 2. Data collection and analysis

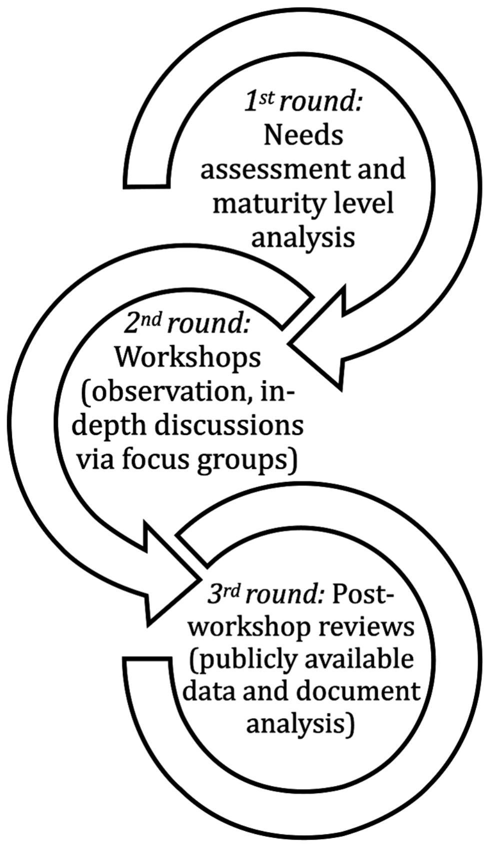


Table 1. Workshop characteristics (group related and project related)

			Workshop 1	**Workshop 2**
Characteristics	Group related	Number of participants	15	20
		Number of staff (S) & managers (M)	S: 12, M: 3	S: 10, M: 10
		Number of groups	3	4
		Seniority level	Low to Medium	Medium to High
		Diversity	High	High
		Project management literacy	Low to Medium	Low to Medium
	Project related	Project subject	Context free	Context related
		Project domain knowledge	Low	High
		Project uncertainty	High	Medium
		Project complexity	High	High
		Approach adopted	Design Thinking	Conventional

tional project management instead of the adoption of a new approach (design thinking). Top management's intervention caused the researchers to make a number of adjustments in W2 characteristics and structure as explained in Table 1 and Table 2.

The workshops were divided into two sessions (Session 1 and Session 2) and were structured as seen in Table 2. Session 1 takes three hours. The researchers think that involving the participants in discussion and reflection on their own actions and intentions makes sense (Harrell & Bradley, 2009). Session 1 decomposed into four parts. The first part, which is the kickoff, began with a warm up and lasted approximately thirty minutes. One researcher started the discussion on overall project management literacy and contemporary project management approaches. The researcher delivered generic questions to confirm the background and ensure the common understanding of the project management domain among all participants. Before conducting the workshops, the first round of data collection (needs assessment and maturity level analysis) revealed that the participants demonstrate low to medium project management literacy. Likewise, the first part of Session 1 provided confirmation to the same level of project management literacy and competency (low to medium).

The second part of Session 1 was reserved for focus groups (see Table 2). Two focus groups were conducted in two workshops because this is helpful for investigating complex behaviors and opinions, and for collecting a diversity of project management experiences (Clifford et al., 2016). The number of participants was fifteen and twenty respectively. Groups were made up of diverse participants who already knew each other through work and had encountered common problems in challenging Industry 4.0 projects. The researchers utilized focus groups as dynamic group discussions providing insights about the type of issues they had confronted. Thus, the method permits rich discussions of project management challenges. Data collection through focus groups was partially structured. Two researchers formulated the questions. Descriptive questions were asked to better understand the organizational project management practices. One researcher took the role of facilitator/moderator, allowing interactions between participants and keeping discussions on topic. The researcher, who acted as moderator, facilitated the free-flowing discussion and encouraged participation to provide rich description and examples (Harrell & Bradley, 2009). Focus groups were conducted in the workshop days and at the plant in a U-shaped meeting room allowing face-to-face interaction, lasting approximately ninety minutes.

Table 2. Workshop design

<table>
<tr><th colspan="2"></th><th>Workshop 1</th><th>Workshop 2</th></tr>
<tr><td rowspan="4">Session 1</td><td>Kickoff / Warm up</td><td colspan="2">Project management literacy
Contemporary approaches to project management</td></tr>
<tr><td>Focus groups</td><td colspan="2">Organizational project management practices / participants' experiences / examples
Organizational, departmental and individual problems / issues in managing Industry 4.0 projects</td></tr>
<tr><td>New approach introduction</td><td>Design Thinking</td><td>N/A</td></tr>
<tr><td>Preparation for Session 2</td><td colspan="2">Project subject introduction
Random group formations</td></tr>
<tr><td colspan="4">Break</td></tr>
<tr><td rowspan="2">Session 2</td><td>1st Round</td><td>Hands-on group projects adopting design thinking approach</td><td rowspan="2">Hands-on group projects via conventional project management approach
(project-specific questions provided for guidance)</td></tr>
<tr><td>2nd Round</td><td>Evaluation rounds & iteration for continuous improvement</td></tr>
</table>

The third part of Session 1 was allocated for new approach introduction (design thinking). None of the participants had any experience of design thinking methods. At the beginning of the third part, one researcher referring to notes taken in focus groups summarized the management issues which had arisen in the case organization in Industry 4.0 projects. The researchers were offered a route to partial insights into what participants do and think via focus groups (Clifford et al., 2016). The issues derived from the focus groups helped the researchers to link the challenges of Industry 4.0 project management to the benefits of new approaches such as design thinking. One researcher presented a refreshed perspective of project management in the new era and new methods that may contribute to solving complex problems in 21st century society. Design thinking approach and several of its tools/techniques (such as visualization, brainstorming, prototyping) relevant to the case organization were introduced. The alignment of Industry 4.0 project management and the potential advantages of the new approach were discussed. This took approximately one hour. The third part of Session 1 was only held in W1. It was not duplicated in W2 due to the intervention of top management. In W2, instead of new approach introduction, dynamic group discussion via focus groups was held, enabling extended discussion of participants' experiences and problems. Hence, the focus group of W2 took nearly one hour longer than the focus group of W1.

The fourth part of Session 1 was reserved for preparation for the hands-on group projects in Session 2. In this last part, the participants randomly formed the groups, the researcher introduced the project subject/problem, and the session ended.

Session 2 started after the thirty-minute break and took four hours. This session was held for hands-on group projects. Participants worked in groups to submit requested project deliverables/artifacts at the end of Session 2. Meanwhile, two researchers observed the groups, answered questions and took notes.

In Session 2, W1 groups were assigned a context free project subject having high complexity and high uncertainty. All three groups of W1 were invited to adopt a design thinking approach in hands-on group projects, and were provided design thinking tool kits (plasticine, markers, post-its, highlighters, pencils and pen, tape, dot stickers in various colors, paper sheets in various sizes and colors, glue, scissors etc.). In the first round, applying a three phased design thinking approach (exploration, ideation, prototyping and testing) and using three design thinking tools (visualization, brainstorming, prototyping) the groups were asked to develop problem solutions for the context free project subject in a set time. In the second round (evaluation round), each group visited other groups' project artifacts (documents, prototypes, visuals, paper sheets), provided feedback and put up stickers for visualizing votes (red stickers for problematic issues, green stickers for favorable aspects of a proposed solution). At the end of the evaluation rounds, problematic issues (red intense areas) became apparent to everyone. All groups reached a consensus on the most appropriate solution. Then, continuous improvement started due to the iterative nature of the approach. In addition, the researchers had the W1 participants complete a reflection document (problem solving framework) to explore how they constructed the task and proceeded with the solution process, and to understand the way the participants think and work.

The original research design involved assigning two context free project subjects and the same project tasks to the participants of W1 and W2 in Session 2. The project groups in W1 would adopt a design thinking approach, whereas the project groups in W2 used conventional project management approaches. The aim of the hands-on group projects was to assess the impact of design thinking approaches on the participants' perception of the project task and its context. However, in Session 2 due to the senior management's intervention, W2 groups were assigned a context related project and applied conventional project management approaches. Therefore, four W2 groups were given various exercises

Table 3. Various exercises in workshops

	Workshop 1	Workshop 2
Project subject	Context free	Context related
Approach adopted	Design Thinking	Conventional
Exercises	• Developing problem solution to the context free project subject (free format visuals, prototypes) • Writing reflection document (brief explanation of problem-solving framework)	• Developing project deliverables/artifacts (draft versions): Strategic positioning Project organization Project life cycle model Stakeholder analysis Responsibility Assignment Matrix (RAM) Project charter Project scope statement Work breakdown structure (WBS)

/ project tasks and provided further project-specific questions to further define the project's problem and find their ways in hands-on group projects, in contrast to the W1 groups. Table 3 summarizes the exercises involved in the workshops.

In the third round of data collection, two researchers conducted post-workshop reviews. All project deliverables / project artifacts of all groups (researchers' reflective notes, groups' project documents, prototypes and reflection papers of W1 participants) were examined and publicly available data was analyzed.

SOLUTIONS AND RECOMMENDATIONS

This section of the chapter discusses the results from the case study and argues for a new perspective in Industry 4.0 project management.

Two researchers observed the participants, held in-depth discussions and reviewed the hands-on project deliverables/artifacts and reflection papers. Evidence suggests that,

In W1,

- **Level of abstraction was not adequate to manage exploration and ideation phases:** Exploration and idea generation stages require extensive conceptualization. Understanding, thinking, abstracting and evaluating the project subject/problem leads the participants to brainstorm, negotiate and plan for action for framing the problem, developing solutions and solving the problem. These two stages require intensive cognitive skills and effective communication. Groups were asked to outline the problem formulation via reflection papers. Mapping the problem to higher constructs was inadequate.
- **Prototyping/Testing was far from being implementable:** Prototyping and testing stages engage participants in discovery and understanding of the nature of the problem. Project subjects with high complexity and uncertainty requires iterative inquiring and assumption elimination. Low project domain knowledge could be eliminated through constant questioning. W1 groups lacked sufficient inquiring and proper representations.

- **Various range of models and prototypes was observed:** Two groups generated poor models and prototypes while only one group generated a slightly better or more representative version. Inadequate investigation during exploration and idea generation stages affected the richness of models and prototypes negatively.
- **Self-defensive behavior of participants was observed when receiving feedback from others:** In evaluation rounds participants lacked the personal attribute of confidence and exhibited self-defensive behaviors. Justifying own ideas and trusting own professional abilities were poorly realized. Groups rarely embraced others' comments, expertise and know-how. Being open and responsive to diverse perspectives and accepting feedback from other groups was limited.

In W2,

- **Well defined stages/documents/deliverables but lack of creativity (similar solutions developed) was observed:** Following the set of project-specific questions provided by the researchers, groups produced project artifacts which were satisfactory, implementable, but quite similar.
- **Groups just focused on completing the deliverables of the context related project (result-oriented groups):** The most aggressive constraint in the organization's projects is time. Groups were exposed to time pressure in almost all departmental and/or cross-functional projects. Such time pressure forces participants to complete the work as soon as possible without any distraction and time wasted. The acquired practice continued in the workshop. Groups solely concentrated on completing the project artifacts as they normally do.
- **Groups were too confident of the way they work (near to paradigm blindness):** Four groups were overconfident of their way of working. Having good command of domain knowledge and the given context related project comforted the groups. However, the excess of confidence restricts the embracing of innovative ideas. The groups perceived that they had demonstrated the best way of working, which may be regarded as an indicator of paradigm blindness. It seems contradictory to have such a perception while attempting to improve organizational project management capabilities using new approaches. The organization needs to be aware of challenges regarding paradigm blindness.
- **Openness to learning new ways of working was low:** The overconfidence mentioned above resulted in poor acceptance of new ideas. The capacity to deal with new approaches is limited.

Although top management declares that it is seeking new approaches to successfully manage Industry 4.0 projects and to become more flexible and agile in addressing various dimensions of complex transformation processes, it seems that their main priority is to have the context related project completed as soon as possible, rather than facilitating new ways of thinking and working. The organization does not seem able to let the participants invest time and space to co-create and learn new skills.

When employees do not have prior experience with such new methods (design thinking) and top management is too keen to have the work rapidly carried out, challenges to adoption may lead to giving up on the method without becoming aware of its potential benefits (Seidel & Fixson, 2013). However, the skills needed to adopt a new method/technique successfully develop in an individual over time.

Design thinking is a way of thinking that leads to transformation, evolution and innovation, to new forms of living and to new ways of managing business (Tschimmel, 2012). The approach provides a way of thinking that is close to a philosophy to change a company's traditional culture into a dynamic culture that has a core competency of transformational readiness (Ochs & Riemann, 2017). Literature regarding the professional competences useful for Industry 4.0 project management and competency models for Industry 4.0 employees (Cerezo-Narvaez et al., 2017; Prifti et al., 2017) highlights people's (human capital) role in competing in the digital age.

Ochs & Riemann (2017) propose a comprehensive approach to overcome the traditional perception that change is not an episodic element but a continuum. Transformation towards Industry 4.0 proceeds in non-linear and overlapping phases (evolutionary pace). Industry 4.0 does not only encourage a continuous change regarding technology, but also regarding the DNA of a company. In this context, innovative thinking activates new business capabilities and replaces traditional silo mentality. In such circumstances, traditional change management methodologies have limitations and a search begins to find new approaches to support the transformation leading to new elements/approaches in which design thinking is also involved. This new approach does not only support the innovation processes but also encourages a corporate culture enabling seamless Industry 4.0 transformation.

FUTURE RESEARCH DIRECTIONS

Conceptual implications based on the challenges cited and empirical implications of the research are summarized in Table 4. Our empirical findings suggest that organizations can be stuck into being closed to innovation and tend to manage Industry 4.0 transformation without taking into account business model orientation. Industry 4.0 encourages new business models as well as new products and services, which may call for innovation in Industry 4.0 project management. The researchers believe that understanding pragmatic behaviors to deal with ill-suited project contexts for Industry 4.0 project management is an open issue for both researchers and practitioners.

Standard project management measures the project's success using triple constraints (time, cost, quality). However, a broader and fresher perspective, focusing on business- and entrepreneurial-oriented dimensions such as strategic value, success in the market and value propositions is needed in new project contexts. In such cases, uncertainty of goals causes expectations to be uncovered through the project and leads to an iterative approach and trial-and-error type management (Pajares et al., 2017). Minimum viable products (MVP) are generated, tested in the market, and enhanced (iterative process). MVPs are utilized to find a convenient business model. The researchers believe that the question of how to leverage emerging techniques utilized in complementary areas (e.g. lean start up) for Industry 4.0 project management is one possible future research direction (Ries, 2011).

One can expect that in many cases, change governance can be centralized (top-down) but may not be aligned with firm-level strategizing. This approach neglects the importance and contribution of stakeholders. This research (the case organization) demonstrates high dependency on a single supplier. Industry 4.0 projects require the commitment of people and organizations with multidisciplinary expertise and abilities constituting an ecosystem. Open innovation is compulsory in firm networks.

The above-mentioned attributes of Industry 4.0 project management (iteration, trial-and-error, learning, exploration, innovation, cross-disciplinary competences) are common characteristics of design thinking as well. In fact, these are the themes or concepts where the three notions of Industry 4.0, project management and design thinking converge.

Table 4. Conceptual and Empirical Implications

<table>
<tr><th>Notions/Subjects</th><th>Conceptual Implications</th><th>Empirical Implications
(Adoption context)</th></tr>
<tr><td rowspan="4">Industry 4.0</td><td>Change governance (centralized vs decentralized)</td><td rowspan="15">1) Characterizing Project and/or Problem situation
● Project subject: Context free vs context dependent
● Project complexity: high
● Project uncertainty: high vs medium
● Project domain knowledge: low vs high
● Approach adopted: Design thinking vs conventional
2) Behavioral approach for uncertainty and complexity handling
(Individual & Team level)
● Incompetent problem formulation
● Lack of proper inquiring and representation
● Weak modelling and prototypes
● Self-defensive behaviors and a deficit in the personal attribute of confidence
3) Appropriate learning style and culture
(Team & Organizational level)
● Lack of openness to learning new ways of working
● Priority is time-to-market with opportunistic agenda rather than visionary outlook
● Lack of encouragement for investing time and space to co-create and learn new skills</td></tr>
<tr><td>Continuous evolutionary vs revolutionary approach</td></tr>
<tr><td>Technology push vs managerial human centric approach</td></tr>
<tr><td>Automation vs T-shaped new capabilities</td></tr>
<tr><td rowspan="5">Industry 4.0 Project Management</td><td>Different ecosystem (open innovation / projects in network)</td></tr>
<tr><td>Uncertainty & complexity</td></tr>
<tr><td>Emerging projects & products (unknown goals, technologies, methods, market & customer requirements)</td></tr>
<tr><td>Firm-level strategizing</td></tr>
<tr><td>Mobilizing stakeholders for formative project context</td></tr>
<tr><td rowspan="4">Design Thinking</td><td>Open, complex problems</td></tr>
<tr><td>Complex thinking process</td></tr>
<tr><td>Lack of definitive solutions</td></tr>
<tr><td>Uncertainty reduction</td></tr>
</table>

Pajares et al. (2017) suggest there is a need to investigate new methods utilizing the learning-emerging approach beyond the agile framework, and emphasize the link between innovation management and project management practice; researchers concerned with innovation need to inquire into the potentials of the design thinking method.

CONCLUSION

This research is concerned with adoption of design thinking as a new approach to transformation of organization by Industry 4.0 projects. In particular, we examined a real case of two project contexts where traditional and design thinking-oriented project management approaches were adopted.

The understanding of Industry 4.0 is revisited and expands through a multidimensional viewpoint addressing project context, uncertainty and complexity handling, learning style and culture. The common discourse states that the fundamentals of Industry 4.0 appear to be built on a technology push, whereas in practice it requires a holistic change regarding managerial and human centric aspects. This emerges at a continuous evolutionary pace rather than as a big bang or revolution. It necessitates automation, while requiring T-shaped, multidisciplinary new capabilities. Furthermore, a mindset shift is needed from production thinking towards design thinking.

In recent years, Industry 4.0 projects are becoming increasingly strategic transformation-oriented rather than short-term outcome oriented. These projects require intra-company and cross-company integration and collaboration in and among networks in a different and innovative ecosystem, instead of competition.

Design thinking and project management in the Industry 4.0 context are held together as transformation factors and processes, evolving and shifting toward a strategic perspective to embrace recent advances in the socio-technical, digital and economic landscape. Balancing the stakeholders' needs and expectations through an integrative view is the common focus of both fields. Individual creativity in the design field expands into the collaborative design of project teams. As a result, Industry 4.0 projects adopting design thinking might be associated with various innovation types including business model, organization and process innovation at the firm and network level through project portfolios.

Deciding whether, and to what extent, design thinking needs to be adopted in practice in Industry 4.0 project management is a challenge. In this study, the researchers emphasize the need for aligning agile approaches such as design thinking with project management approaches in Industry 4.0 context.

There is some agreement between innovation management and project management in this new context. The convergence of these two subject areas (design thinking and project management in Industry 4.0 context) and their alignment can be examined by utilizing various theoretical lenses such as organizational maturity, organizational learning and complexity handling.

An organization's Industry 4.0 readiness and maturity need to be discussed using a holistic viewpoint embracing various dimensions such as technology, people, culture, strategy and leadership. The willingness and competence of management, the competence of employees, and the openness of people to new approaches, as well as the readiness to invest time and space for collaborative learning, and to encourage creativity through new approaches are vital links in the Industry 4.0 chain. The design thinking approach promises to contribute to the enriched perspective on project management and deserves further study.

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KEY TERMS AND DEFINITIONS

Complex Transformation: The significant change of status quo (state) that triggers adoption of socio-technical elements to the context perceived as critical to system sustainability.

Design Thinking: A way of complex problem solving by means of creative, iterative, learning focused, collaborative, experimental and explorative approach.

Chapter 6
Insights Into Managing Project Teams for Industry 4.0

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ABSTRACT

In a fast-paced and changing world demanded by Industry 4.0, the continuous delivery of products and level of integration of technologies are required. This is achieved through the introduction of agile but agile itself demands changes in the way projects are managed. The role of the project manager itself is changing from a command and control to a collaborative and coaching style of leadership. Project teams on the other hand should be self-organizing and self-directed to be agile. Managing agile teams requires a different approach as the idea is to deliver workable solutions and products at a faster space. New project manager skills and competencies are required as well as ways to manage agile teams. A conceptual model is introduced, highlighting the required enablers for an agile environment. The enablers have an impact on how the agile project manager interacts with the agile team. The end result is that products are faster deployed enabling organizations to react to the changes demanded by Industry 4.0.

INTRODUCTION

Projects and project management have a long history. Some of the major projects undertaken by humankind delivered the Great Pyramid of Giza (2550 – 2530 BCE), the Colosseum (70 – 80), the Cathedral at Hagia Sophia (532 – 537), the Taj Mahal (1631 – 1648) and the Empire State Building (1929 – 1931) (Kozak-Holland & Procter, 2014). These civil engineering projects evolved into various other types of projects including space exploration projects and information system projects, for instance the implementation of an ERP system (Sudhaman & Thangavel, 2015).

The history of formal project management does not stretch that far back, and project management was introduced in the late 1950s between the second and third Industrial Revolutions (Seymour & Hussein, 2014). A formal way was needed to manage projects and the notion of project management was born.

DOI: 10.4018/978-1-5225-7865-9.ch006

The introduction of project management as a discipline resulted in new opportunities for researchers as well as organisations: project management standards and best practices were introduced, roles and competencies of the project manager and team members were documented and ways were created for determining the success of projects (Söderlund & Lenfle, 2013).

The skills and competencies of project managers and those of project team members have also been researched and various research articles as well as competence models have been published. Some of the well-known competence models include the Project Management Institute's Project Manager Competency Development Framework (PMCDF) (Project Management Institute, 2017c) and the International Project Management Association's Individual Competence Baseline for Project, Programme & Portfolio Management (ICB) (International Project Management Association, 2015). The PMCDF focuses on personal and performance competences. The ICB, on the other hand, focuses on three competence areas, i.e. perspective, people and practice (Marnewick, Erasmus, & Joseph, 2016).

Industry 4.0 have a disruptive impact on various industries such as manufacturing and logistics (Santos, Mehrsai, Barros, Araújo, & Ares, 2017). These disruptions are caused by various advances in technology such as the Internet of Things (IoT), wearable technology, artificial intelligence and machine learning. Traditionally, these new technologies or systems would have been implemented through projects and project management. Just as Industry 4.0 has a disruptive impact on other industries, it is evident that Industry 4.0 has a disruptive influence on project management and project teams in particular (Weber, Butschan, & Heidenreich, 2017). The disruption focuses on the way and manner that projects are implemented and team members interact with each other as well as new skills and competencies needed to manoeuvre through the 4^{th} Industrial Revolution.

Current project management practices and standards do not cater for or meet the needs of Industry 4.0. Agile project teams have already resulted in some challenges in the working environment. Some of these challenges are the co-location of teams and the cross-skilling of individual team members (Svejvig & Andersen, 2015). Industry 4.0 challenges the project management discipline in various ways. Some of these challenges are the dynamics of the project management discipline itself in Industry 4.0, the organisational structure in project-oriented organisations, the effects on the project managers' responsibilities and roles, Industry 4.0 tools and approaches used in project management as well as agile project planning (Project Management Institute, 2018b).

The problem that project management faces currently as a discipline is that there has been no development in best practices since 1994 (Svejvig & Andersen, 2015). Svejvig and Andersen (2015) state that project management as a discipline needs to include the following categories to be relevant during the 4^{th} Industrial Revolution:

1. **Contextualisation:** Projects are not run in isolation, and with the advent of cloud computing and the Internet of Things (IoT), it will become important for each project to be assessed based on the context within which it is implemented. Concepts such as sustainability and the organisational strategy should be considered when the context is determined.
2. **Social and political aspects:** Projects are implemented within a certain context and this context is influenced by social and political aspects, which can have either a positive or a negative influence on projects. An example might be the political influences of stakeholders and the emotional intelligence of the project manager and the project team members.

3. **Rethinking practice:** Current best practices and standards have not changed dramatically since their introduction a couple of decades ago and new or alternative best practices and standards need to be introduced, such as agile and scaling agile.
4. **Complexity and uncertainty:** Marnewick, Erasmus, and Joseph (2017) have identified 75 features that contribute to a project's complexity and project managers need to wade their way through these complexities. This is only possible if they understand how to manage complexity. Complexity and uncertainty are even more prevalent in the 4th Industrial Revolution but a counteraction is the application of agile principles to reduce complexity and uncertainty.
5. **The actuality of projects:** There is a need to understand the difference between practice and theory to determine how projects are actually implemented. Marnewick et al. (2016) suggest that there is a discrepancy between practice and theory. In the case of information technology (IT) projects, IT project managers do not necessarily apply all the principles of theory to practice, resulting in project failure.
6. **Broader conceptualisation:** Alternative perspectives on projects and project management need to be offered. An example is the introduction of agile as a way to implement software versus the traditional waterfall method.

The next section deals with the role of the project manager from a historical perspective, focusing on the competencies that a project manager had to master. New competencies and skills that project managers should exhibit in an agile environment are then analysed. These new competencies and skills are very different from current traditional competencies.

ROLE OF THE PROJECT MANAGER

The project manager is assigned by the organisation to lead and manage the project team in order to realise the strategies (Project Management Institute, 2017b). A good project manager needs various skills to lead and manage the project team. The most important skills are (i) a sound knowledge of the body of knowledge, (ii) the application of knowledge, national and international standards as well as regulations, (iii) knowledge of the project environment, (iv) general management skills and (v) soft skills (Schwalbe, 2016). However, Bredillet, Tywoniak, and Dwivedula (2015) caution that we still need to delineate what constitutes a good project manager and the level of performance expected of the project manager. This is even more applicable in an agile environment where the role of the project manager is changing dramatically. According to Bredillet et al. (2015), a project manager should act wisely and perform the right acts within the context of the project.

Hodgson and Paton (2016) state that the focus of the traditional project manager is to plan, monitor and control projects. This is all done within the framework of proprietary bodies of knowledge. The concern is the difficulty in applying standard bodies of knowledge to a changing environment dictated by the 4th Industrial Revolution (Hodgson & Paton, 2016). The current project management bodies of knowledge from which project managers draw their knowledge and technical expertise are not fit for purpose and project managers find it difficult to perform in a constantly changing environment. Project managers should be able to deal with soft issues relating to team members and relationships (Loufrani-Fedida & Missonier, 2015). This is especially important in an agile environment where the focus is on coaching and servant leadership.

The project manager should also portray additional competencies apart from those highlighted in the competency standards. Loufrani-Fedida and Missonier (2015) are of the opinion that agile project managers should also portray servant leadership, the ability to communicate at multiple levels, have verbal and written skills as well as the ability to deal with ambiguity and change.

Current project management competency standards focus on traditional competencies and do not consider the competencies needed for the 4th Industrial Revolution.

Traditional Competencies

Competence within the project management environment is the application of knowledge, skills and techniques in order to complete an activity successfully (Marnewick et al., 2016; Mnkandla & Marnewick, 2011). There are various project management competency standards that provide guidance on the types and level of competencies a project manager must possess and have mastered. The Project Management Institute (2017c) identifies three major competencies:

1. **Technical project management skills:** the skills that a project manager uses to apply his/her project management knowledge effectively.
2. **Leadership:** the ability to guide, motivate and direct the team. Within a scaled agile environment, traditional leadership is replaced by servant leadership. This is discussed in more detail later in this chapter.
3. **Strategic and business management:** the ability to see the overall view of the organisation and effectively negotiate and implement decisions and actions that support strategic alignment.

The Global Alliance for Project Performance Standards (2007) has a slightly different view of the competencies of a project manager, as the focus is more on the technical aspects of managing a project. According to GAPPS, six competencies need to be mastered:

1. Managing the stakeholders and subsequent relationships
2. Developing the project schedule
3. Managing the project's progress on an ongoing basis
4. Managing the acceptance of the final product or service
5. Managing the transition of the final product or service into operational management
6. Evaluating the project's performance and improving areas as highlighted through a lessons-learned exercise.

The International Project Management Association (IPMA) clusters project management competencies into three competence areas (International Project Management Association, 2015; Marnewick et al., 2016):

1. The people competence area defines the personal and interpersonal competencies required to deliver projects successfully.
2. The practice competence area defines the technical aspects that a project manager should master to manage projects successfully.

3. The perspective competence area defines the contextual competences that must be navigated within and across the broader project environment.

The focus of the PMBOK® Guide and the ICB is mainly on attribute-based competencies, whereas the GAPPS standards focus on performance-based competencies (Bredillet et al., 2015).

The project management competencies as preached by the competency standards are not appropriate to the 4th Industrial Revolution and an agile environment. These competencies are very prescriptive and do not allow for the project manager to coach and lead. Project performance can only be improved when the individual competencies are combined into a common endeavour (Loufrani-Fedida & Missonier, 2015). This is achieved through joint problem solving as introduced by agile and an understanding of the bigger picture through systems thinking.

Just as the project manager's competencies need to change, the role of the project manager also needs to change to address the demands of the 4th Industrial Revolution. The role of the project manager is currently changing and will continuously change in an agile environment as dictated by the 4th Industrial Revolution.

Changing Role of the Project Manager

According to the Project Management Institute (2017a), the role of the project manager within an agile environment is becoming a misnomer. This is due to the fact that the project manager's role is not defined in any of the various agile frameworks. Dikert, Paasivaara, and Lassenius (2016) mention that mixing the role of the project manager and scrum master has created a conflict of interest whereas the role of the scrum master has become one of coaching and not one of policing.

In an agile environment, the focus of the project manager shifts from command and control to serving and managing the team (Project Management Institute, 2017a). The project manager's skills in an agile environment include servant-leader, coach, collaborator and stakeholder manager. Various new roles have emerged from within an agile environment that fulfil the traditional role of the project manager:

- The product owner guides the direction of the product and is ultimately responsible for the delivery of the product (Project Management Institute, 2017a). The product owner prioritises the work based on business value, defines the stories and prioritises the backlog based on the business value while maintaining the conceptual and technical integrity of the features (Scaled Agile Inc., 2018).
- The scrum master is a servant-leader and performs the role of a coach. The main responsibility is to create a conducive environment, through the removal of obstacles, for team dynamics, continuous flow and improvement. The time of the scrum master is spent assisting other team members in communicating and collaborating (Bass, 2014; Scaled Agile Inc., 2018).
- The release train engineer (RTE) facilitates the events and processes associated with an Agile Release Train. The RTE also assists agile teams in delivering value. RTEs are the centre point of all communication with stakeholders, they escalate issues and concerns, manage risk and drive improvement (Scaled Agile Inc., 2018).

The project manager traditionally performed these three roles (product owner, scrum master and RTE). In an agile environment, the agile project manager needs to adopt new methods as depicted in table 1. In addition, agile project managers also need to have skills to manoeuvre in an Industry 4.0 environment.

Table 1. Comparison of agile and traditional methods

Traditional	Agile	Industry 4.0
Command and control	Leadership and collaboration	Systems thinking
Autonomous	Cooperative	Business analytics expertise
Disciplined	Flexible	Maneuverable
Manager as planner	Manager as facilitator	Manager as change agent
Explicit knowledge	Tacit knowledge	Artificial intelligence
Individual reward system	Team reward system	Organisational reward system

(Bishop, Rowland, & Noteboom, 2017, 2018)

Table 1 illustrates that project managers need to focus on two main aspects. The first aspect is how to manage teams in an agile environment. This is different from the traditional way of managing project teams. The second aspect is that while teams needs to be managed differently, project managers should master new skills as demanded by Industry 4.0. The combination of these two aspects challenges the project manager to upskill and sometimes re-skill. Project managers also need to move away from the more traditional way of managing projects. Embracing the new way of managing projects requires them to acquire new skills and knowledge. New skills focus on the technical aspects of agile project management, such as features, sprint planning backlogs and sprint reviews. New knowledge that project managers should master includes how to manage agile team members. The focus should be on leadership and collaboration instead of command and control.

The agile project manager places greater emphasis on servant leadership that empowers, encourages and supports the team. The notion of command and control has no place in an agile environment (Bishop et al., 2018). The biggest challenge for the project manager is to strike a balance between the individual team members' autonomy within self-organising teams and the organisational strategies. The focus of the team is on flexibility, value creation and incremental delivery (Craddock, Roberts, Godwin, Tudor, & Richards, 2014).

Managing projects during the 4^{th} Industrial Revolution is getting more complex every year. Project managers need to adapt to this complexity as well as respond rapidly to the constantly changing economic, social and technical situations imposed by the 4^{th} Industrial Revolution (Ramazani & Jergeas, 2015). Agile project managers should be adaptable, be critical thinkers and have multidisciplinary as well as collaborative skills (Ramazani & Jergeas, 2015).

Different types of projects should be approached differently (Andersen, 2016) and this is the case with agile projects as well. Irrespective of whether a project is adopting an agile approach, value should be created through the final product and/or service (Andersen, 2016). There is a definite shift from the more traditional waterfall project management towards agile project management (Levitt, 2011).

The composition of project teams are also changing in this new environment dictated by agile and the 4^{th} Industrial Revolution.

PROJECT TEAM COMPOSITION

In an environment that is constantly changing as demanded by Industry 4.0, agile as a mindset is a perfect solution for the management of projects because the underlying principles of agile focus on change and therefore agile is perceived as a change agent. This constantly changing environment requires constant and frequent interactions with the customer or user as well as quick delivery and deployment of the product or service (Bishop et al., 2017). The focus is shifting from prediction and control to adaptation and innovation (Vinekar, Slinkman, & Nerur, 2006). This is a new mindset and challenges current project management standards and best practices. Current standards and best practices need to be revamped to reflect the new development methodologies (Hoda, Noble, & Marshall, 2008; Project Management Institute, 2017a).

Within the agile environment, the focus is on the team and how the respective team members interact with each other. Part of this interaction among team members is to create self-organising teams (Vinekar et al., 2006). Hoda et al. (2008) are of the opinion that the agile project manager should be a visionary.

The management style in an agile environment creates an environment that is conducive for creative thinking and problem solving. Some elements of an agile project stay the same, for example the management of customer relations and risk management, but the execution of these elements is different within the agile framework and requires a different way of thinking from the agile project manager and the team members (Hoda et al., 2008).

Irrespective of whether the project is executed in an agile way or a more traditional way, the success of the project is anchored around the project team. The agile team should be in a position to "*perform together toward a common goal, which results in the creation of a collective outcome, an outcome that could not be accomplished by one member due to its complexity*" (Ruuska & Teigland, 2009, p. 324).

Managing Agile Teams

Agile teams need to be co-located as team members are required to embrace change and rapidly changing requirements. Agile team members are required to have a high level of commitment to the team as they perform various roles and responsibilities within the team (Fernandez & Fernandez, 2008).

The following challenges have been identified with regard to agile teams:

1. The vision and strategies of the organisation are not easily translated back to agile teams as they are constantly addressing and resolving issues (Augustine, Payne, Sencindiver, & Woodcock, 2005). In a scaled agile environment, the work of agile teams can be related back to epics (Scaled Agile Inc., 2018).
2. Team members are dealing with additional stress as they need to incorporate management skills into the self-organising team instead of just focusing on their professional contribution to the problem (Augustine et al., 2005).
3. Self-organising teams are highly motivated and self-driven. Team members that are not exhibiting these qualities add additional stress to the team and the agile project manager (Bishop et al., 2017; Stone, Russell, & Patterson, 2004).
4. There are no hierarchies with agile teams and this creates conflict as some individuals still believe that there should be some seniority with the teams (Taylor, 2016; Vinekar et al., 2006).

The value of agile teams is that they are empowered to decide on their own what the best way is to perform an activity and this decision is based on the competence level of each individual team member. Agile teams also decide on the order in which activities are to be implemented. Table 2 provides a comparison between traditional and agile teams.

Various new attributes have an impact on the way that agile team members engage with each other to perform at an optimal level. The first two attributes in the table above speak to the essence of an agile team. Agile team members choose among themselves who will perform what activities and when they will perform them. This speaks to the flow of work within the project. The teams also decide which activities they will perform. All of this is done with the sole purpose of delivering a minimum viable product sooner rather than later. Another important attribute is that team members are generalising specialists. This implies that although they are specialists in their own right, they are able to perform other team members' duties when the opportunity arises.

It is evident from Table 2 that agile teams are operating at a different level than traditional teams. This places additional stress on team members to get used to operating in this environment and take ownership of their own destiny. Organisations need to ensure that an environment is created where agile teams have the space and freedom to embrace the attributes of an agile team.

This shift in focus in the way that agile teams are managed also has an impact on the traditional role of the project manager. Project managers also need to learn and acquire new skill sets to manage agile teams. This is even truer for the 4th Industrial Revolution. Agile project managers should also be able to deal with the following managerial challenges (Schneider, 2018):

1. **Analyse and Strategise:** The agile project manager should analyse the environment, determine how Industry 4.0 will benefit the project and have a strategic plan for structuring the incorporation of technology. A second aspect is how the transition from a traditional project manager to an agile project manager will be facilitated.
2. **Cooperate and Network:** The IoT opens possibilities for cooperation and networking that were not possible before. The agile project manager should have an awareness of possibilities and potential risks and these will have an impact on the management of the agile team and project itself.

Table 2. Agile team versus traditional team attributes

Agile team	Traditional team
Self-organised	Leader organised
Self-directed	Leader directed
Cross-functional	Functional
All team members are accountable	Project manager is accountable
Servant leadership	Direct and regulated leadership
Small team	Large teams
Multi-skilled team members	Single-skilled team members
Generalising specialists	Specialists
Make their own decisions	Leader makes decisions for the team
Focus on group success	Focus on individual success

(Canty, 2015; Project Management Institute, 2017a)

3. **Business Models:** Current business models are not necessarily designed for Industry 4.0 and this is the case for project management as well. The project management model should be adapted as highlighted by Svejvig and Andersen (2015). Agile project management might be a possible alternative business model.
4. **Human Resources:** Agile project managers must understand and manage the impact of Industry 4.0 on task depth and content. The workplace of the future is also going to change with regard to competencies, skills, education and training.
5. **Change and Leadership:** Agile project managers should create an environment where team members are able to experiment, fail and rapidly recover from their failures.

The next section focuses on enablers that bring about change in the organisation itself. Change is necessary as the 4th Industrial Revolution demands rapid change and agility from organisations. Organisations that are not able to change will not be competitive and will lose market share to their competitors.

ENABLERS

The use of agile is becoming popular in a world demanding support for constant change and innovation (Bishop et al., 2018). The adoption of agile is driven by several influential factors such as project size, complexity, employee skillset, organisational culture and Industry 4.0 (Bishop et al., 2018). Transitioning from a more traditional way of implementing projects to an agile environment where projects are delivered in an iterative way does not happen overnight. The journey takes some time but before organisations can embark on this journey, certain enablers must be in place to ensure the success of this transition. The following enablers have been identified from literature: culture, servant leadership, technology and scaled agile (Cho, 2009; da Silva, Amaral, Matsubara, & Graciano, 2015; Iivari & Iivari, 2011; Laanti, 2014; Project Management Institute, 2018b; Turetken, Stojanov, & Trienekens, 2017; Winston & Fields, 2015).

Culture

Culture is an important factor to understand organisational behaviour as it matters in projects, especially in an agile environment (Ramos, Mota, & Corrêa, 2016). According to Bishop et al. (2018), the organisational culture and management style have an influence on the way agile is adopted. If the organisation is not willing and able to embrace the changes that agile brings, then the adoption of agile is doomed (Bishop et al., 2018). Adopting agile as a new way of working requires various changes to how work is conducted. An important change is the focus on customer needs and a degree of adaptability to the continuous changes to the requirements. Another cultural change is the introduction of self-regulating teams that are collaborative and transparent. Teams meet frequently for short periods of time in order to achieve transparency, ensuring that many eyes are on each problem encountered. To achieve effective teamwork in an agile world, the notion of a leader needs to be transformed. Leadership in an agile world is much more likely to take the form of facilitation and coaching. Rather than leadership positions, individuals take on roles that could change from project to project.

Servant Leadership

Within the agile environment, project managers adopt a servant leadership style. The project manager focuses on facilitating team members' performance and development, acts in the best interest of the team members and does not engage in manipulative, self-interested actions (Winston & Fields, 2015). The project manager thus becomes the steward of both the project and the team members' interests.

Although the project manager is now a servant-leader, this does not imply that they can abdicate their responsibilities and accountabilities. The emphasis is on encouraging the development of autonomy and responsibility of the team members (Winston & Fields, 2015). A project manager can only be a servant-leader if there are high levels of trust among the team members and the project manager (Sendjaya & Pekerti, 2010). A servant-leader project manager should exhibit the following characteristics: (i) voluntary subordination, (ii) authentic self, (iii) covenantal relationship, (iv) responsible morality, (v) transcendental spirituality and (vi) transforming influence (Sendjaya & Pekerti, 2010).

Table 3 highlights the attributes of a servant-leader. It is evident that the project manager's focus shifts towards the well-being of the team and that of the individual team members. The emphasis is on achieving the project's objectives through the team by creating a supportive environment that allows the team members to be creative and exhibit their strengths.

Technology

Technology has dramatically reshaped all forms of work over the last decade. The 4th Industrial Revolution came about as a direct result of the significant technological developments in ICT, cyber-physical systems and the IoT (Li, 2017). The focus of this revolution is on the integration of various technologies that enable ecosystems to function in an intelligent and autonomous way, decentralising factories and integrating product-services (Santos, Mehrsai, Barros, Araújo & Ares, 2017). Table 4 shows the top technology trends over the last decade and it is interesting to note that these trends are fluctuating.

Table 3. Servant-leader attributes

Functional attributes	Accompanying attributes
Vision	Communication
Honesty and integrity	Credibility
Trust	Competence
Service	Stewardship
Modelling	Visibility
Pioneering	Influence
	Persuasion
Appreciation of others	Listening
	Encouragement
Empowerment	Teaching
	Delegation

(Russell & Stone, 2002; Stone et al., 2004)

Table 4. Top 10 strategic technology trends 2008 – 2018

#	2008	2012	2013	2015	2018
1	Social Software	Media Tablets and Beyond	Mobile Device Battles	Computing Everywhere	AI Foundation
2	Metadata Management	Mobile-Centric Applications and Interfaces	Mobile Apps	Internet of Things	Intelligent Apps and Analytics
3	Web Mashup, Cloud Computing and Composite Applications	Contextual and Social User Experience	Personal Cloud	3D Printing	Intelligent Things
4	Web Platform and Web-oriented Architecture (WOA)	Internet of Things	Enterprise App Stores	Advanced, Pervasive and Invisible Analytics	Digital Twin
5	Fabric Computing	App Stores and Marketplaces	Internet of Things	Context-Rich Systems	Cloud to the Edge
6	Real World Web	Next-Generation Analytics	Hybrid IT & Cloud Computing	Smart Machines	Conversational Platforms
7	Business Process Modeling	Big Data	Strategic Big Data	Cloud/Client Computing	Immersive Experience
8	Green IT	In-Memory Computing	Actionable Analytics	Software-Defined Applications and Infrastructure	Blockchain
9	Unified Communications	Extreme Low-Energy Servers	In-Memory Computing	Web-Scale IT	Event Driven
10	Virtualization	Cloud Computing	Integrated Ecosystems	Risk-Based Security and Self-Protection	Continuous Adaptive Risk and Trust

(Gartner, 2017)

Organisations that are mature in their digital strategy and adoption have made these disruptive technologies a priority (Project Management Institute, 2018a). The role of the project manager should also be that of a technology advocate, to motivate teams to implement disruptive technologies and become an authority on these technologies.

Three technologies have a direct and positive impact on agile project management (Project Management Institute, 2018b):

1. Cloud computing offers new levels of collaboration and information access and frees up schedules so professionals can lend expertise to projects and customer issues.
2. The IoT offers increased and constant connectivity for the entire agile team. The automatic transfer of data will have a positive impact on the effectiveness of communication. The IoT also increases data efficiency that allows for accurate data-driven decision-making.
3. Artificial Intelligence reduces human error and biases when it comes to creating budgets, predicting cost overruns and developing schedules. AI-assisted tools could mean that project monitoring and schedule changes require less time and fewer resources.

Organisations that adopt disruptive technologies experience increase in productivity, development of better products and services, automation of mundane tasks and stronger connections between team members.

Disruptive technologies need to be incorporated into agile projects consistently. The challenge with incorporating these new trends is twofold. Firstly, agile teams do not necessarily have the knowledge to implement these trends and secondly, these trends contribute to the complexity of agile projects.

Scaled Agile

Agile per se will not be able to deliver the intended benefits that organisations wish for. To gain the benefits through the adoption of agile, agile needs to be scaled. Scaling agile in large organisations needs to focus on enterprise architecture, interteam coordination, portfolio management and scaling agile itself (Laanti & Kangas, 2015). The benefits of scaling agile can be summarised as an increase in more motivated employees, faster time-to-market, increase in productivity and a reduction in defects (Dikert et al., 2016).

Through the scaling of agile, the number of deliveries is improved. This improvement in productivity ensures that projects are delivered quicker and the user or customer uses the product or service as an outcome of the project quicker. This quicker delivery is only possible through better resource utilisation and flow. Traditional project management focuses on optimal resource utilisation. Technical staff are organised into pools, for example architects, developers, testers, project managers and business analysts, and these pools are the source of available resources. Various problems or issues are associated with this approach.

A new philosophy needs to be instilled to implement scaled agile. Utilisation of 100% of the resources limits the flow of activity. Organisations need to focus on maximising the flow of applications and services and therefore on flow and not resource utilisation. To achieve this, organisations need to establish a fixed capacity model and then prioritise tasks accordingly, so that they address a rate that matches the fixed capacity. An advantage of the fixed capacity model is that the release of products or services occurs at a more predictable rate. The fixed capacity model also allows organisational strategies to drive the overall pattern of activity.

The next section focuses on a conceptual model that can be utilised by organisations and project managers. This conceptual model allows organisations and project managers to position the project management discipline in such a way as to deliver continuous solutions.

CONCEPTUAL MODEL

For organisations to become agile, agile technical practices as well as an agile mindset are required (West, 2017). The technical practices ensure consistency among teams and the agile mindset focuses on the customer, collaboration, openness to change, a willingness to fail and transparency (West, 2017). Organisations operating within the 4th Industrial Revolution should realise that products and services will become increasingly digital. The result is that organisations will have to operate in a more dynamic environment "driven by regional and global economics, regulatory mandates and increasingly demanding, technology-savvy customers" (Norton & West, 2017, p. 3). Adopting agile focuses on two levels:

- Breadth by scaling agile
- Depth by applying agile principles end to end from strategy to delivery

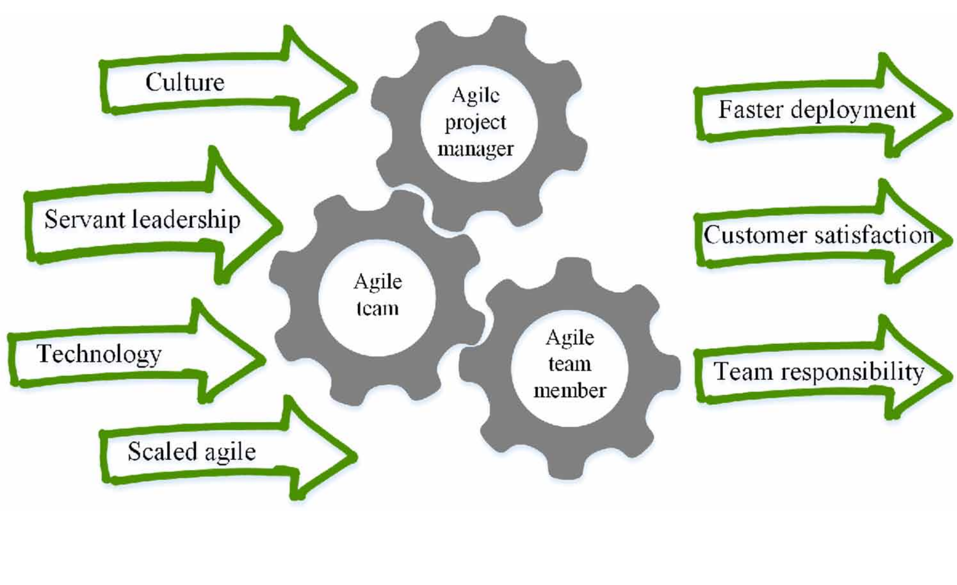
The conceptual model depicted in Figure 1 highlights the enablers and interaction between the agile project manager, the agile team and the individual agile team member.

The 4th Industrial Revolution demands that organisations deliver products and services quicker, smarter and better. Four major enablers need to be present before projects can be executed in an agile way. The four enablers are inter-related with each other and cannot create the necessary change individually. Cultural change is needed to facilitate the organisation and project teams for the transition into Industry 4.0. Culture also has an impact on the way that project managers manage their respective teams. The command and control style of leadership is not conducive anymore and a servant leadership approach is required. This style has its benefits as illustrated in Table 2 and Table 3. Industry 4.0 requires constant organisational change to incorporate new technologies as well as the changes introduced by technology, Agile as a change agent, is the perfect solution to deliver these changes as quick as possible, Agile, therefore delivers projects quicker and more reliable but the benefits of agile can only be harvested in a scaled agile environment. Scaling agile is only possible if the organisational culture allows it and when the project managers have adopted a servant leadership style.

The first enabler is the culture of the organisation. Agile is as much about culture and core values as it is about principles and practices (Norton & West, 2017). Management from business and IT should send a consistent message around the adoption of agile and they should actively promote it. The move to agile and adopting an agile culture takes time and comes with considerable stress to both the organisation and the employees (Norton & West, 2017). Management should create an environment that encourages change.

The second enabler is the adoption of a servant-leader leadership style by the agile project manager. This allows the agile project manager to lead and motivate rather than command and control. This change in leadership style is only possible when the culture of the organisation allows the traditional project manager to transform into an agile project manager that applies a servant leadership style.

Figure 1. Industry 4.0 and Agile Project Management Conceptual Model



Technology is the foundation of the 4th Industrial Revolution, especially the IoT and artificial intelligence. Agile project managers and teams should know how to embrace this technology and how it can make the management of projects easier. The adoption of technology is a two-way street. Technology can be used to enable the agile team to manage and deliver the project in a smarter way. An example would be to use artificial intelligence for the generation of burn-down charts. Technology can also be used to deliver the product and service and here an example might be to provide the solution via the latest technology such as smart watches. The Project Management Institute (2018a) has determined the impact that disruptive technologies have on the role of the agile project manager. Some of these impacts are:

- More expertise and experience are required in agile approaches. This is obvious as the 4th Industrial Revolution requires quicker deployments that are facilitated by agile.
- More business analytics expertise is needed.
- Subject matter expertise is also required. This is especially the case where the project manager needs to understand the impact of technology on the project,
- Project managers' core skill sets must be modified. As seen earlier in this chapter, agile project managers cannot continue to rely on old competencies and skills. They have to learn new competencies and skills that are dictated by technology.
- Current project management standards and best practices do not incorporate disruptive technology and therefore agile project managers will not know how to deal with it. This requires agile project managers to acquire knowledge beyond the current project management certifications.

Organisations cannot and will not be able to reap the benefits of agile if agile is not scaled within the organisation. Various frameworks can be used to scale agile within an organisation with SAFe® (Scaling Agile Framework) as the most popular scaled framework. Scaling agile implies the adoption of Lean-Agile at a portfolio, large-solutions, programme as well as team level. VersionOne Inc. (2018) mentions five enablers for scaling agile: (i) internal agile coaches, (ii) consistent agile practices across all project teams, (iii) the implementation of common tools such as JIRA for reporting, (iv) external agile consultants and (v) executive sponsorship. Scaling agile does not come without its challenges such as an organisational culture that does not support agile or the lack of skills and experience in agile.

The enablers create an environment conducive for the delivery of agile projects. This environment allows agile project managers and teams to ultimately deliver agile projects. Agile project managers, using servant leadership, lead the team to deliver the product or service. The team members portray the attributes as presented in Table 2. Agile project managers as well as agile team members must transform their traditional project management habits and practices into agile habits and practices. Both entities must make this transformation, as a non-agile project manager cannot lead an agile team and vice versa.

The result is a product or service that is delivered faster. Delivering products or services faster than competitors and maintaining the leading edge is a prerequisite for organisations to survive and thrive in the 4th Industrial Revolution. A fully integrated and scaled agile approach allows for small continuous changes and manages the additional complexity of self-organised teams. One of the agile principles is to collaborate extensively with customers to produce a product or service that actually meets the requirements stipulated by the users. This is only possible when everyone in the organisation has an agile mindset. This is also applicable to the users themselves. They should also embrace an agile mindset and be involved from the start to the end of the project.

SOLUTIONS AND RECOMMENDATIONS

Traditional project management has a role to play when new product development and customisations are not involved. The moment organisations engage in new product development or customisations, an agile approach is required. Traditional IT projects such as infrastructure upgrades can be done without an agile approach but there are lot of lessons that can be learned from an agile approach. It is therefore recommended that organisations embrace agile as the preferred choice of implementing projects, irrespective of the type and nature of the project.

Changing from a traditional project manager to an agile project manager does not happen overnight. To become an agile project manager, a conscientious effort must be made to adopt a servant leadership style. This will allow the agile project manager to focus on the management attributes as per Table 2. Project managers who cannot make this change on their own will face problems and challenges in managing agile project teams, as the management style will be in direct conflict with that of the team and the organisation at large. The agile project manager should also realise that different competencies are needed in a world dictated by the 4th Industrial Revolution. The competencies will be more of a coaching and leading nature. Organisations should have interventions in place to train and reskill agile project managers in these new competencies. Reskilling cannot be left to the agile project manager to resolve.

Team members should also realise that they themselves need to change in the new world introduced by the 4th Industrial Revolution. Traditional skills are no longer applicable and team members should become experts in their specific disciplines and master the art of their discipline. This specialisation leads to the formation of guilds which reflect the original guilds formed by various artisans (Frey & Osborne, 2017; James & Charles, 2003). Team members belong to guilds for training, development and innovation (PWC, 2017), thus introducing a culture of continuous learning. The team members have high levels of knowledge and experience and are intrinsically motivated (Levitt, 2011). Team members perform their activities with the minimum supervision or oversight, making the role of the project manager obsolete. They are motivated by their level of status and respect in their respective guilds rather than by their salary, formal title or position in the hierarchy (Levitt, 2011). Working in this kind of environment, with very few rules or procedures about how to do things, requires workers to have a high tolerance for ambiguity. There is no right way to do things except the way that they choose to do them (Levitt, 2011).

FUTURE RESEARCH DIRECTIONS

The Project Management Institute (2018a) identifies ten technologies that will have an impact on project management. Five of these technologies will have a direct impact on the way agile projects are managed. These five technologies are cloud solutions, IoT, artificial intelligence, 5G mobile internet and voice-driven software. Research is definitely needed on how these technologies will have an impact on the following:

- Agile project management: The question that needs to be answered is whether these technologies will have a positive impact on the four agile principles and what this impact will be.
- How agile project managers lead and coach their team. Can these technologies be used to make the agile project manager a better coach and leader?
- How agile team members engage with their discipline and with each other.

Apart from the technical research implications on agile project management, research is also required on the implications on the management of agile projects. Agile projects are currently managed with a 3rd Industrial Revolution mindset. This will have to change to adapt to a management style that is conducive for the 4th Industrial Revolution. Research will have to investigate this phenomenon.

CONCLUSION

The overall purpose of this chapter was to determine how Industry 4.0 impacts on the role of the project manager and how agile project management facilitates this transition. It is evident from the discussion that traditional project management cannot and will not be able to deliver products and services in an Industry 4.0 environment. Changes are required and these changes incorporate the way project managers perceive themselves in an agile environment as well as how they are going to manage agile teams.

The role of the project manager is changing to that of an agile project leader. This agile project leader should display new skills as highlighted in Table 3. The most important change is to move away from command and control and to focus on collaboration and coaching. The agile project leader needs to become a servant-leader that focuses on the well-being of the team members as well as of the project itself. The role is more on guiding and providing lanes within which to operate. If a team member wishes to function in the slow lane at a particular point in time, then it is their prerogative. The agile project leader should have empathy for this choice and provide the necessary support.

Agile team members will also change their behaviour. Team members are more empowered in an agile environment. This empowerment places additional responsibilities on the team members. They need to take accountability for their own choices. These choices might result in failure, which is fine in an agile environment. The challenge is to recover quickly from these failures and to learn from them. Agile team members also need to acquire new skills in order to perform optimally in an Industry 4.0 environment. How these skills are acquired and mastered also poses a challenge as traditional teaching and learning is not necessary conducive for mastering these new skills.

For project management and the project manager to be relevant in the 4th Industrial Revolution, the following changes have to be made:

1. The project manager will have to see agile projects within the context of Industry 4.0. Agile projects cannot be implemented by ignoring the impact and influence of Industry 4.0.
2. The current practices and standards need to be updated to include agile and scaled agile. This is also applicable to the competency frameworks. These frameworks need to focus on the competencies that agile project managers should master.
3. Industry 4.0 brings complexity and uncertainty to the table. Agile project managers should be able to apply the notion of complex adaptive systems to an agile project to simplify the complexity and uncertainty.

The role of the project manager is definitely changing in the new environment created by Industry 4.0. Project managers are going to face more demands and a new set of competencies and skills are required to deliver projects successfully for the 4th Industrial Revolution.

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Chapter 7
Managing Uncertainties in the Project 4.0 Lifecycle

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ABSTRACT

Three out of four projects are not getting off the ground. It is questionable whether industry 4.0 represents an additional obstacle to the execution of projects or contributes to overcoming these barriers. The fourth industrial revolution extends to all phases of the value-creation process. The project, ubiquitous in Industry 4.0, suffers a fundamental change covered by the definition of a Project 4.0. Uncertainties arising from the far-reaching changes in the environment and companies over the entire lifecycle of a project are not taken into account yet. Considering the uncertainties, there is an uncertainty descent from early to late stages of the Project 4.0 lifecycle. Here, by describing anomalies of subjective uncertainty assessment, the massive uncertainties perceived by decision makers were put into perspective. This serves as prerequisite for the design of a sound tool for an unambiguous decision on the execution of a Project 4.0. This tool contributes to insuring that more than one out of four projects succeeds.

INTRODUCTION

Three out of four projects are not getting off the ground. Can Industry 4.0 be a game changer or are the uncertainties associated with projects even increasing by the fourth industrial revolution?

The fourth industrial revolution is more than just limited to production or company boundaries as it extends to all phases of the value-creation process. Hereby, digitization acts not only as basis for new business models, projects, smart products, innovative services and batch size one, but also as source of

DOI: 10.4018/978-1-5225-7865-9.ch007

uncertainty. Uncertainty about the economic benefits of Industry 4.0 represents the central implementation barrier for 46% of industrial companies (PricewaterhouseCoopers, 2017; Hertel, 2015). The core idea of merging the physical world with the digital world makes Industry 4.0 a threat to the industrial centrepiece of the german economy for many companies (Sommerfeldt, 2015). By malware, such as Stuxnet, computer viruses, for instance Goldeneye, or hacker attacks on Deutsche Telekom in 2016, digitally induced uncertainties become open to the public. In addition to the publically known problem of information security, numerous other uncertainties are neither discussed publicly nor evaluated within the company (Alberstadt & Dörsam, 2014; Bundesamt für Sicherheit in der Informationstechnik, 2016). While the management of individual uncertainties used to be the focus, today - driven by discontinuities in the corporate environment, technologies and digitization - it is primarily a holistic management of uncertainties of entire businesses and projects that is in the spotlight.

The desire for custom-developed products and shortened product lifecycles requires mass production with batch size one that represents the ideal image of the fourth industrial revolution. The fourth industrial revolution's focus on batch size one requires a customer-focused ad-hoc configuration of networks. This ad-hoc network configuration corresponds to the definition of a project. Projects are essentially characterized by their uniqueness but also by the consistency of the conditions in their entirety, such as objectives, time, financial, personnel and other limitations, delimitation from other projects or their project-specific organization. In Industry 4.0, it is no longer companies that compete, but networks that cooperate in projects. Projects are ubiquitous in Industry 4.0 as value is created throughout project partnerships. As a result, the nature of a project suffers a fundamental redesign. This requires a redefinition of the project named Project 4.0.

Due to the growing complexity of uncertainty, only a quarter of all companies control project-specific uncertainties. With the rise of the fourth industrial revolution, this share surprisingly has been reduced by more than half since 2010. Long-term uncertainty assessments were increasingly replaced during this period by short-termed uncertainty assessments. Overall, three quarters of all projects do not meet with success.

These uncertainties resulting from the massive and far-reaching changes in the environment over the entire lifecycle of projects need to be taken into account. This is the only way to process uncertainties transparently on the one hand and to decide on the implementation of a project on the other. This leads to three research questions that span the scope of this paper:

- What are the properties of a Project 4.0?
- Which uncertainties arise in a Project 4.0 and when do they occur during project execution? How can the uncertainty assessment of decision-makers be put into perspective by anomalies of subjective uncertainty assessment?
- How to carry out a target-oriented uncertainty assessment of the project and unambiguously decide on its implementation?

These three research questions map the paper's procedure:

First, the key elements of Industry 4.0 are applied to projects. Objectives are the definition of a Project 4.0 and the presentation of the dynamic ad-hoc network configuration.

Subsequently, the decision-making situation marked by uncertainty is outlined followed by the derivation of thirteen different sources of uncertainty. These thirteen project uncertainties are then classified into a proprietary Industry 4.0-Project Lifecycle.

This is the foundation for an ex-ante uncertainty assessment in a Project 4.0 afterward 4. The purpose is a precise and well justified acceptance or rejection of a Project 4.0 supported by a suitable decision rule. The structurally derived and modified supporting tool for decision-making is finally demonstrated by using an example from the industry of additive manufacturing.

The paper concludes with a summary and outlook.

PROJECTS IN INDUSTRY 4.0

The Fourth Industrial Revolution

The term Industry 4.0 was created in particular by the acatech research union established by the Federal Ministry of Education and Research (BMBF). After the introduction of the term at the Hannover Trade Fair in 2011, the term Industry 4.0 quickly spread to many industries. Despite government, academics and practitioners seeing significant potential in Industry 4.0, there is still a lack of a broadly accepted definition.

A literature review is a valuable orientation support in a developing field. The neologism Industry 4.0 is composed by the parts industry and 4.0. Industry describes the field of application of the predicted revolution while “4.0” is a version name borrowed from the software language, which refers both to the fourth stage of the industrial revolution and at the same time carries digitization as its essential driver in its name.

By definition, industry 4.0 is a new type of production paradigm which, triggered by a conglomerate of emerging technologies, leads to increasing individualisation of products with shorter development times. However, any significant technical change can potentially be understood as a revolution (Mertens & Barbian, 2016). Therefore, there is no consensus on the definition of industrial revolution. Historians, for example, argue that the invention of the mill in the 13th century and the civil use of nuclear energy and air traffic in the 20th century represent industrial revolutions. However, no economist follows this view of historians.

What makes industry 4.0 a well-accepted revolution by economists?

The beginnings of the change to decentralized and self-organizing value chains of industry 4.0 can already be identified in 1968. The first machine networks in the USA were followed in 1976 by the first Distributed Numerical Control system suitable for industrial use, which made it possible to embed computer-controlled machine tools (CNC machines) in a network. As the examples of the mill, the civilian use of aviation and nuclear energy demonstrate, for economists a technological invention is not enough to proclaim an industrial revolution.

The justification for a revolution is based on organizational aspects that contribute to intelligent and networked value creation, which already have their origins in 1988. The idea of a revolution in production through “smart machines” was first formulated in 1988 by the American economist Shoshana Zuboff (1988). Zuboff describes the massive social and economic effects of integrating computer-based technologies into production. Shortly afterwards, the commercial use of the Internet began. The IP addresses required for comprehensive internal and external networking and an Internet of Things were expanded in 1998 by the introduction of the Internet Protocol Version 6 (IPv6) from a total of 4 billion addresses to 600 billion addresses per square millimetre of the earth’s surface (Steven & Klünder, 2018).

Hereby, it becomes clear that the description of industry 4.0 as the "digitization of manufacturing" (Ivezic, Kulvutunyou & Srinivasan, 2014) is an understated and insufficient definition.

By definition, an industrial revolution occurs when new technologies lead to a profound and lasting change in society and in particular in production technology. Thus, characteristics of an industrial revolution are changes at the organizational level, achieved through the widespread use of new technologies. Therefore, Industry 4.0 will likewise be explained by using an organizational and a technological component:

The presented literature overview in table 1 is the starting point for the formulation of an appropriate Industry 4.0-Definition.

In summary, the following definition for industry 4.0, containing all relevant characteristics, seems appropriate:

At the organizational level, Industry 4.0 is characterized by the horizontal and vertical integration of companies, which enables individualized, sustainable, flexible and resilient production across the entire network in a decentralized and self-organized value chain by which time, cost and quality leaps can be generated.

These organizational value creation changes are technologically promoted by the networked use of real-time-capable Cyber-Physical Systems in the Internet of Things and Services, so that digitally integrated, autonomous factories emerge (Steven & Klünder, 2018).

It is absolutely necessary for companies to adapt to this new production paradigm in order to leverage the potential of Industry 4.0 and to be ready for its challenges. An interview with experts from science and practice revealed that 52.4% of a company's Industry 4.0-Readiness is determined by cooperation-related factors in cross-company networks (Reder, Steven & Klünder, 2018). For this reason, in context of Industry 4.0 a closer look at the network is necessary.

Table 1. Literature Review of complementary Industry 4.0 Definitions

Author (Year)	Key Statement	Characteristics
Bahrin et al. (2016)	"[…] the goal is mainly to develop a smart factory in which products are able to find their own way through production and establish alternatives in case of disturbances (…)"	■ Resilience ■ Flexibility ■ Smart Factory
Oesterreich & Teuteberg (2016)	"Industry 4.0 […] can help construction companies to reduce complexity and uncertainty, to enhance information exchange and communication between project stakeholders and thus to increase productivity and quality."	■ Resilience ■ Time Leap ■ Quality Leap
Shafiq et al. (2015)	"[…] Industrie 4.0 is combining of intelligent machines, systems production and processes to form a sophisticated network. Moreover it emphasizes the idea of consistent digitization and linking of all productive units in an economy and creating real world virtualization into a huge information system."	■ Horizontal and vertical integration ■ Network ■ Digital Integration
Stock & Seliger (2016)	"A paradigm Industry 4.0 will be a step forward towards more sustainable industrial value creation. […] The decentralized instances will autonomously consider local information for the decision-making."	■ Autonomy ■ Sustainability ■ Individualization

The Relevance of Networks in Industry 4.0

The literature of supply chain management is packed with synonyms and corresponding buzzwords like value chain or logistic chain. The supply chain is a network of organizations covering all stages of the value chain, including the flow of materials and the associated flow of information. The network describes a series of relationships. This leads to a complex network comprising numerous sources of supply and numerous participants at the point of consumption. Four types of networks can be distinguished: regional networks, strategic networks, project networks and dynamic networks (Sydow & Winand, 1998):

- **Regional networks** are characterized by a territorial concentration of all equal network partners.
- **Strategic networks** are managed by a core company that defines the target market and the suitable strategy.

Both network types appear to be unsuitable and obsolete as a regional concentration as well as a centralization contradicts to the vision of Industry 4.0.

- While in some cases projects that a company manages simultaneously and their relationships to each other are perceived as project networks, this article follows the view of project networks consisting of relatively autonomous network participants jointly pursuing a project goal. The business relationships in project networks are typically accompanied by a hierarchical network structure in which a focal company coordinates the project.
- **Dynamic networks** emerge from a portfolio of potential network partners who temporarily form ad-hoc networks in accordance with market requirements or upcoming business opportunities (Scheer & Angeli, 2004). During the entire value creation process, autonomous network partners contribute their complementary core competencies. The integration of the network partners is based on a cross-network information and communication system that promotes the formation of dynamic networks (Corsten & Gössinger, 2008).

The latter two types of networks address the key conditions and challenges of value creation in Industry 4.0.

Thus, Industry 4.0 emphasizes the importance of project networks. In addition, the networks are becoming increasingly dynamic due to the digitization associated with Industry 4.0. Project 4.0 Networks are defined through project networks and dynamic networks as reference networks in the following sub-chapter.

The Project 4.0

A project is a sequence of unique, complex and connected activities having one goal or purpose that must be completed by a specific time, within budget and according to specification (Wysocki, Beck & Crane, 1995).

In general, projects have seven characteristics: (i) a single focus, (ii) a specific purpose and desired outcomes, (iii) a start and an end date, (iv) a timeframe for completion, (v) the involvement of a cross-functional group of people, (vi) a limited number of resources and (vii) a logical sequence of interdependent activities (Randolph & Posner, 1992).

Since in an increasingly individualized and digitized world a majority of all business activities are limited by time and budget constraints and can be regarded as unique and complex, the definition of a project received an ongoing clarification which is fully reflected in different standards and guidelines. In addition to the 21500:2012 standard according to the International Organization for Standardization (ISO), the German DIN standard 69901, the British PRINCE 2 standard and the US Project Management Body of Knowledge (PMBOK) should be mentioned in this context (Aichele & Schönberger, 2015). Table 2 outlines the key project definitions:

Industry 4.0 is leading to strengthened digital networking with all value creation partners, the provision of solutions instead of simple products, and increasing one-to-one transactions with customers. Those definitions were developed between 1992 and 2012 and do not embrace this revolutionary transformation of value creation through Industry 4.0, which is rapidly expanding since Hannover Fair in 2011.

Due to the increasing digital networking of companies in self-organizing value chains for the production of batch size 1, every customer order in Industry 4.0 appears to fulfill the project definitions mentioned above. This project nature of business processes in Industry 4.0 requires an adapted project definition. The acronym SMART is used to explicitly define goals in projects. Goals in projects have to be

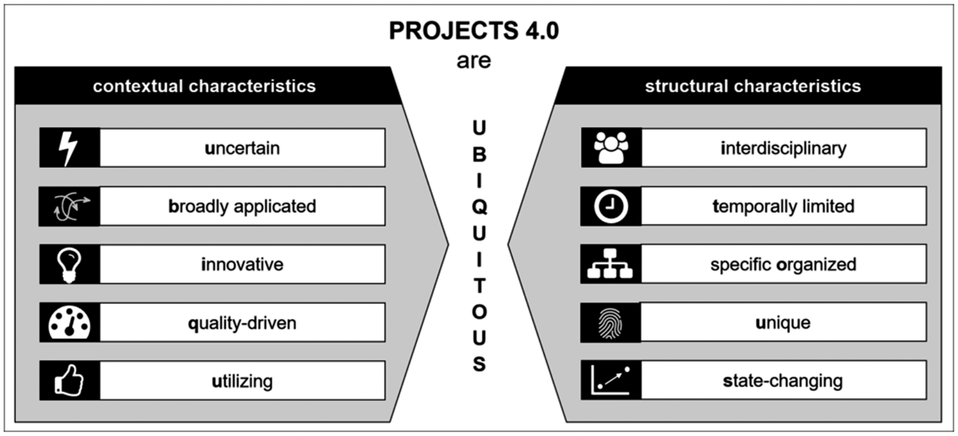
- **s**pecific,
- **m**easurable,
- **a**chievable,
- **r**easonable and
- **t**ime bound.

In accordance with this, projects 4.0 are defined with the acronym UBIQUITOUS. Projects are ubiquitous in Industry 4.0. They are characterized by uncertainty. The projects are broadly applicated and innovative due to a quality-driven increase in customer perceived utility. For this purpose, an interdisciplinary team is put together temporally limited in a specific organization to reach a unique, target-oriented state transition (see figure 1).

Table 2. Overview of project definitions

Author	Definition	Characteristics
DIN 69901-5	"Intentions which are essentially characterised by the uniqueness of the circumstances in their entirety, e.g. time, financial, personnel and other limitations, differentiation from other intentions, project-specific organisation."	unique/innovative temporally limited limited resources target-oriented specific organization
ISO 21500:2012	"A project consists of a unique set of processes consisting of coordinated and controlled activities with start and end dates, performed to achieve project objectives."	unique/innovative temporally limited target-oriented
PRINCE2:2009	"a temporary organization that is created for the purpose of delivering one or more business products according to a specified Business Case"	temporally limited target-oriented
PMBOK	"A project can thus be defined in terms of its distinctive characteristics—a project is a temporary endeavor undertaken to create a unique product or service. Temporary means that every project has a definite beginning and a definite end. Unique means that the product or service is different in some distinguishing way from all other products or services. For many organizations, projects are a means to respond to those requests that cannot be addressed within the organization's normal operational limits."	temporally limited unique/innovative specific organization

Figure 1. Structural and contextual characteristics of a project



The influence of several participants and ambiguous states of nature require a project manager to lead the project and plan, coordinate and control the different and complex processes (Liikamaa, 2015; Atkinson, Crawford & Ward, 2006; Flannes & Levin, 2001).

In projects 4.0, the project manager is turned into a cross-company coordinator, leader and communicator who unites the interests of all project participants. However, the company representative designated as the decision-maker is not necessarily the project manager. Instead, each company decides exclusively on the implementation of a project, whereby an individual company decision-maker becomes relevant who distinguishes himself from the superior project manager.

Ad-Hoc Configuration in the Project 4.0: Lifecycle

The definition clearly points out that projects 4.0 are characterized by their uniqueness, interdisciplinarity and temporal limitation. This is a result of the network formation described above. Establishing a network is a prerequisite for meeting the challenges associated with Industry 4.0 and represents a dynamic process. The core component of this dynamic process is the ad-hoc network configuration in the Industry 4.0-Project Lifecycle shown in figure 2.

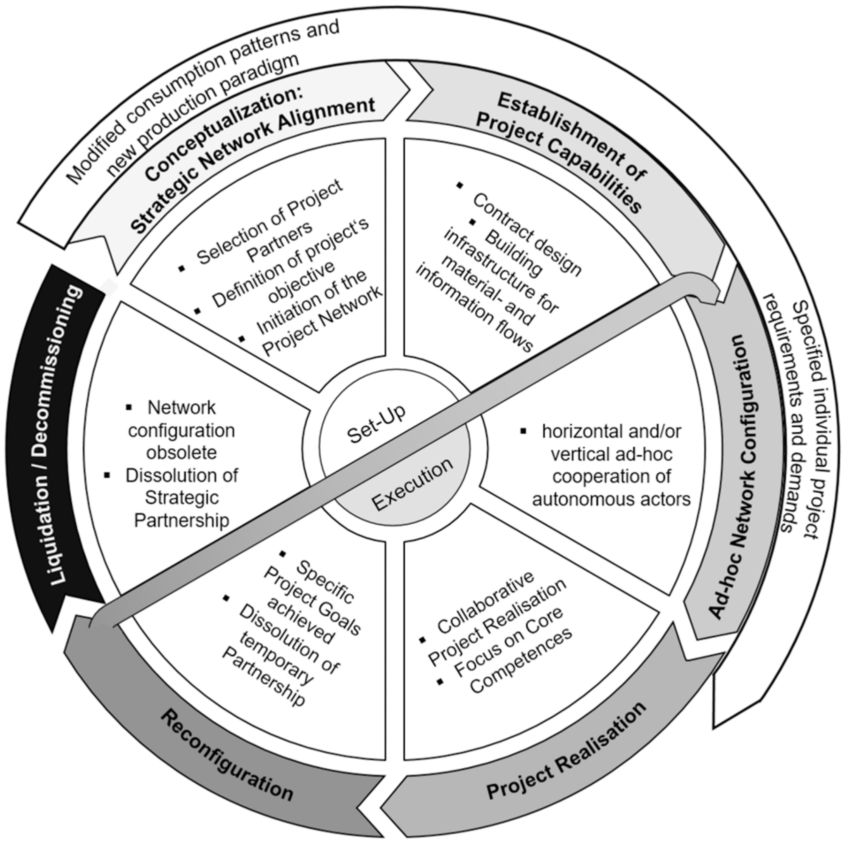
In terms of strategic network orientation, the project network is being initiated by changing consumption patterns and anticipated demand. These include the selection of partner companies and joint strategy formulation.

The proliferation of project-like value creation in Industry 4.0 leads to extensive changes in the lifecycle of projects (Westland, 2007). The lifecycle consists of six phases (see figure 2):

1. Conceptualization via Strategic Network Alignment

In the phase “Conceptualization: Strategic Network Alignment” a desired result and the expected benefit of the result are determined. The defined project goals comply with the SMART rule described above. The Strategic Network Alignment begins with a trigger event if an initiating organization member perceives an opportunity or a request. At this point, the project result can only be a rudimentary

Figure 2. Project 4.0- Lifecycle



sketch. The project's objective is formulated, project partners are selected and the inter-company project network is established.

2. Establishment of Project Capabilities

In the framework of the strategic concept, the contract law design and the construction of the infrastructure for the necessary flow of material and information are established.

3. Ad-Hoc Network Configuration

With the ad-hoc network configuration the project network is set up and the projects execution starts. The execution of the Project 4.0 begins with the initiation of the ad-hoc network configuration. A project-specific organization is configured to meet individual requirements based on the concretization of project requirements.

Here, at this stage in the lifecycle, a decision is made on execution of the concrete project. As the term ad-hoc already indicates, this is a decision to be made promptly and at short notice. This decision requires appropriate decision support. A tool to support this decision will be developed below.

4. Project Realization

The project plan is realized by accomplishing the tasks defined therein and managing the various technical and organizational interfaces. In addition, the contract management, i.e. the administration of the contractual aspects, takes place.

5. Reconfiguration

Whenever a network configuration can no longer meet the customer demand, the project partners return to the Industry 4.0-network. The temporary partnership is dissolved and capacities can be assigned to new projects. If the Industry 4.0-project-network is no longer able to handle the volatile consumption patterns due to its strategy formulation, it will be dissolved.

6. Liquidation / Decommissioning

The lifecycle of the network ends with the disconnection of financial, material and immaterial links between the project partners.

Each of these phases is associated with specific uncertainties that are analyzed below (Dörseln, Klünder & Steven, 2017).

UNCERTAINTY IN INDUSTRY 4.0 PROJECTS

Decision Making Analysis

The primary aim of this paper is to support decision makers whether to participate in a project or to deny its execution. Decision makers are directly responsible for deciding on the implementation of a project. Phases I and II of the Project 4.0-Lifecycle can therefore already have been completed (set-up). Thus, there is no strategic decision on the establishment of a network alignment, but a decision on the actual execution of a project, which is limited in its effect to the duration and scope of the respective project (execution). In order to comprehensibly present the decision situation a fictional Project 4.0 case is used. In This case a focal manufacturer has several possible applications for their additive manufacturing technology but only a limited number of production systems available. Therefore, he may only choose one of the following alternatives. The first application is the individualization of tools. Customers may individualize their tools with their company logo or even add an ergonomic handle that is specifically adapted to the user's hand. In the second possible application additive manufacturing is used to strengthen medical products such as bandages by printing individual strings onto the product. The non-participation in a Project 4.0 and is also possible and represents the third option for the decision maker.

When making a decision about the execution, decision makers need to take into account that possible disruptions might occur throughout the execution phase. Such disruptions endanger the entire production network and might lead to higher costs that can jeopardize the profitability of a project. Therefore, it is necessary to analyze the decision making process and present an effective way to handle this problem accordingly.

If the decision maker knows exactly which event will occur the situation is considered as decision under certainty. If several events might occur but the decision maker is unable to predict which event or whether at all an event will take place, then the decision maker has to reach a decision under uncertainty in a broader sense (Milliken, 1987).

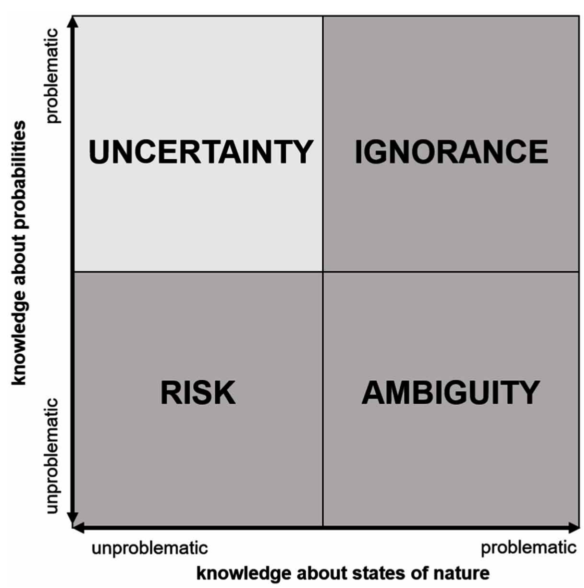
Depending on the knowledge about the possible events and the knowledge about their occurrence it is possible to distinguish between a decision under risk, under uncertainty in a narrower sense, under ambiguity or under ignorance (see figure 3) (Stirling, 2010).

The state of nature is a conceivable constellation of possible events relevant in a given situation. If the possible events that might occur are known, gaining knowledge about the states of nature is unproblematic. A decision about the further course of action is either reached under uncertainty in a narrow sense or under risk. The difference lies in the awareness of the occurrence probabilities. If the probabilities are known the decision will take place under risk otherwise it will be a decision under uncertainty in the narrow sense (Werners, 2013).

If the decision maker has knowledge about the probabilities of possible events, but no knowledge about the exact turnout and consequences, he faces a decision under ambiguity. And, if he collects no information about possible events and their probabilities and therefore displaces possible disruptions, he makes decisions under ignorance (Esser, 1999; Jost, 2013).

As for Projects 4.0 the possible events that might jeopardize the project are presented below in subchapter 3.2. Therefore, the knowledge about possible events is given. The probabilities of their occurrence are unknown though since they depend on the specific configuration of each project and can vary between different projects. Thus, decision makers in Projects 4.0 face decisions under uncertainty in a narrow sense.

Figure 3. Decision Matrix
(Stirling, 2010)



In order to further analyze possible uncertainties to which a project 4.0 network is exposed, it is important to distinguish between endogenous and exogenous uncertainties (Trkman & McCormack, 2009).

Endogenous uncertainties are caused inside the network and lead to changing relationships between the individual network partners.

Exogenous uncertainties have their source outside of the network and endanger the network entirely.

Sources of Uncertainty

In the following, possible events that may occur throughout the project lifecycle are presented (figure 4). These events and the uncertainty about their occurrence have to be taken into consideration before committing to the project (Jüttner, Peck & Christopher, 2003; Tang & Tomlin, 2008; Wagner & Bode, 2008, Zsidisin et al., 2004). The relevance and possible impact of such events are evaluated in consideration of a non-digitized network.

Endogenous Events

A central uncertainty is represented by data theft or misuse of sensitive company information in the project network (Roth & Siepmann, 2016). During the establishment and the decommissioning of the strategic network, the use and possession of information, e.g. patents or customer data, must be clearly regulated by contractual arrangements. With extensive interconnectivity, the uncertainty of an uncontrolled flow of information increases.

During the project realisation, unexpected events in the production such as a machine failure become relevant. The increasingly decentralized production in large networks reduces the uncertainty about these events, as extensive machinery can be used flexibly.

Increasing requirements on the qualification of the employees through increasingly digital processes lead to possible personnel errors (Lorenz et al., 2016; Diederichs, 2012), which impairs the Industry 4.0 network right from the beginning.

A possible dependency occurs if there are no short-term alternatives to the corporate network due to organizational or technical interdependencies (Wildemann, 2016). The organizational dependency is caused by specific competences of the partners, whereas in the case of technical dependency the partners are difficult to replace due to the specific digital interconnectivity. The impact of such an event tends to increase since the specific network partners are already chosen with regard to their specific profitable skills.

The violation of compliance guidelines if network partners disregard moral standards can lead to a loss of popularity across the entire network (Moder, Jahns & Hartmann, 2008). The possibility of such an event exists particularly during the project realization.

Disruptions due to information asymmetries are caused by the incomplete or incorrect supply of information in the execution phase, especially during the reconfiguration (Reese & Waage 2007). The close interconnectivity of communication systems and the dependency between network partners leads to a lower significance of this uncertainty.

The uncertainty about false intentions of cooperating network partners arise from communication difficulties and a lack of trust between project partners (Steven & Pollmeier, 2015). Trust-based communication is essential, especially for ad-hoc network configuration. The uncertainty about possible misdemeanors is to be assessed as low, as the partners pursue common goals due to their strategic orientation.

The exchange of material, information and financial resources between the various locations of the corporate network entails possible disruptions during the transfer (Steven, 2007). Since digitization enables the continuously monitored flow of material and information, the occurrence of an event like this is of minor importance.

Exogenous Events

An information-technology (IT) security breach describes the manipulation of the correct, complete and on-time availability of data and secure communication within the network (Fallenbeck & Eckert, 2014). The risk of an unauthorized system access is already important during the strategic network alignment, since decisions on the basic concept and thus also the IT system to be used are made here. The impact of such an IT breach increases due to the increasing use of IT as a result of digitization.

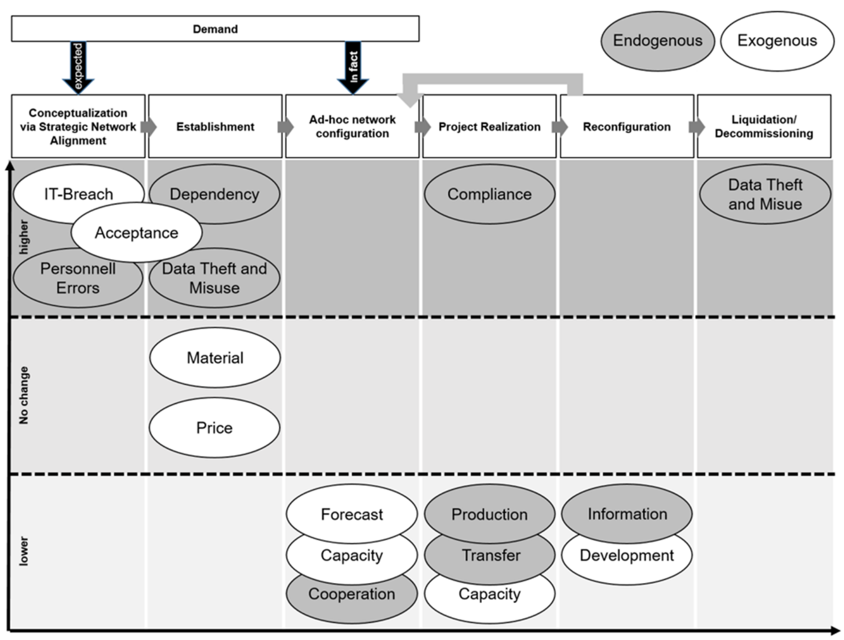
Discrepancies between the forecasted and the actual demand represent the uncertainty of a shortage of demand or excess capacity in particular (Wagner & Bode, 2007). Due to the high availability of data in the era of digitization, the quality of forecasts rises. Therefore, this event is less likely than in a non-digitized network.

Uncertainty about the capacity describes the possibility of not being able to react to short-term orders due to bottlenecks in production (Locker & Grosse-Ruyken 2015). The significance of this uncertainty decreases in line with the forecasting risk.

Extreme volatilities in material quantities and prices need to be taken into account during the establishment of project capabilities (Fischl, Scherrer-Rathje & Friedli, 2014). The relevance of this uncertainty will not change in an Industry 4.0-Network.

All in all, there is an uncertainty descent from early to later phases of the life cycle. This serves to relativize the overall uncertainty of Industry 4.0 in the following chapter.

Figure 4. Uncertainties in Project 4.0 Lifecycle



ASSESSMENT OF UNCERTAINTIES IN THE INDUSTRY 4.0 PROJECT LIFECYCLE

Anomalies of Uncertainty Assessment

When assessing the risk of Industry 4.0, it must be taken into account that decision makers do not represent the ideal image of the homo economicus. The highly subjective perception of risks - 46% of companies perceive Industry 4.0 as a source of risk - can be explained by different anomalies:

- **Cognitive Heuristics:** The easier it is for a decision-maker to find examples of an event's occurrence, the higher its probability of occurrence is estimated. For example hacker attacks on Deutsche Telekom or ThyssenKrupp in 2016 as well as the data breach by Cambridge Analytica promote increased awareness of the IT security risk (Handelsblatt, 2016).
- **Endowment Effect:** The endowment effect describes that ownership is attributed a significantly higher benefit than the willingness of the decision maker to pay for the object (Thaler, 1980). Before investing into new Industry 4.0-technologies, its perceived benefits have to be significantly higher than the benefits of the existing technologies that were overestimated by the endowment effect.
- **Sunk Costs Effect:** Similar to the endowment effect, the more time and money decision-makers have invested in a decision, the more they stick to it. If a company owns a machine park that was associated with high investment costs, it is unwilling to invest in Industry 4.0-related technologies.
- **Anchor Heuristics:** The anchor heuristics state that an insufficient correction of the judgement emerges from new information. If the maturity level of Industry 4.0-technologies increases, uncertainty is objectively reduced, but the decision-maker's assessment of the associated risk is not adjusted.
- **Perception of a Risk Reduction:** The reduction of a high risk by a known probability of occurrence is perceived less strongly than a reduction by the same probability of occurrence to zero. For example, there is a high probability of IT security risks occurring, which can currently only be successively reduced (Brunner et al., 2016).
- **Decline in Marginal Utility:** Higher profits in the future are assessed positively by decision-makers, but with decreasing marginal utility. Therefore, an additional success, which can be achieved through Industry 4.0, provides a steadily decreasing incentive for implementation.
- **Risk Discounting:** Decision-makers overestimate current consequences, while risk effects are discounted by a factor of 25% per period in the future. If a risk reduction occurs in the future, this cannot offset an increase in risk by the same degree in the present.
- **Principle of Profit Protection and Loss Repair:** If a decision-maker is in a profit situation, like most German industrial companies, decision-makers act more risk-averse than companies in a loss situation (Pelzmann, 2000).
- **Risk Avoidance Through Omission:** Decision-makers prefer to omit from making a decision. In order not to suffer from negative consequences, the implementation of a project is often disregarded.

These anomalies in risk perception indicate that the subjective assessment of Project 4.0 risks is not sufficient. The implementation barrier in Industry 4.0 results from those risk anomalies and thus leads to the neglect of potential opportunities of Industry 4.0. Decision-makers therefore require methodological support in order to make a clear decision on the implementation of a project.

Decision Making Methods

A decision is the choice of a suitable decision alternative from several alternatives that are mutually exclusive. A large number of aspects must be taken into account in the decision. The decision situation is characterized by:

- A discrete and a-priori known number of project alternatives
- Where the non-implementation of a project is part of the set of alternatives
- A larger number of relevant evaluation criteria
- That have to be expressed in monetary terms

The evaluation of economic entities is mainly subjective, so that the appropriate methodological support attempts to disclose these subjective assessment criteria.

The premises for the decision on project implementation in Industry 4.0 are:

- Pessimistic decision-maker
- High complexity of the decision problem
- Possibility of the implementation and integration of the Industry 4.0 lifecycle

A variety of decision rules are available for deciding on the implementation of Projects 4.0 (see figure 5).

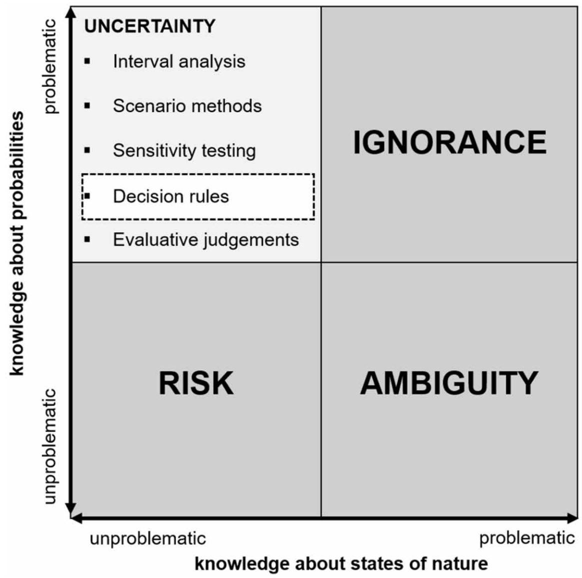
Decision Rules

The use of non-probabilistic methods such as interval analysis, scenario methods, sensitivity testing and evaluative judgements leads to complex mathematical optimization tasks, which are usually non-linear and can only be solved with complex numerical solution methods (Gurav, Goosen & van Keulen (2005). Such complex numerical solution methods are time-consuming even with the use of technology. Most importantly, these procedures are non-transparent and therefore not easily accessible to decision-makers (Scholz, 1983).

A decision rule is a technique that, in the presence of a decision model, should enable the selection of the action alternative that appears to be optimal depending on the subjective preferences of the decision-maker.

The most well-known decision rules for uncertainty situations include the Hurwicz principle, Maximax rule, Maximin rule, Laplace principle and Savage-Niehans principle. These rules can lead to concordant, but may also lead to conflicting recommendations for action. Therefore, a careful selection of the decision rule is necessary.

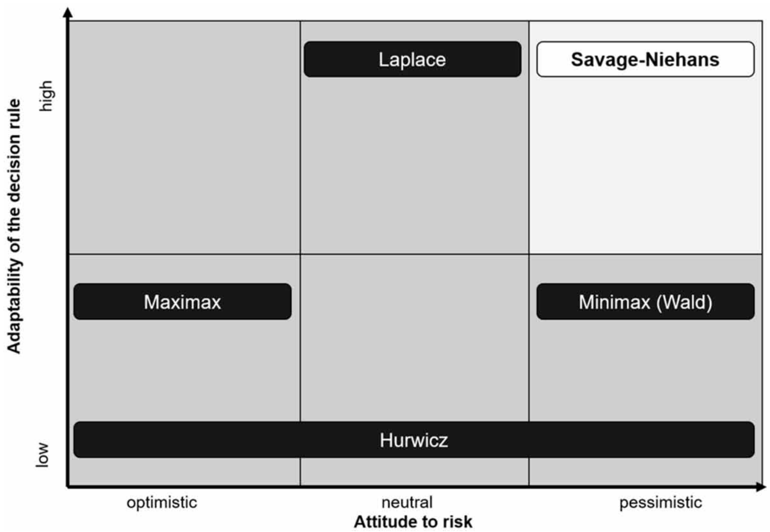
Figure 5. Uncertainty Instruments in the Decision Matrix
(Stirling, 2010)



- **Maximax-Principle:** Applying the Maximax rule, the alternative that provides the best result in the best case is selected.
- **Minimax-Principle:** The alternative is selected which, in the worst case, will produce the best result.
- **Hurwicz-Principle:** The preference value of an action alternative is calculated according to the Hurwicz principle from a weighted sum of the best and worst possible results of the alternative. The Hurwicz-Principle is a combination of the Maximax- and Minimax-Principle (Gaspars-Wieloch, 2014).
- **Laplace:** Using the Laplace principle, the average of the results for all states of nature is simply calculated. It is assumed that all states of nature are equally probable. This corresponds to the calculation of the expected value in risk situations.
- **Savage-Niehans:** Selection of the action alternative whose highest regret (lowest opportunity costs) is the lowest regret of all action alternatives (Rapoport, 1998).

These decision rules can be evaluated in terms of risk attitude and adaptability. A person with an optimistic attitude to risk is a person who will value the opportunity of a positive outcome more highly than the risk of a negative outcome. However, a pessimistic person would value the possibility of a negative outcome more highly than the opportunity of a positive. A risk neutral person would value both outcomes completely equally. With exception of the Hurwicz principle, the above decision rules require an attitude of risk. The assumed risk setting is shown on the horizontal axis in figure 6. In addition, some decision rules are very rigid and cannot easily be extended to a large number of states of nature or action alternatives, so that the decision rule is not very adaptable. An evaluation of the adaptability of the mentioned decision rules is located on the vertical axis in figure 6.

Figure 6. Evaluation of Decision Rules



It becomes clear that the Savage-Niehans Principle is the only decision rule that implies a pessimistic decision-maker and allows sufficient degrees of freedom to adapt to the desired context.

The Savage-Niehans Principle, likewise applied within the decision-making process under uncertainty, is also called Minimax-Regret Principle, is a decision rule. Uncertainty arises from the inability to make precise predictions about the future. It may be possible to predict some environmental conditions and outcomes, but it is extremely difficult to metrically specify these anticipations (PricewaterhouseCoopers, 2017). Knowing these parameters, the decision on project execution would be unproblematic. But if many factors are not deterministic at the time of decision, the decision maker must choose the appropriate alternative based on some predicted scenarios.

The Savage-Niehans principle consists of two steps: First, the regret values, also called opportunity cost or loss, for all cases are calculated. A regret value corresponds to the difference between the maximum value of a particular measure for the respective consequence and the value of a particular alternative for the same consequence. The rule then selects the alternative with the smallest maximum regret value.

The Savage-Niehans principle measures the regret that occurs if a given situation s_j occurs and the payout of the particular alternative a_i is below the maximal achievable payout under the current state of nature.

The calculation of the regret b_{ij} allows a transformation of the decision matrix into a regret matrix. Thus, b_{ij} represents the maximum payoff attainable under the state of nature s_j.

$$b_{ij} = \max w_{ij} - w_{ij}$$

$$\forall i = 1,2,\ldots,n$$

and

$$j = 1,2,\ldots,m$$

Then the maximum regret R of each alternative a_i is determined.

$$R\left(a_i\right) = max_j b_{ij} \ \forall \ i = 1, 2, \ldots, n$$

Finally, the minimal maximum regret is selected as a solution to the decision problem.

$$R\left(a^*\right) = min_i R\left(a_i\right)$$

The application of the Savage-Niehans rule is briefly outlined using a simple numerical example with 4 project alternatives and 3 conceivable states of nature:

The combination of Savage-Niehans Principle and the risk descent derived in Chapter 3.3 provides decision support for decision makers. For this purpose, the lifecycle phases are integrated into the application of the Savage-Niehans Principle. When applying the Savage-Niehans Principle, each action alternative is divided into 6 sub-components. These 6 subcomponents represent the six lifecycle phases of a Project 4.0 from chapter 3.3. This enables a decisive and small step-by-step assessment of the payoff of each action alternative in each state of nature by taking the derived uncertainty factors into account. Hereby an over- or underestimation of payoffs is prevented. This allows an ex-ante decision on the implementation or non-implementation of a project under uncertainty. The procedure is shown in the figure below and is essentially based on the basic logic of the Savage-Niehans Principle (see figure 8):

Figure 7. Procedure of the Savage Niehans Principle

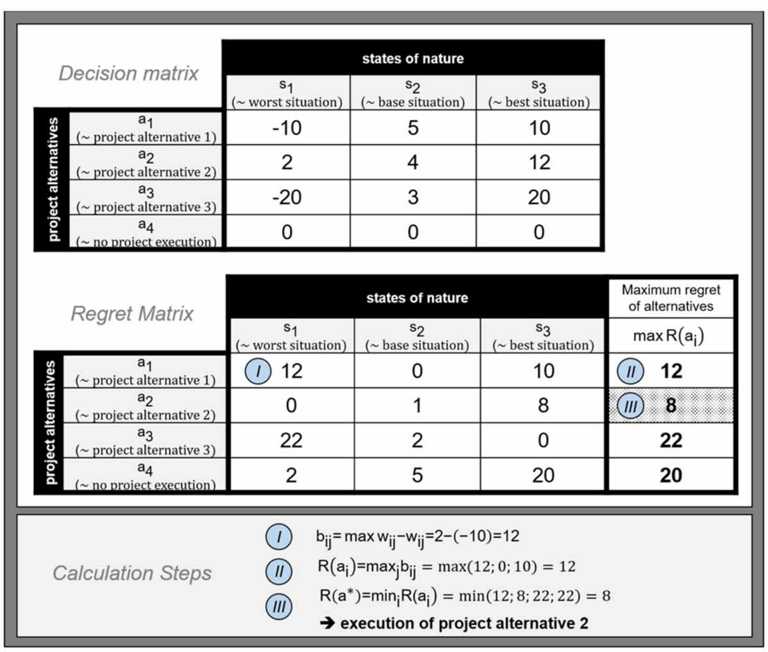
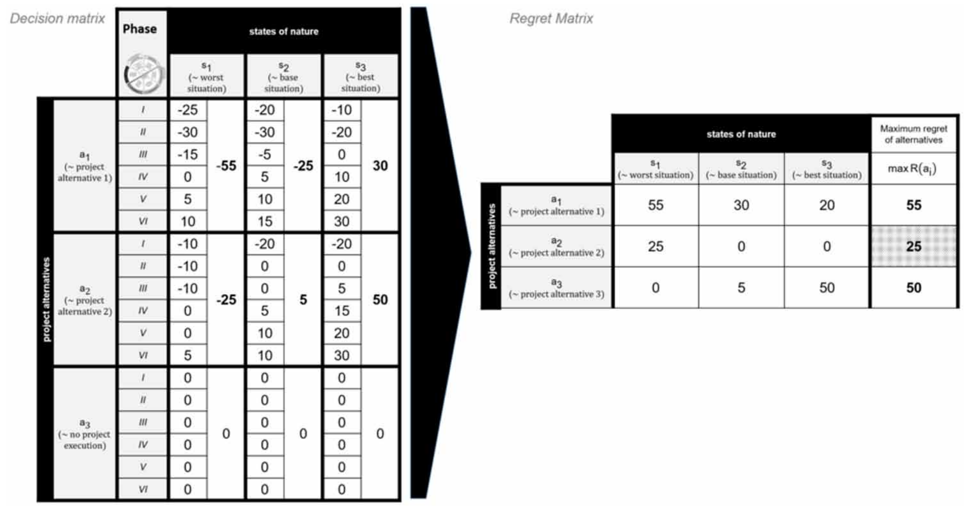


Figure 8. Implementation of Project 4.0-Lifecycle in the Savage-Niehans Principle



Decision matrix

project alternatives	Phase	s_1 (~ worst situation)		s_2 (~ base situation)		s_3 (~ best situation)	
a_1 (~ project alternative 1)	I	-25	-55	-20	-25	-10	30
	II	-30		-30		-20	
	III	-15		-5		0	
	IV	0		5		10	
	V	5		10		20	
	VI	10		15		30	
a_2 (~ project alternative 2)	I	-10	-25	-20	5	-20	50
	II	-10		0		0	
	III	-10		0		5	
	IV	0		5		15	
	V	0		10		20	
	VI	5		10		30	
a_3 (~ no project execution)	I	0	0	0	0	0	0
	II	0		0		0	
	III	0		0		0	
	IV	0		0		0	
	V	0		0		0	
	VI	0		0		0	

Regret Matrix

project alternatives	s_1 (~ worst situation)	s_2 (~ base situation)	s_3 (~ best situation)	Maximum regret of alternatives max $R(a_i)$
a_1 (~ project alternative 1)	55	30	20	55
a_2 (~ project alternative 2)	25	0	0	25
a_3 (~ project alternative 3)	0	5	50	50

There are three alternatives to choose from in this application example. Alternatives 1 and 2 represent project alternatives, while alternative 3 describes the non-implementation of a project and therefore does not contain any payoffs. Here it is possible to refer back to the previously introduced example. Alternative 1 represents the use of the additive manufacturing technology to individualize a tool. Alternative 2 stands for the improvement of the product properties of medical products by the application of strings. And last but not least, it is always a possibility not to use the production technology (alternative 3). The payoffs of this alternative are equal to zero. The structured decomposition of payoffs, highlighted by the roman numerals I to VI, enables an multi-person evaluation of an alternative decision. Each lifecycle phase of each action alternative in each state of nature taken into consideration is assessed with an individual payoff. The aggregation of these partial payoffs enables the familiar application of the Savage-Niehans Principle in the following step. Alternative 2 in figure 6 shows the minimal maximum regret and is the best action alternative (see figure 7). The manufacturer should therefore carry out the structural-mechanical optimization of medical products by applying strings to bandages (alternative 2).

CONCLUSION

The paper started with the statement that three out of four projects are not getting off the ground. Main reason for the failure of so many projects were misguided decisions about the execution of a project. Therefore, this article focusses on supporting decision makers about the execution of a project with a suitable decision method.

In Industry 4.0 the individualism of every customer request leads to specifically configured networks for every order. Thus, value in Industry 4.0 is created on a project base. Due to this influence the project definitions to this date are no longer adequate. Projects in Industry 4.0 are ubiquitous. These projects are characterized primarily by their uniqueness, interdisciplinarity and temporal limitation. The interdisciplinarity leads to the ad-hoc configuration of project networks. The long-term relationship in these networks runs a lifecycle. This lifecycle is marked by uncertainties that can disrupt entire projects.

Considering these uncertainties along the life cycle, a descent of these uncertainties from early to late life cycle phases was determined. This uncertainty descent explains the decision-makers' fear of implementing projects in Industry 4.0. This fear could be put into perspective by anomalies of the uncertainty assessments, so that a contribution to the future successful implementation of Projects 4.0 was created.

However, there was still missing a tool for decision-makers to decide on the implementation of a project. A suitable tool was identified in a structured manner on the basis of the uncertain decision situation and subsequently adapted for Project 4.0 specific use. The Savage-Niehans Principle appears as a suitable tool and has been supplemented by the six lifecycle phases of the project partnership and thus made operational for project managers in Industry 4.0. All in all a contribution was made in order to insure that more than one out of four projects gets off the ground.

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Chapter 8
Managing Customer Journeys in a Nimble Way for Industry 4.0

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ABSTRACT

In the Fourth Industrial Revolution, customers expect companies to provide journeys in line with rapidly changing expectations. This allows for great potential for project portfolios that can enable tailored experiences, powered by technology and insights coming from the 360° view of the customer, to improve the experience and touchpoints before, during or after the main interaction of customers with a company. This chapter will illustrate that project managers need to master a dual dynamic to do so. On the one hand, new types of projects, changing expectations and shifting habits offer humbling challenges. On the other hand, governance, change and delivery continue to be the foundational baseline. By integrating theoretical insights and real-life cases from conservative and progressive industries, the author wants to stimulate project managers. Rather than seeing Industry 4.0 as a transformational tsunami, they should see it as an opportunity to remain curious, nimble and committed, while working in a reality where rapidly changing demand entails growth, learning and great value.

INTRODUCTION

While technological evolutions are airing at high speed, companies are continuously challenged to reinvent themselves. Digital Transformation is seen as one of the means to get there. Early 2016, the World Economic Forum in Davos called it the Fourth Industrial Revolution. They stated that these changes hold great potential, but that the related patterns of consumption, production and employment also pose major challenges requiring proactive adaptation by corporations, governments and individuals (Schwab & Samans, 2016).

Companies need to be aware that Industry 4.0 is not a temporary add-on. Likewise, it is not about technology itself, but about how to integrate it to transform businesses and shape the way of working (Caudron & Van Peteghem, 2014). One of the biggest changes that comes with it is therefore the transition from a product and competition-based economy to a service and customer journey focused reality (Janssens, 2018).

DOI: 10.4018/978-1-5225-7865-9.ch008

Given the fundamental changes coming with Industry 4.0, new customer experience and the growing impact of data power, it can be stated that all stages of project management discipline will be changed.

In this chapter, a more differentiated angle will be taken. It will be explained that traditional project management fundamentals remain valid, but the emphasis on specific dimensions needs to be adapted. Aspects that require increased attention are: an agile project approach from elaboration up until the reporting, empowering people, managing change for everyone, and continued delivery.

By integrating attention points for the project management silver lining with examples and cases from reality-based experience in both conservative and progressive industries, the author wants to illustrate that the Project Management fundamentals in the Industry 4.0. remain strongly valid, but involve a different emphasis, embedded in a more proactive and collaborative dynamic.

BACKGROUND

Every industrial revolution is driven by new technologies. In the Fourth Industrial Revolution, new technologies get combined with technologies that finally become mature and affordable, like computing power, connected devices, genetic sequencing, artificial intelligence and the like.

From a corporate perspective, facts are available in spades to illustrate the vastness of the impact of this evolution. In 2016, the CEO of technology and consultancy company Accenture stated that digital transformation is one of the main reasons half of the companies on the Fortune 500 have disappeared since 2000 (Nanterme, 2016). The growing impact of the GAFAs and the NATUs[1] only confirms this.

From a human perspective, the way people live, work and interact is transforming at high speed: more than 2 billion people were on Facebook in 2017; some predict that more people will have mobile phones by 2020 than will have electricity or running water in their homes or villages; and children born in 2017 may never drive a car (Arbib & Seba, 2017; Javelosa & Marquart, 2017; Schwab, 2016).

The transformation of physical and digital worlds entails great potential. At the same time, this leads to (pressure for) increased human productivity. Customers expect businesses to anticipate their needs and provide personalised service through any communication channel. Business-to-Business (B2B) and Business-to-Consumer (B2C) businesses alike need to shift therefore from a model focused solely on selling products, to a service model driven by deeper connections with customers (Janssens, 2017).

This deeper connection is embodied through the concept of ‘customer journeys.’ Customer journeys are the sum of experiences and touchpoints customers go through when interacting with a company, before, during and after the main interaction (Schadler, 2018; Truog, 2018; Van den Brink, 2018). By improving customer journeys, companies can remain relevant in the Fourth Industrial Revolution.

Data Is the New Currency

In the Digital Age, people are using connected devices, privately and professionally, and are sharing large data volumes every day. In 2017, it was expected to grow to 163ZB by 2025, of which a quarter in real-time (Reinsel, Gantz & Rydning, 2017).

Through the data fuel, Artificial Intelligence (AI) is driving innovation across growing numbers of products and services. In 2017, organisations with AI expected to see a 39% increase on average in their revenues by 2020, alongside a 37% reduction in costs (Economic Times, 2017).

The higher the quantity and quality of the data, the higher the quality of the artificial learning. Machine learning algorithms and the like are therefore able to help businesses anticipate trends in consumer demands, personalize promotions for individual customers, and optimize pricing. Consumer sentiments towards a specific brand(s) can be unveiled (Stephen, 2017), supply chain operations can be further optimised (Gaus, Olsen & Deloso, 2018) and different types of cancer cells can be spotted through AI improved imagery (Tucker, 2018).

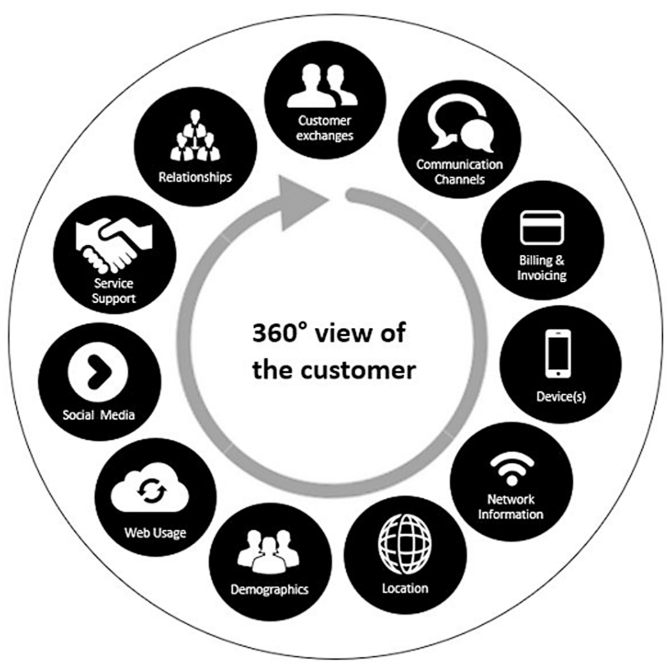
360° View of the Customer

To make data tangible, 360° views are key. A 360° view is the ability to see everything around you with no blind spots. It allows companies to capture every single part of the end-to-end relationship(s) it has with its customers. It includes sales and service information, marketing data, and information about who they are. From a B2B perspective, it also includes information about their business, what businesses they relate to, who has the buying power and the like (Loesel, 2014).

In addition to creating an organisation's institutional memory, 360° information helps a company to understand who are in practice the largest accounts, identify whitespace for cross-selling opportunities, and connect in a more meaningful way with the biggest customers (Digital Marketing Institute, 2018).

In the past, this information got captured through different systems. Luckily, an increasing number of platforms, like Salesforce or Microsoft Dynamics, allows to capture this in a smooth way. To get there, clean and complete data are key (Sebastian-Coleman, 2013). It is therefore crucial to make it, on the one hand, easy for people to capture qualitative data, and, on the other hand, required to do so. By combining both aspects, contributing to the data power will become an organisational norm.

Figure 1. 360° view of the customer
Source: Own elaboration



New Customer Journey(s)

One of the biggest changes of Industry 4.0 is the transition from a product and competition-based economy to a service and customer journey focused reality (Janssens, 2017). That is a profound shift. The opportunity, on a service perspective, is to rethink the way to satisfy a customer's need through a service (Schadler, 2018; Van den Brink, 2018), especially as many services were not there before.

Through data and 360° views, companies need to understand how to evolve to continue to matter. They need to embrace new technological possibilities and look through the blurring frontiers between offline and online realities (Hinssen, 2014; Truog, 2018). Understanding this requires courage and commitment, especially as pressure on delivery and results remain constant.

It requires a dynamic silver lining, compatible with interactive work clusters and a hybrid organization (Janssens, 2017). Typically, this results in a new way of working and an appropriate approach to power this way of working. Altogether, the success of projects in the age of Industry 4.0 goes through truly integrating technological possibilities and dynamic customer journeys in the corporate DNA.

SOLUTIONS AND RECOMMENDATIONS

New Types of Projects

From a project perspective, the 4th Industrial Revolution has initiated a new series of projects, in complement of traditional ones focusing on organisational change, process standardisation or a combination of both. Typically, projects focusing on advanced analytics or artificial intelligence have become mainstream (Fockedey, 2017). Similarly, more projects are focusing on a revision of the product and service approach, by opting for customer centricity (Hollander, Hertz, & Wassink, 2013).

The autonomous driving industry has been very emblematic for AI-powered transformations. The American branch of Germany-based MM Automotive[2], for instance, is active in the production of automotive parts and the development of car navigation solutions. In 2016, there was a high risk to turn virtually overnight from an iconic company into a fallen glory, as major multi-annual contracts were ending, and no new contracts were secured yet.

The company made organisational shifts and changed their project management approach. Most importantly, however, they extended the car navigation division with a new sub-division for autonomous driving solutions. They developed capabilities in artificial intelligence and built collaborations with specialised knowledge hubs. Similarly, efforts were put in the development of user experience capabilities, and in user centric project management approaches. While no final products were delivered yet by 2018, MM Automotive managed to generate new research contracts with major car manufacturers in the US, France and Germany, through their distinctive focus on customer journey services combining AI and User Experience.

Reinforcing the focus on the customer has also been present out of the technology industry. At AG Insurance, for example, shifting the organisational model towards customer centricity has been part of the 2015-2020 project portfolio roadmap. Since its creation in 1824, AG had a product centric approach. Throughout their historic growth, the company has been organised around life insurance, non-life insurance, and supplementary pensions product lines. With evolving customer expectations, they were not able to provide services that met the growing demand of reactivity and responsiveness. Typically, customers desiring information about different acquired products had to contact each department individually, rather than being able to count on a centralised service (Janssens, J., personal interview, Dec 20, 2017). By launching a profound transformation program, they aimed at changing their organisation, their internal processes, their data model, their tools and, in the end, the service provided to their customers, to answer the needs of the 'modern' customer journeys, based on a 360° view of the customer.

Managing Projects in the Fourth Industrial Revolution

Given the fundamental changes coming with technology, new customer experience, the growing impact of data power, and rise of new types of projects it could be assumed that all stages of project management will have to change. At the same time, a different angle can be taken: traditional project management fundamentals remain valid, albeit with an adapted emphasis on specific dimensions.

In addition to the earlier mentioned drivers of the Fourth Industrial Revolution themselves, the project management discipline is facing changes: evolutions in organisational reality, maturing acceptance of the agile way of working, and the growing impact of new generations (Laloux, 2014; Stillman & Stillman, 2017; Versione, 2018).

At the same time, other fundaments remain very much present: the crucial impact of change management, the need for follow-up and governance, and the need to collaborate, manage and deliver.

Industry 4.0 Goes Agile

Several changes put in motion by the Fourth Industrial Revolution are possible thanks to a convergence of different factors. Agile project management is not linked to digital transformation or the Fourth Industrial Revolution as such. When representatives from diverse development practices wrote the agile manifesto in 2001, they did not do it for the Fourth Industrial Revolution. Rather, they wanted to find an alternative to the dominant, heavy development processes (Highsmith, 2001).

Nevertheless, maturing agile project practices have an impact on project management of Industry 4.0. An increasing number of organisations evolved from using agile in pilot projects to accepting it as one of the main project management approaches. Agile (at large) will therefore remain at the core of projects of the coming years (Versione, 2018).

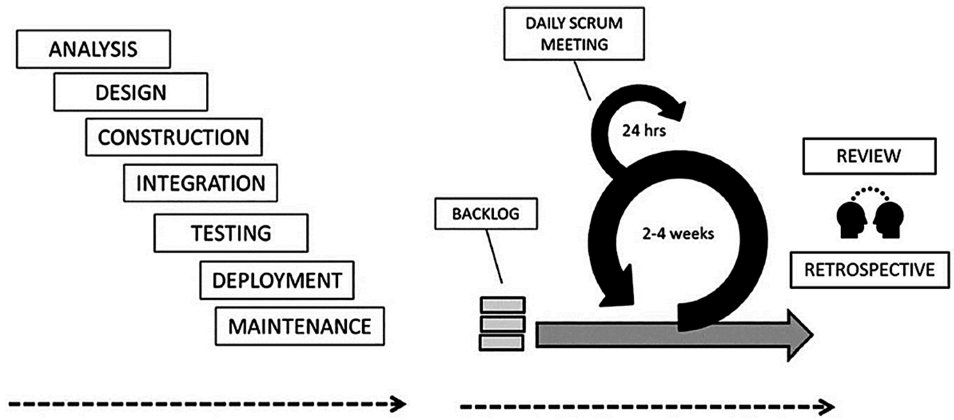
For details on approaches, the author refers to dedicated literature[3]. Some attention points can nevertheless be highlighted.

Firstly, the fluidity associated with agile requires discipline of the main actors. Scope control, failing fast and regular iterations are part of the core principles. The success of agile comes from the unconditional availability of decision takers towards rapid feedback, during and after the iterations (Janssens, 2017).

Secondly, agile perimeters might have to integrate with traditional ecosystems. To make such hybrid contexts work, managerial compromises must be made. When agile subsets are inserted in a waterfall environment[4], they must work with less autonomy and with a different time perspective. Similarly, waterfall entities will have to adapt to a flexible way of working – or agile Scrum might have to blend with agile Kanban (Reddy, 2015).

Thirdly, the overarching focus on agile should not become a goal on itself. Managers can start by breaking large tasks into small steps and test working models, by streamlining activities to focus on the most valuable customer benefits, or by celebrating learning (Rigby, 2018). In the end, however, managers should not forget to focus on developing their quantified intuition and taking decisions that make a

Figure 2. Combining waterfall approaches and agile might be needed
Source: Janssens, 2016



difference. The aim of agile is to be in support of the overall goal: providing appropriate solutions to customer needs and preferences (Highsmith, 2001).

Lastly, it should be noted that agile is not the same as agility. Agile is an iterative approach to software development and project management with specific principles. Agility, on the other hand, is an organisational trait characterized by durability, speed, flexibility and readiness (Prosci, 2017). It is a core competency and source of competitive advantage.

Agile and agility are related. As an organization grows agile project management practices, it can increase agility. Similarly, many organizations working on improving their agility use agile development approaches for the desired outcome of agile and its inherent value for blended transformation leadership styles and strong teams (Viaene, 2018).

Overall, both agile and agility aim thus at equipping organizations to more effectively seize opportunities. By combining the strengths of both, project managers can reinforce the project management dynamic and contribute to shape a company for reactivity and flexibility.

Industry 4.0. and Evolutions in the Organisational Reality

Some organisational models have developed a growing impact in the corporate world. As it will be further explained, this footprint can have a project management impact when seen in combination with the different drivers of the Fourth Industrial Revolution as it might impact the DNA of a company, and therefore also its project management practice.

Teal

A first one is the approach of transforming a company in a 'teal organisation.' Teal starts from the assumption that people are longing for better ways to work together. The approach wants to go far beyond a better life/work balance. Teal wants to develop a culture of self-management, wholeness, and a deeper sense of purpose (Laloux, 2014).

Although this approach might seem hard to reconcile with project goals or corporate targets, experience in small to large companies supports the potential of this approach (Laloux, 2014). Organisations desiring to avoid radical change can introduce some elements separately. Over time, however, obtaining the full benefit depends on the extent to which organisations embrace this approach on a structural level, including the organisation of the daily work as well as matters like human resource management, strategy definition and financial management.

Digital web agency Yools, for example, went through a profound transformation in 2015. After several years of existence and thousands of web development projects, they wanted to put the company-focus back on people. They wanted more happiness and trigger a positive impact on business development, on customers and on society. They transformed the organisation based on principles of meaningful mission, self-steering and trust (Aerts, 2017).

Firstly, they proposed a new mission for the company, less based on money, but more driven by values. In complement, all employees got empowered to revise periodically the mission and the vision of the company, to keep their sentiment in line with the company's direction (Aerts, 2017).

Secondly, all 'Yoolsies' were mandated to take decisions. People wanting to improve the company had to draft a proposal, ask others for feedback, and decide themselves if their project was worth it, before making things happen themselves. A foundational aspect was the increase in transparency. Yools decided to focus on transparency for decision taking, project cycles, and company results. Transparency on finance and salaries was deemed to radical of a change (Aerts, 2017).

To guide the transformation, daily and weekly ceremonies stimulated communication, canalised alignment and reinforced human bounding. Playbooks were created to support every process. One-on-one evaluations got replaced by group-driven peer feedback. Similarly, all employees got trained in new ways of self-expression and non-violent communication (Aerts, 2017).

Thirdly, trust was stimulated. The goal was to deliver qualitative project results without mandatory targets or timesheet controls. The idea was that the increased motivation would lead to increased ownership, which would ensure a regular delivery. Coaches were appointed to help people in their new journey, in combination with moments of open sharing (Aerts, 2017).

Subsequently, people left the company because they did not adhere to the new philosophy. To reinforce the company, the hiring process got adapted as the human fit had become the main catalyst for acceptance. The entire process could last from a couple of weeks to a couple of months (Aerts, 2017).

Table 1. Evolutions in human collaboration

	Description/Focus	Guiding Metaphor	Foundations
ORANGE	Beating competition; achieving profit and growth. Management by objectives.	Machine	Innovation Accountability Meritocracy
GREEN	Culture and empowerment to boost employee motivation. Stakeholder replace shareholders as primary purpose.	Family	Empowerment Egalitarian Management Stakeholder Model
TEAL	Self-management replaces hierarchical pyramid. Organisations are regarded as living entities, oriented towards realising their potential.	Living organism	Self-Management Wholeness Evolutionary Purpose

Source: Laloux, 2014

From a project perspective, all web projects were affected by this model based on trust, motivation and self-steering. The initial phase of teal operation appeared to be extremely cumbersome for internal collaboration and external delivery. For senior employees, the long selection process of new resources appeared to be most challenging in periods of high demand. Strictly respecting the lack of managerial authority was not straightforward either, especially during periods of high pressure (Aerts, 2017).

After two years of human reshuffling, evolutive governance and growing understanding of and adherence to the model, project delivery attained a level of steady output and increased customer satisfaction. The company is growing and continues to hire new resources (Aerts, 2017).

For employees that stayed throughout the transformation, the only major impact on project management is that most Yoolsies would not want to work again in a traditional project setting. Also, benchmarking with other companies indicated that the potential value in an era of digital transformation is tremendous, but highly dependent on a rigorous adherence to the model, even in periods of project risk (Aerts, 2017).

Start-Up Power

A second organisational repositioning practice that has bloomed in parallel with the Fourth Industrial Revolution is the internal change towards start-up inspired dynamics: large companies want to go beyond their traditional way of working and implement best practices of start-ups (Markides, 2018). Especially for product and service development, expertise is used differently, and services are delivered much faster.

In practice, the reality is rather contextual. According to some, much of the thinking on making corporations more innovative by being more like start-ups, is misplaced. Big corporations should not try to be a start-up. Like individual people, they should use their own strengths for their own good. At best, they should collaborate (Mohout & Van Peteghem, 2018), or create an entrepreneurial spin-off (Chatterji & Toffel, 2018).

Despite the lack of unanimous conclusions, project managers can integrate insights from start-up inspired dynamics in their way of managing projects, especially for matters like leadership, user value, governance, quality assurance and people management.

On user value, research projects in innovative start-ups offer useful insights for project managers. R&D environments tend to be a concentration of bright minds and huge intellectual satisfaction. At the same time, there is a significant risk of low user value for the outside world. It is therefore important to stimulate teams to look beyond isolated ideas, even in agile project management. In line with the fundaments of Industry 4.0, it is key to create a project culture where people think about the end-product/service and meet the internal/external customer (Burke, 2013; Solis, 2015).

On governance, start-up contexts are easily associated with unlimited freedom of action. In practice, this often leads to lack of quality and value, or burned-out people and budgets. A nimble way of project management starts with shaping the project culture and people's mindset. This can only unfold, however, through ceremonies and targeted governance (Steyaert, 2016). This will gradually unlock value and lead to mature independence.

Beyond the start-up organisation as such, much can be learned from a start-up mindset at the level of people and values. Salesforce's CEO Marc Benniof, for instance, started his company in a San Francisco apartment. Ever since, he has been injecting entrepreneurial curiosity and value awareness in his company (Lashinsky, 2017). It has led to a forward-looking culture in the company, voted number 3 of the World's Most Innovative Companies in 2018 (Dyer & Gregersen, 2018). Project organisations should follow the same approach. They should make the voice of their projects be heard, while keeping growth of project members in mind.

On quality, start-ups and large companies alike want either to stretch timelines to go for the ultimate perfection before shipping to the world, or they want to deliver quickly and fix often. In the former case, project risks to be over budget and the scope outdated. In the latter case, unexpected, repeated fixing entails damages for the product, the project and the company (Gailly, 2011).

Start-up projects learn therefore increasingly to fail forward. Project teams should dare to fail and embed rapid improvement in their project mindset. Rather than going for the ultimate perfection at the first step, they should go for a good enough first hit, iterate, learn and move forward – with the customer.

Overall, transformational approaches focusing on teal self-organisation and self-management, or on internalisation of start-up dynamics have a growing impact on project ecosystems. As projects need to serve the company and/or the user communities they are related to, project management approaches can contribute to this impact as well. This is a fortiori so when several approaches are combined, or if an approach is reinforced through a symbiosis with agile project management and other digital catalysts inherently linked to the Fourth Industrial Revolution.

Empowering People in/for the Fourth Industrial Revolution

Customer journeys are evolving. Organisations are evolving. And technological evolutions assume people with different skills and abilities. Projects for Industry 4.0. imply therefore project teams that are ready and able to take the leap, as well as a healthy dose of human understanding and people skills on project management side.

Management of skills disruption is an urgent concern in the Digital Age, and the rate of skills change accelerates across old and new jobs (Schwab & Samans, 2016). Consequently, project managers need to look for people that fit and that show, at the same time, a high level of adaptability.

Firstly, project managers need to nurture their people for and with the mental insights and technological catalysts of the Fourth Industrial Revolution, and create a stimulating environment (Bushnell & Stone, 2013; Knapp, Zeratsky & Kowitz, 2016). To do so, it has been increasingly important to do proactive workforce management, in collaboration with the out-of-project corporate organisation.

Secondly, to make sure that people adhere to the company and take ownership in project ecosystems, project managers need to consider generational traits of teams (Bradt, 2014). This recurring concern has become increasingly relevant with the growing inflow of Millennials (also known as Generation Y) and Generation Z employees (Table 2).

Millennials value workplace satisfaction more than monetary compensation. Work-life balance and togetherness is considered essential. They are less likely than previous generations to put up with an unpleasant work environment. When satisfied, however, they are often passionate advocates for the organizations they work for (Tulgan, 2016). For projects, they are potent change agents.

To Generation Z project members, company culture (and by extension project culture) is also more important than salary. They are looking for a sense of purpose (Stillman & Stillman, 2017). This does not mean that they are not ambitious. Generation Z ‘work hard and play hard’ and see their ambition as one of their most valuable assets, albeit in a different way. Rather than aiming at growing into the upper levels of the organisation, they want to strengthen their CVs through micro-careers. They want to grow through lifelong learning and provide value to the organisation through short projects (Stillman & Stillman, 2017).

Table 2. Generational composition of the US labour force

	Silent and Greatest generations	Baby Boom generation	Generation X	Millennial generation (Generation Y)	Post-Millennial generation (Generation Z)
Born	1945 or earlier	1946-1964	1965-1980	1981-1996	1997 and later
Age of working age adults in 2017	72 and older	53-71	37-52	21-36	16-20
% of US labour force in 2017	2%	25%	33%	35%	5%

Source: Fry, 2018

To have Generation Y and Z project members motivated and really own their work, they expect to be led, rather than being managed in the traditional way. For project managers this implies emphasizing feedback, focusing on the team (instead of focusing only on the project), and offering them independence and inspiration (Bradt, 2014).

From a project point of view, it might be challenging to apply each of the above, while respecting time, budget and other constraints. Applying one or more, or taking time for human value exchange, however, may already help to increase involvement, motivation and therefore ownership.

Thirdly, project managers need to learn to talk digital, data and customer journey themselves. They do not need to know everything. They should be able to ask questions to their teams and understand the answer (Groysberg & Slind, 2012). It reinforces faith in the project culture and cascades down to others.

Specifically on AI, realism has to be injected in project boards. Organisations tend to expect magic coming out of the blue, delivering quickly unparalleled performance without having to skill-up competencies (Brooks, 2017). In practice, many innovations take far longer to be deployed than people in the field imagine, and with extrapolated targets that are downscaled to a more stringent reality. Moreover, AI is not only driven by technology. It involves an important human component. Exactly as in financial investment where ambiguity tolerance still beats artificial intelligence, AI and data science projects require a significant share of professional expertise (Schuller, 2017).

When working with people for Industry 4.0, it is therefore important to find a good balance between aiming for the sky and stating the reality. While it might temper the motivation of some people, it strengthens the project focus towards targets that might remain aggressive, but that are perceived as more realistic. Doing so creates a climate of ambitious trust, which, in turn, motivates the blended project teams to fully take up their work.

Having the appropriate human capital on board and managing them accordingly is thus one of the cornerstones of project management for the Fourth Industrial Revolution. This implies creating an appropriate environment and project culture, nurturing people, and managing them with a solid understanding of what Industry 4.0 means for them and for the service to the customer.

Customer Journey Projects Still Imply Change

Project management results depend on different factors. At the core, vision and experience are of uttermost importance – so do methodologies and people management. At the same time, the ability to anticipate change is at the centre of success (or failure) for many projects, also in the age of the Fourth Industrial Revolution. Anticipating and managing change amongst internal and external users is essential.

Tools like Change Diagnostics (Campens, 2011) and methodologies like ADKAR[5] and related (Cameron & Quinn, 2011; HBR, Kotter, Kim & Mauborgne, 2011) remain relevant for Industry 4.0, given that a sound understanding of the project context and a shaded guidance along the different phases of the project remain necessary.

Admittedly, project organisations might have to re-evaluate tools and past conclusions due to rapidly changing reality. This, however, is more related to the organizational project management maturity, the change of project cycles and increased presence of agile iterations. In other words, change management has to continue to follow the pace of the organisations it serves.

It is even expected that the velocity of change will continue to increase, as organizations experience faster and more cross-functional change in a dynamic customer expectation landscape. The continued need for change management reinforces therefore the point that project management is not going to change radically in the Fourth Industrial Revolution.

Certain sources state that companies have to move out of siloed organisations due to digital transformation dynamics, and that change management will follow the same trend (Proctor, 2017). Despite the relevance of looking for change management solutions across silos and develop end-to-end approaches, the need to do so is not new.

Already before the raise of Industry 4.0., managers desiring to have a lasting footprint had to look beyond their expertise and experience by investing in the building of organizational bridges. Change needs indeed to move from isolated initiatives to integrated programmes across the value chain, combined with agile project management and organisational agility (Janssens, 2017).

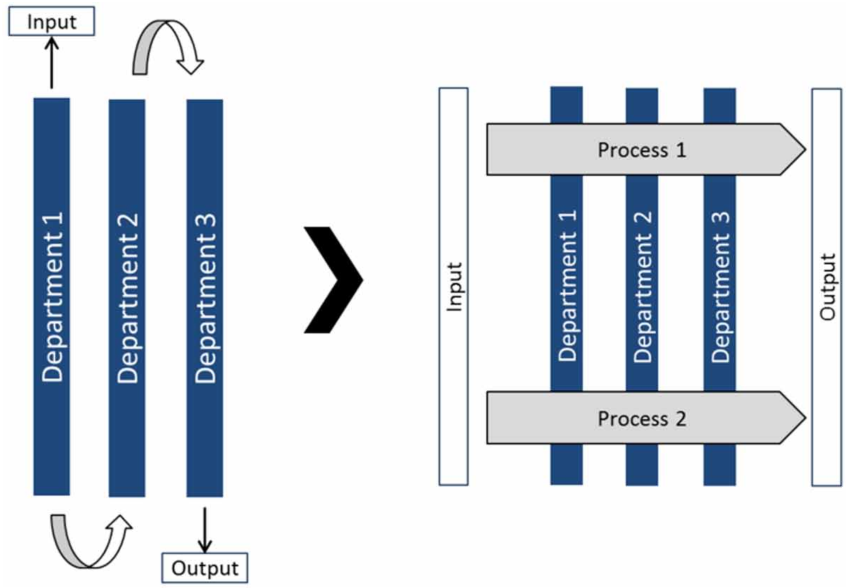
This does not mean that corporate silos must be torn down. Organisationally, they allow companies to function in a canalised way. At the same time, they cause problems potentially impacting internal or external customers. Some decisions need therefore to be made across silos (Smith & O'Connell, 2012). Through cooperation, communication and understanding other departments' priorities, managers should connect and eliminate silo problems, rather than tearing silos down (Figure 3).

To adapt approaches to the cross-silo reality, project managers need to consider insights obtained with change diagnostic tools. When managing large roll-out based projects, for instance, it is advised to integrate the cultural aspects in the cross-departmental backbone. The perceived value must be considered as well. It is namely not through the complexity that people get convinced and adhere, but also through the clarity and feasibility of a solution.

One aspect where it can be argued that change management might indeed change, is on the roles of each actor. Audra Proctor (Proctor, 2017) expects the roles to change as follows:

- The network of **Change Sponsors** across the organization will become stronger. While accountability for change may rest with different sponsors, each needs to be aware of concurrent changes and ensure that the end-to-end view is aligned.
- **Change Agents** will be embedded in agile project teams rather than in support teams. With increased access to users and increased ability to influence project outcomes, they will need to use digital tools to increase their efficiency during rapid iterations.
- For **Project Managers,** change management will be at the forefront of project planning, from ensuring that change experts are to planning for cross-organizational alignment and engagement.

Figure 3. Silos should be connected
Source: Own elaboration



- **Line managers** will have to be aware of the impact changes have on their team, and on other teams. Capturing the 'big picture' for their teams and triggering the thought process around the end-to-end implications of changes, is an important component of enabling the whole organization to start thinking holistically about change.

Overall, change management should move to an integrated end-to-end view to provide value. It could be stated that tools, methodologies and roles have to be revised as well. As indicated, the need for continuous improvement and growth in maturity is not a new need. It has been an attention point in the past and it still is an attention point, with or without Industry 4.0. It has been explained what attention points must be kept in mind to do so.

Projects in Industry 4.0. have therefore to continue integrating change management as one of the operational backbones, be it before, during or after the project.

Governance Remains a Must

The Fourth Industrial Revolution obliges companies to be increasingly ambidextrous. To remain on top of things, they need to manage the present while already anticipating the future. This needs to be done in a climate of rapidly changing customer expectations and technology-driven omnichannel interactions. It could be tempting to say that such a dynamic reality requires dynamic project environments with flexible rules and a lot of freedom for reactive improvisation. In practice, the opposite is true. Whereas periodic reinvention and nimble mindsets are indeed needed, this should not be mistaken for a lack of guiding frameworks – quite the contrary. Time and again, reality shows that governance is a prerequisite for project success (Janssens, 2018).

At the earlier mentioned MM Automotive, the management team obtained support to strengthen the portfolio dynamic. The underlying idea was to improve the maturity of the different organisational layers to increase quality and predictability of project delivery[6].

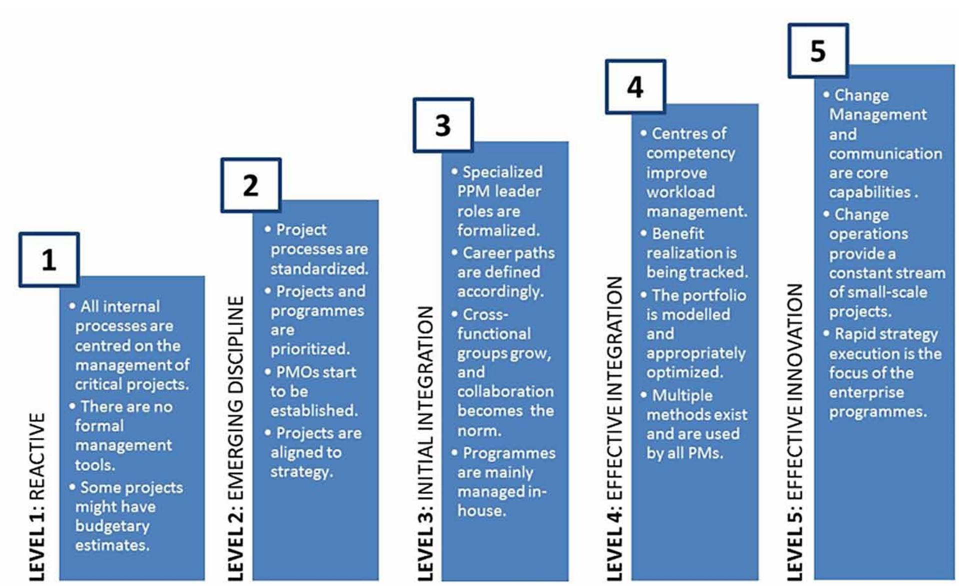
One of the structural actions focused on governance. An agile Scrum way of working was replaced by a hybrid agile Kanban approach, combined with Scrum. This change was realised through training and role-playing exercises. It is, however, only through subsequent coaching on rigorous application of the project ceremonies that the project throughput became steady.

Similarly, teal environments like Yools regard governance as one of the cornerstones of their self steering and their ability to combine happiness with customer delivery (Aerts, 2017). This approach is also followed by other teal companies, like tomato processing company Morning Star or consultancy company Hifluence (Laloux, 2014; Vanlangendonck, 2017).

Even when assuming that the project management approach would remain unchanged, multichannel interactivity of Industry 4.0. relies heavily on good governance. Digital transformation projects, for instance, aim at delivering operational benefits by having customer related processes integrated on one platform. Having all this information integrated on the same platform provides indeed a 360° view on a company's customers. This makes it people to organise people and projects in a more intelligent way. The only way to get there is to define clear rules, especially for increased data integration, and provide a guiding governance framework (Janssens, 2018).

With cross-industry applicability in mind, a framework worth using is the Programme and Portfolio Management Maturity Model developed by research and advisory firm Gartner[7]. Focused on programme and portfolio management, it distinguishes five core dimensions: interdependence of people, project portfolio management practices and processes (PPM), project value management, technological growth, and human relationships (Mieritz, Fitzgerald, Gomolski & Light, 2007). The evaluation of these dimensions results in a specific maturity level indicated in Figure 4.

Figure 4. The five maturity levels of Gartner's PPM model
Source: Mieritz et al., 2007



Compared to models like CMMI[8] and P3M3[9], Gartner's PPM model captures best the project and portfolio maturity matter at hand, as it shares the transversal expertise captured in CMMI and P3M3, but with a stronger focus on actionable steps, that prove to be of added value in practice (Janssens, 2018).

Maturity models give an organization the occasion to perform a factual and comparable health check of its strengths and weaknesses, as well as a larger and more detailed assessment with a full development plan (Sowden, Hinley & Clarke, 2010). Conversely, rather than a means to identify performance weaknesses and apply only short term 'quick wins', maturity improvement should - even in the age of rapidly changing customer expectations and dynamic requirements - be managed as a transversal, long-term process, involving incremental improvements on many different levels (Janssens, 2018).

Project management maturity, for example, is impacted by the maturity on portfolio level, as balancing portfolios has a direct influence on the critical path of related projects. At the same time, portfolios are influenced by the maturity on resource management, as the timely availability of skilled resources fuels the delivery. In parallel, process and programme efficiency can only function within the organizational reality if governance provides sufficient and appropriate smoothening – and if it is followed accordingly.

Rapid tweaks on one dimension might help to obtain a short-term gain on that very dimension. It is however only by investing efforts on intertwined aspects that structural, lasting benefits will be obtained.

Industry 4.0 Projects Still Need to Deliver and Other Projects Too

With growing visibility of agile, Industry 4.0 customer expectations and revisited organisational strategies cascading down on project organisations, there is a risk to focus more on the conceptual shaping of projects than on what they are really about: delivering. Projects are, at their core, about creating value through the delivery of a product or a service within a certain period, in line with specific quality criteria.

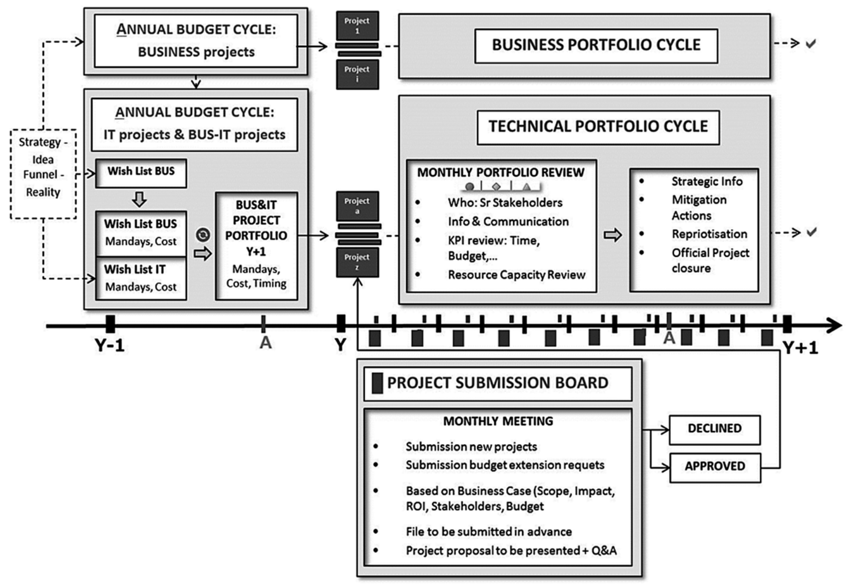
In addition, project portfolios are not only about Industry 4.0 projects. They still include a combination of transformation projects, customer journey projects and traditional business improvements projects. These projects need to be followed by the same senior stakeholder board(s) (Axelos, 2011).

This portfolio follow-up implies that the project health is monitored with the same key performance indicators (KPIs) for all projects, especially in mature organisations (Kerzner, 2017). In the Fourth Industrial Revolution, discussions will continue about whether innovation projects need a different set of KPIs than other projects, and whether agile/Kanban KPIs should remain on the project level or should also be included on the portfolio level. Similarly, debates will continue to whether companies must include project submission KPIs like return on investment (ROI), total cost of ownership (TCO) and strategic contribution. Given this need of homogenous macro-monitoring of mixed project portfolios (Catlin, Scanlan & Willmott, 2015), however, project managers will be 'stimulated' to keep a comparable way of project management across projects.

To solve this catch, project organisations have three options:

- Stimulate specific project management approaches for specific types of projects and convince the portfolio boards to review each sub-portfolio in a different way.
- Keep the homogenous portfolio reporting, while allowing different project management approaches. This would oblige project managers to do a 'double' project reporting but would allow them to still work in the way they deem most appropriate.

Figure 5. Portfolio bodies support KPI based project reviews
Source: Janssens, 2018



- Keep a harmonised portfolio reporting and keep a harmonised project management approach. This requires more effort on the project level, but increases the comparability of the projects, and gives the impression that senior arbitrage and related mitigations actions are facilitated.

The author regards the first option only likely in a minority of cases (only for companies that want to be 'Industry 4.0- ready' by going for a radical big-bang transformation). Depending on the organisational maturity for project management, companies will rather choose for option 2 or 3. This will undoubtedly influence the project management approach. Strictly speaking, however, this evolution is less driven by the Fourth Industrial Revolution as such, and more due to blended project approaches rising in parallel.

Reality Checks in Industry 4.0.

To give more depth to the ambiguous reality Industry 4.0 project management is facing (shaping transformation while continuing to build upon traditional project management pillars), some examples will be analysed, in complement to those highlighted in earlier sections.

In a first example, the importance of taking the Industry 4.0 train will be illustrated with a company active in a conservative industry. While the company has a culture of rigorous people management and governance, it is, however, less used to managing vast, transformational projects.

In a second example, the challenges are illustrated that come with project contexts that combine new organisational models with strong attention for change management, governance and stakeholder management. While the company is used to deliver many projects every year to and with their clients, it has only a low project management maturity.

Both companies are very much aware of the importance and power of data.

When analysing the cases, the emphasis will not be on KPIs. Rather, the return on experience will be obtained by highlighting the fit of the organisation with Industry 4.0., and by reviewing to what extent the project management fundamentals are included. By integrating all elements, the author wants to illustrate that project management fundaments remain valid in Industry 4.0., albeit with a different emphasis.

While illustrating real-life experience, names and corporate specificities have been adapted. Personal experience from the author.

Case 1: Bridgebay

Project Context

Bridgebay is a Las Vegas-based company, created in the 1970's. Its portfolio includes more than 40 premium hotels throughout the USA. It owns, develops and leases hotels. It focuses on leasure and other private stays. Continuous improvement projects are decided on a corporate level[10].

In 2017, it had to take a digital leap to move away from the traditional way of working. This was driven by two important groups of challenges.

On the one hand, the hospitality industry was facing strong customer experience changes. Customer journeys got increasingly characterised by the need for personalised experience (before, during and after the stay), growing expectations on technology (partially driven by a generational shift in the guest community) and the need to interact continuously on social media (Weinelt & Moavenzadeh, 2017).

At the same time, the top business challenges were: improving guest profiling and targeted marketing; delivering digitally-powered experiences; and increasing internal efficiencies to stimulate competitive advantage and revenue growth.

In addition, Bridgebay resources were actively requesting efficiency-enabling improvements, although there was limited room to free up resources for improvement projects.

Traditionally, improvement projects were very much tied to the organic growth of the group and limited to the punctual deployment of new software packages specialised in the support of the value chain.

Project Approach

To tackle the challenges, they decided to transform Bridgebay's customer experience. The scope of the project was organised around three components:

- Engaging customers with a customizable customer relationship management platform (CRM): Creating one dynamic view across Sales, Service and Marketing to optimize customer lifecycles.
- Driving operational excellence: Closing deals faster and maximizing revenue through automation and analytics.
- Super-charging sales representatives: Empowering people to sell from anywhere and on any device, through the implementation of productivity and collaboration tools.

Rather than launching the project in all hotels, Bridgebay opted for a pilot in the hotels in San Francisco.

The project approach was influenced by the Fourth Industrial Revolution at the level of the scope. Customer journeys had to be rethought, interactions had to be repowered, and a historically grown aggregation of tools had to be replaced by an integrated platform that leveraged data power to create advanced insights and lighter processes for employees.

The project was less influenced by organisational transformational models, as Bridgebay wanted to improve their way of working, without going through a fundamental organisational redesign. This choice was not driven by budget concerns as such. This was rather linked to the fact that hospitality management has a relatively slowly evolving DNA.

The advantage of this DNA was that teams were used to work in a disciplined way. Setting a clear governance was regarded as an important, natural, aspect of the project.

Similarly, driven by efficiency and experience, creating awareness for change was regarded as a fundamental part of the project, as well as foreseeing enough time for training on the new way of working and the use of the platform.

Although agile was proposed, Bridgebay was relatively neutral with regards to the choice for a waterfall, agile or hybrid project approach. To them, projects need to set rules, and rules need to be followed to deliver qualitative results by coordinated teams in the foreseen timeframe.

Overall, this example illustrates thus that projects with a strong Industry 4.0 focus might require dedicated attention to the Industry 4.0 reality, without fundamentally changing the project approach as such.

Case 2: Radical Transparency International

Project Context

Radical Transparency International is a B2B2C evangelism marketing agency, created in the early 2000s. Based in Singapore, their portfolio includes 400+ projects per year across Asia-Pacific. Organisationally, they evolved from a traditional agency into a fluid, almost teal organisation[11].

Due to their activity, Radical Transparency International has been very aware of how the Fourth Industrial Revolution is influencing society, customer expectations and people's sense of purpose.

While being at the forefront of the debate for/with their own clients, they faced challenges in the growth of their internal efficiency. They perceived themselves as internally relatively well organised, while delivering projects of superior quality. At the same time, they felt that they left a lot of business potential unnoticed. To them it was not clear if they had to move towards a different way of working and managing projects to unveil this potential, or if this could be done through new digital activation tools.

Project Approach

Rather than launching a vast transformational programme, Radical Transparency International decided to focus on creating value by awakening their institutional memory and unleashing the potential of their firmographic data:

- Unveil the value of experience: Capture continuously who in the company could share what valuable insights on experience, thanks to an integrated CRM platform.
- Increase communication and employee engagement: Synchronise the customer platform with the employees' agendas to enable reinforced insight sharing.
- Increase value from connections: Combine each of the above with AI and social media mapping.

Although the company delivers services for customer journeys in Industry 4.0, they wanted to practice only a limited part of what they preached themselves. Rather than going for a profound organisational transformation or driving operational excellence for the complete Lead to Cash journey, they decided to go for a project with a limited scope.

A first reason was the limited willingness to spend money for their own growth. Historically, they had grown organically without major investments. The executive board of the agency was relatively open to fresh ideas. Paying large projects, however, was less of a habit.

A second reason was the human-organisational reality. Organised as mobile nomads, employees were used to a lot of personal freedom. The flipside of this mobile reactivity was that organisational processes had different variants, depending on the frequency of collaboration between people. For projects, this iterative growth resulted in a pragmatic way of working. Despite its intrinsic potential, it lowered the openness for change, as internal change was usually associated with the reduction of personal freedom.

To take this reality into account and ensure adherence towards future delivery, an agile project management approach was proposed, with reinforced attention to change, training and periodic stakeholder reviews. Also, the future journey of its employees got challenged and explained at great lengths prior to the project.

Overall, this example illustrates therefore that not all projects will focus on Industry 4.0, nor on significantly different project dynamics, even for companies that are fully immerged in the reality of the Fourth Industrial Revolution.

FUTURE RESEARCH DIRECTIONS

The Fourth Industrial Revolution influences customer expectations, corporate organisations and project ecosystems. Certain drivers have a potential influence on project management through the transformation of the organisational DNA, others impact the inflow of new project demands. At the same time, foundational project insights resulting from (cross) industry best practices and personal experience continue to be the project managers' guiding safeguards towards quality and organisational shaping.

To nurture project portfolios for Industry 4.0, it would be beneficial to move further from a double dynamic to a more integrated approach. This might oblige project managers to go through a hybrid phase with change management, agile and human focus as backbones of the modern toolbox. Still, it is by analysing further what value each can bring - and how it can be combined - that projects will be managed in a way that fits to the true nature of project ecosystems and the future results that they envision.

Similarly, it will be worth to further integrate the value that advanced analytics can bring to project management practices. This might induce discomfort at first, as the switch to a more digitised intuition might be perceived as a risk for experience-based skills. The author believes, however, that the latter will continue to be at the core of project management, and that project managers will continue to grow by taking the digital leap in their own adaptive evolution.

From a project portfolio perspective, companies would benefit from project portfolio approaches that create a synergy between strategy-driven macro follow up and project management approaches that are in line with the customer centric and adaptive nature of today's challenges. Doing so would contribute to growing an organisation's maturity and further nourish the corporate strategy that projects are serving.

Obviously, best practices will require regular revisiting as this context is in constant evolution. The author believes nevertheless that the recurring efforts will be largely compensated by the advantages in quality and outcome of the concerned portfolios.

CONCLUSION

The Fourth Industrial Revolution is transforming physical, digital and biological worlds. Well on its way, it is impacting people and organisations. It is transforming at high speed the expectations customers have with regards to relations with companies.

For products and services alike, customers want that companies provide an experience in line with rapidly changing expectations. This concerns the entire customer journey, covering the touchpoints before, during and after the key moments. This entails a great potential for companies that can move to tailored experiences, powered by technology, data and insights coming from the 360° view of the customer.

It has been illustrated that the Fourth Industrial Revolution influences the project portfolio that companies set up to realise this transformation.

Firstly, it has been explained that Industry 4.0 induces new types of projects. Typically, this includes projects focusing on advanced analytics and AI, or on more customer-centric products and services. Examples illustrated that new types of projects are growing in technology driven industries, as well as in more ‘conservative’ industries.

Secondly, the duality of project drivers arising in the Fourth Industrial Revolution has been analysed.

On the one hand, some factors are clearly influencing project management. Agile project management practices – or hybrid versions of it -, evolutions in the organisational reality, and human expectations from new workforce generations are important aspects that project managers must consider delivering qualitative projects in the Digital Age.

On the other hand, project management will continue to build upon existing foundations. It has been illustrated that customer journey projects still require a solid dose of change management and governance. Moreover, as project delivery remains the bottom line goal of project portfolios, projects have to continue to function partially as they do, to enable senior stakeholders to take the necessary decisions.

The different elements of this dual dynamic have been illustrated with real life examples. In parallel, future research indications highlight that the potential of this situation should be further explored by analysing the growing potential of technology for project managers, when shaping their project management toolset for Industry 4.0.

Overall, the author firmly believes that the Fourth Industrial Revolution as such is not fully transforming the project management practice. Project managers are facing new types of projects and changing expectations, and have to adapt to new managerial insights and shifting habits. To the author, this is part of the DNA of a project manager and driven by changes that were on their way before Industry 4.0. Rather than seeing it as one transformational tsunami, project managers should manage it as a dual dynamic, obliging project managers to remain curious, nimble and committed, while working in a reality where rapidly changing demands entail great value.

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KEY TERMS AND DEFINITIONS

360° View: Ability to capture every part of the end-to-end relationship a company has with its customers. Includes sales and service information, marketing data, transactional information and information about who they are.

Agile: Project management methodology, in which the development is characterized by the breakdown of tasks into short periods, with frequent reassessment of work and plans.

Customer Journey: Sum of experiences and touchpoints that customers go through when interacting with a company. Includes experiences and touchpoints before, during and after the main interaction.

Digital Transformation: Process in which human and corporate society is shifted to new ways of working and thinking with digital and social technologies. Involves a change in leadership, a different mindset, the encouragement of innovation and new business models, and an increased use of technology to improve the experience of internal and external customers.

Fourth Industrial Revolution: Industrial revolution driven by cyber-physical systems involving entirely new capabilities for people and machines. Represents new ways to embed technology in society and induces new ways of working and thinking for human and corporate matters.

Kanban: Agile method to manage work by limiting work in progress. Team members pull work as capacity permits, rather than work being pushed into the process when requested. Stimulates continuous, incremental changes. Aims at facilitating change by minimizing resistance to it.

Scrum: Iterative and incremental product development framework used in agile projects.

Teal: Stage in the evolution of human and organisational consciousness. Focuses on the development of a culture of self-management, wholeness, and a deeper sense of purpose.

ENDNOTES

1. The growing impact of technology is embodied by two groups of technology giants: Google, Apple, Facebook and Amazon (GAFA); and Netflix, Airbnb, Tesla, Uber (NATU)
2. While illustrating real-life experience, names and specificities have been adapted. Empirical experience from the author.
3. For information on agile, the author refers to https://www.scrum.org/ and https://www.scrumalliance.org/ for scrum, and to https://www.atlassian.com/agile/kanban for Kanban.
4. For information on waterfall methodologies, the author refers to: http://www.pmi.org/PMBOK-Guide-and-Standards.aspx (PMBOK), http://www.prince-officialsite.com/ (Prince2)
5. For information on ADKAR, the author refers to https://www.prosci.com/adkar/adkar-model
6. While illustrating real-life experience, names and specificities have been adapted. Empirical experience from the author.
7. For information on Gartner, the author refers to http://www.gartner.com/technology/home.jsp
8. For more information on Capability Maturity Model Integration, provided by the CMMI Institute, a subsidiary of ISACA, the author refers to https://www.isaca.org/Pages/default.aspx
9. For more information on P3M3, the author refers to https://www.axelos.com/best-practice-solutions/p3m3
10. While illustrating real-life experience, names and specificities have been adapted. Empirical experience from the author.
11. While illustrating real-life experience, names and specificities have been adapted. Empirical experience from the author.

Chapter 9
An ANP Approach for Prioritizing the Agile Project Management Criteria in Industry 4.0 Transition

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ABSTRACT

The Fourth Industrial Revolution requires today's companies to bring the physical and digital world together to achieve a higher efficiency and gain competitive advantage. This transformation can be made possible using advanced technologies which has interdependencies on one another and their implementation can be best achieved using project management principles. Agile principles (e.g. multiple iterations, stakeholder involvement) play an important role in executing this transformation. In this study, the authors first defined the processes and technologies required in the Industry 4.0 transition. Since the projects related to different technologies may require the prioritization of project management dimensions to cope with complexity and uncertainty, agile project management criteria are specified to prioritize them adopting a multi-criteria decision-making approach, namely the Analytical Network Process. Using the results obtained, suggestions for the creation of a framework to manage the Industry 4.0 transformation in an agile manner were presented.

INTRODUCTION

In the new global economy, agility and flexibility have become central issues for companies to respond rapidly to the increasingly individualized customer preferences while providing high quality products and/or services. Many companies have been greatly challenged in the past few decades to offer a 'reasonable' degree of product variety while competing in intensely competitive markets, where price fluctua-

DOI: 10.4018/978-1-5225-7865-9.ch009

tions and demand volatility are typical, without suffering from economies of scale and manufacturing costs. However, not long ago an opportunity has emerged for them to adapt quickly to the changes in the market by transforming their traditional manufacturing systems into 'smart' ones through automation and digitalization. This paradigm shift in manufacturing has recently blossomed into a new concept called Industry 4.0 which looks quite promising in offering highly customized products with increased resource efficiency.

Following its introduction in 2011, Industry 4.0 has been attracting a lot of interest as it is believed to transform traditional factories into more intelligent, flexible, dynamic, self-organizing and optimizing ones (Lu, 2017). Equipment, tools and technologies such as collaborative robots, mobile devices and wearables, ID tags and transponders, sensors, actuators, microcomputers, and autonomous systems (Schlund and Baaij, 2018) will definitely play a vital role in the physical aspect of this transformation; however, Industry 4.0 is expected to revolutionize the entire value chains. Thus, not only the manufacturing systems of companies will go through a metamorphosis, but also their organizational culture and management practices will be profoundly changed. This is why this relatively new concept is also known as the Fourth Industrial Revolution (Schwab, 2017).

Some argue that Industry 4.0 have already begun. As reported in Xu et al. (2018), a doctor can nowadays effortlessly check her patient's heart rates and blood pressures whenever necessary, owing to a common medical device and the Internet or a food manufacturer can collect instant food deterioration data via bio-sensors. Jose and Paola (2018, citing Berg et al., 2017) stressed that 3D design and virtual prototyping, digital printing, RFID, and automated manufacturing will have a remarkable effect on the fashion industry over the next 5 years. Roblek et al. (2016, citing Baunsgaard and Clegg, 2015) mentioned about smart phone applications that could remotely control the door locks, adjust the thermostat, and control the supply of food in the refrigerator at home. Even though Industry 4.0 is said to have contributed more in areas such as technology management and just-in-time manufacturing so far (Fettermann et al., 2018), other industries are also believed to adopt its technologies quickly and efficiently with the help of current Information Technology (IT) infrastructure (Saucedo-Martínez et al., 2018).

Nevertheless, a dominant feature of the implementation process during this revolution will be computer-aided programs. Software development or improvement projects will be executed and launched more than ever in the next few years. Ghobakhloo (2018) asserted that software developers had recently inclined towards positioning their products and services on Industry 4.0 projects. Specifically, dynamic industries that are usually unpredictable (e.g., consumer electronics, biotechnology, medical devices) have been the first to start their digital transformation. On the other hand, Paasivaara et al. (2018, citing Freudenberg and Sharp, 2010) reported that practitioners at the XP conference in 2010 had listed the topic "agile and large projects" as the number one top burning research question. With the introduction of Industry 4.0, large companies that maintain their operations mostly in environments where uncertainty is high (e.g., countries with a lack of necessary standards), will need to execute large and interdependent projects. Arnold et al. (2018) indicated that such environments could negatively affect a company's Industry 4.0 adoption. The agile approach, which was originated in the field of IT, can significantly assist companies, especially when executing large-scale projects, throughout their digital transformation as it plays a crucial role in providing responsiveness and faster decision-making in case of uncertainty.

The Industry 4.0 transformation is rather complex due to interrelated technologies and processes. Agile project management, on the other hand, has evolved in the IT domain which has major similarities with Industry 4.0. Agile project management is a promising approach to be used during the Industry 4.0 transformation. However, this transformation has many different phases and underlying technologies which are quite heterogeneous. Thus, it is important to decide which agile project management approach is appropriate for which Industry 4.0 transformation project(s). Multi-criteria decision making (MCDM) is used to model complex interrelationships among various subcomponents and serve as a quantitative tool to evaluate decisions related to Industry 4.0 transformation projects.

Adopting an MCDM approach, this study aims to prioritize the agile project management principles that can be used during the Industry 4.0 transition considering several aspects. The rest of this study is organized as follows: Section 2 elaborates the concept of Industry 4.0 and provides a brief summary on Agile Project Management and its relation to Industry 4.0 projects, Section 3 explains the Analytic Network Process, Section 4 demonstrates the application of ANP to prioritize the project management characteristics for developing and implementing technologies in Industry 4.0 transition and discloses the results, Section 5 discusses possible avenues for future research, and Section 6 concludes.

BACKGROUND

Industry 4.0

Companies are mainly suffering nowadays from the high complexity in product and process designs, growing and changing expectations and requirements of customers, shortened technology and innovation cycles, the abundance of information, and the consequences of globalization (Bauer et al., 2018; Kiel, 2017). They require flexibility when manufacturing even hyper-customized products and responsiveness in fiercely competitive markets with volatile demand (Bateman and Cheng, 2007; Odważny et al., 2018). Industry 4.0 is envisioned to address these issues and efficiently administer the entire product life cycle from development to manufacturing, recycling to customer services (Bauer et al., 2018) through the intelligent connection of each and every agent (people, machines, objects, production modules, and so on) in the entire value chain in real time (Veile et al., 2018). It also aims for the horizontal integration of various Information Technology (IT) systems used in different stages of manufacturing and business planning processes within a company along with the integration of such systems at different hierarchical levels (Liao et al., 2017).

Industry 4.0 will predominantly depend on digitalization and automation to create an integrated, adapted, optimized, service-oriented, and interoperable manufacturing environment (Lu, 2017) and the extensive connectivity and communication of production facilities and production networks and cooperation of people and machines (Veile et al., 2018). This will require, in turn, technologies such as Cyber-Physical Systems (CPS), Internet of Things (IoT), Internet of Services (IoS), Human Machine Interface, Robotics, Intelligent Production, Augmented Reality, Artificial Intelligence, Big Data Analytics, Cloud Computing, Mobile Computing, Blockchain, and Industrial Information Integration (Lu, 2017; Wiśniewska-Sałek, 2018; Xu et al., 2018). Some of these will be of utmost importance that can steer companies' way to a successful Industry 4.0 transformation, each providing some technical and organizational advantages and improvements; however, companies may incur too much capital expenditure for this purpose (Fettermann et al., 2018).

If companies want to survive the competition in the global market, they will undoubtedly require the adoption of such technologies though. They may either develop applications of their own or use those already available in the market to solve a particular problem (Bauer et al., 2018). Ghobakhloo (2018) stated that the adoption and implementation of Industry 4.0 technologies could be easier for worldclass manufacturers by virtue of the necessary experience and manpower they possess along with the sufficient financial support from their stakeholders. In general, all companies, for which the benefits of Industry 4.0 technologies outweigh their costs, should have the full support of the top management (Arnold et al., 2018), a committed leadership, fundamental resource allocation (Ghobakhloo, 2018), sufficient resources, qualified and trained staff, and well-organized processes (Odważny et al., 2018) for a successful transformation. Furthermore, Fettermann et al. (2018) recommended "the development of basic toolkits that should be capable of overcoming a common barrier for the initial implementation and lack of knowledge." On the other hand, from a project management perspective, Veile et al. (2018) emphasized the importance of executing pilot projects during the implementation process for the testing and evaluation of alternative approaches so as to avoid conducting some tasks more than once. They also added that the standardization of the implementation steps and the acknowledgement of heterogeneity in project teams were crucial.

For companies that rely on Industry 4.0, there are certain benefits identified in the related literature. They are expected to maintain and enhance their competitiveness (Arnold et al., 2016; Veile et al., 2018), to increase their operational efficiency and productivity, quality, and flexibility (Hartmann and Halecker, 2015; Kagermann et al., 2013; Kiel et al., 2016; Lu, 2017; Veile et al., 2018), to achieve greater competency (Xu et al., 2018), to offer higher degrees of customization, develop profitable novel business models, create job designs suitable for future employee requirements (Bauernhansl 2014; Kagermann et al. 2013; Rehage et al. 2013; Hirsch-Kreinsen and Weyer, 2014; Spath et al., 2013; Arnold et al., 2018), to reduce lead times, customize with small batch sizes, reduce costs, achieve a higher level of automatization, improve their adaptability (Lu, 2017), to increase their resource efficiency, have extensive integration and interoperability, attain revenue growth, improve their information sharing and decision-making processes, to better meet individual customer demands, to have flexible and agile engineering and manufacturing processes (Fatorachian and Kazemi, 2018).

Research has also highlighted the potential challenges companies might face during their implementation process. Fettermann et al. (2018) brought up the possibility that developing economies would experience shortage in the highly skilled labor in the management and control of integrated operations in the Industry 4.0 transition, whereas Landolfi et al. (2018) pointed out the need for investments, regular updates of the hardware and improvements of the software, and the review of production strategies.

Agile Project Management

Increased uncertainty due to rapid advances in technology and the required customer responsiveness results in plans to get outdated quickly. Agility is a critical issue for companies nowadays to remain competitive when offering quality products and satisfying fast changing customer requirements. Agile project management was first offered in the area of software development as an alternative to traditional project management to deal with the rigid and front-end planning. It encompasses "a local, adaptive, and incremental development of the product, using smaller requirement packages, called sprints, and a daily but short meeting and collaborative organization, called scrum" (Marle and Vidal, 2016). Agile approaches, today, are mostly adopted when executing IT projects, which are notoriously complicated and complex (Orłowski et al., 2017). Orłowski et al. (2017) reported that the US Government requested in 2013 that all IT projects executed by the Department of Defense needed to be agile. Even though it is still predominantly an IT phenomenon, agile project management has now spread to non-IT projects due to its success (Serrador and Pinto, 2015). Table 1 lists the adoption rates of the agile methodology in various industries that are obtained from the 11th Annual State of Agile Survey by Version One (2017).

Traditional project management techniques manage a project linearly using sequential discrete steps. However, for the most of today's businesses, it is no longer suitable. Today's businesses and new products are driven by rapidly changing markets, customer needs and technological advances. The linear approach and the rigidity of the planning of traditional project management techniques lack tools to effectively adapt the projects to these changes (Cooper and Sommer, 2018). These changes result in inevitable deviations defined as "a situation that deviates from any plan in the project" (Hällgren and Maaninen-Olsson, 2005). The efforts that try to eliminate deviations have long focused on more sophisticated initial plans. First in IT industry, instead of initial plans, multiple iterations through the development cycles have been used to improve the planning process and to cope with the deviations effectively (Serrador and Pinto, 2015). In iterative methodologies, objectives are not frozen and re-planning of a project can be made during the execution phase. This does not mean that no initial planning is made but the planning is dynamic in iterative methods. This both increases the success rates of the managers who struggle with the deviations from fixed plans due to high uncertainty and more importantly increase the adaptability of the project to the changes more effectively. As a result, the productivity, speed and flexibility of projects can be increased.

In agile project management, re-planning occurs throughout the project lifecycle, thus planning efforts are increased as opposed to the belief that planning is less in agile project management. However, documentation is less to facilitate quick response to changes and flexibility. In every phase of the project, customer involvement is significant. The involvement of customers starts early and continues closely to determine the objectives and provide feedback related to releases from the project. In summary, agile project management methodologies adapt effectively to new inputs, customer needs or other changing conditions.

Based on the project characteristics, it may be appropriate to use an approach changing from the spectrum of pure agile or pure traditional project management to a combination of them. The characteristics of the projects which determine the choice of the project management approach are typically the project size, risks (e.g., safety requirements), level of uncertainty/changes (i.e., known future requirements) (Boehm, 2002). Table 2 provides a summary of some project management methodologies used in

Table 1. Adoption rates of the agile methodology in various industries

Industry	Agile adoption rate
Software	23%
Financial services	14%
Professional services	12%
Insurance	6%
Healthcare	6%
Government	5%
Telecoms	4%
Transportation	4%
Manufacturing	4%

practice and reviewed in the agile literature, emphasizing how and when each method is used (Alleman, 2005; 11th Annual State of Agile survey, 2018).

There are two drivers for the efforts to apply agile project management in manufacturing and other industries: the success of the agile project management in software development and the increased use of IT technologies and software in manufacturing and other industries. Thus, during the Industry 4.0 transition, which requires mainly the integration of manufacturing technologies with IT and communication technologies, agile project management methodologies can serve as promising and effective management techniques. However, each project has its own characteristics due to the technologies used and due to industry-specific requirements. In this study, we aim to present an MCDM framework to identify the project management characteristics of typical Industry 4.0 development projects. These project criteria would be important to decide which agile project management methods fit well for the projects. ANP is employed to identify the weights of the project criteria for the specified Industry 4.0 development projects and then using the weighted criteria we evaluate which agile framework would be more appropriate for the Industry 4.0 technology development projects.

There exists a vast literature on agile project management methodologies. For more information, the interested reader is referred to Lei et al. (2017), Conforto (2016), Meyer (2014), and Conboy (2009).

The Significance of Agile Project Management in Industry 4.0

Industry 4.0 can be regarded as a combination of several advanced manufacturing technologies (Arnold et al., 2018) such as real-time analytics and augmented reality and companies will essentially require computer-aided programs for its implementation and administration. Development and improvement of necessary software can better be achieved following the agile project management principles, which have been prominent especially among companies that aimed to improve their manufacturing processes and maximize their resource efficiency (Odważny et al., 2018).

There is a wide range of industries that can benefit from the changes in manufacturing and management practices brought by the fourth industrial revolution and the agile approach can help companies in different ways to realize these changes. In special, Jose and Paola (2018) explained that the fashion industry could adopt design driven innovation and product customization, artificial intelligence, 3D printing, customization and co-creation, design driven business models in the near future and their success would primarily depend on agile networks. Moreover, Scheuermann et al. (2015) demonstrated that how agile software engineering techniques could deal with customer changes during assembly-time (Lu, 2017) and Wang et al. (2016) explained how lean principles could be integrated into smart manufacturing with the aim of quality improvement, efficiency increase, and cost reduction (Lu, 2017) in Industry 4.0. In his framework of best practice business model patterns, Burmeister et al. (2016) also asserted that agile innovation processes are critical for a successful Industry 4.0 implementation.

One should also note that there is an interrelation between agility and the technological enablers of Industry 4.0. For instance, according to Veile et al. (2018), a smooth data flow between the systems and interfaces within the company and between companies can help achieve organizational agility. However, the agile approach can also help companies complete their Industry 4.0 technology adoption period easier and faster.

Nevertheless, the agile approach can play a pivotal role in reproducing processes, which is key to successfully executing Industry 4.0 projects, as the related literature clearly points out the need for software development projects in the fourth industrial revolution.

Table 2. Agile project management methodologies and their properties

Agile PM Methods	Aim	How to Use	When to Use
Scrum	Aims to enhance collaboration between stakeholders working on evolutionary complex products, and the details are changed iteratively.	Project is executed iteratively with systematic interactions between the Scrum Master, Product Owner, and the Team roles.	Appropriate for long-term, complex projects that require stakeholder feedback. Appropriate when the exact amount of work can't be estimated, and the release date is not fixed
Kanban	Aims to visualize the project workflow and prioritize the work in progress (WIP) to limit its content and match with the capacity of the team. Offers transparency and flexibility.	Uses informal procedures and iterations are not fixed and there are no sprints. A Kanban board with sticky notes on boards or online tools is used for visualization.	Appropriate when releases are small and need to adapt to changing priorities.
Lean/Modular	Uses an iterative and incremental development. A minimum viable product (MVP) is introduced to satisfy the customer early with a minimum, sufficient set of features.	After MVP presentation, customer feedback directs the further progress. Formal processes such as recurring meetings or task prioritization is not required to be used.	Appropriate when customer feedback at early stages is important. Appropriate for small-sized and short-term projects. Appropriate when the customer can participate in the project for frequent feedback.
Hybrid	Aims to combine the traditional and agile principles. Uses both the iterative development and sequential development, with front-end planning.	Planning, requirements specification, and an application design are made using traditional principles and typically software development and testing is managed with agile principles.	Appropriate when the project includes both hardware and software development under strict timeframe and budget.
Adaptive	Aims to allow teams to work with optimal flexibility with roughly-defined goals and outcomes	Customers interaction is very high to specify the exact features they need in finished products.	Appropriate for unique challenges which don't call for one size fits all solutions. So, teams are empowered and they aren't expected to blindly follow pre-specified methods.
Extreme Programming	Focuses on technical software development and aims to decrease risks when developing a new system.	Small teams not more than 12 work on the project together with the developers, managers and customers	Appropriate when developing a new system under strict timeframe. with small teams.

METHODOLOGY: ANALYTICAL NETWORK PROCESS (ANP)

ANP is an MCDM methodology that can tackle with complex decision-making problems. The problem is modelled using a network structure which can represent interaction and interdependence among the factors related to the problem. ANP, similar to its simpler form AHP, was first introduced by Saaty (1980). AHP represents the model in a hierarchical way so the interactions are unidirectional among the decision levels, whereas ANP uses a network approach which is a more general methodology. Thus, it is more appropriate for many real-world problems where the elements of a decision level may influence each other and there could be multi-directional interactions between the decision levels.

In the ANP, the term decision levels are not used anymore, but clusters that have no hierarchy between each other are introduced. Each cluster is a group of elements related to a dimension of the decision-making problem. In the network of clusters, two types of influences can be specified. The first type of influence is the inner influence which enables elements within a cluster to interact with each other. The second type of influence is the outer influence where elements in one cluster may influence elements in another cluster. The comparison of the hierarchical and the network structures are given in Figure 1, where the nodes represent the elements of clusters or decision levels which are in general named as components. Arcs between two components represent the outer influences and loops indicate the inner influences of elements within a component. Once the components, elements and relationships between them are specified, the network structure of the problem is obtained.

Then, a matrix representation of the network is constructed. Each element is represented both in the rows and the columns and these elements are grouped by their clusters. This matrix is named as "supermatrix". In a supermatrix, cells are marked when the column element has an influence on the row element. If there exists no influence, the value of the cell is assigned as zero. A supermatrix with an example of one of its general entry matrix (i.e. submatrix) is shown in Figure 2.

Figure 1. Hierarchical and network structures

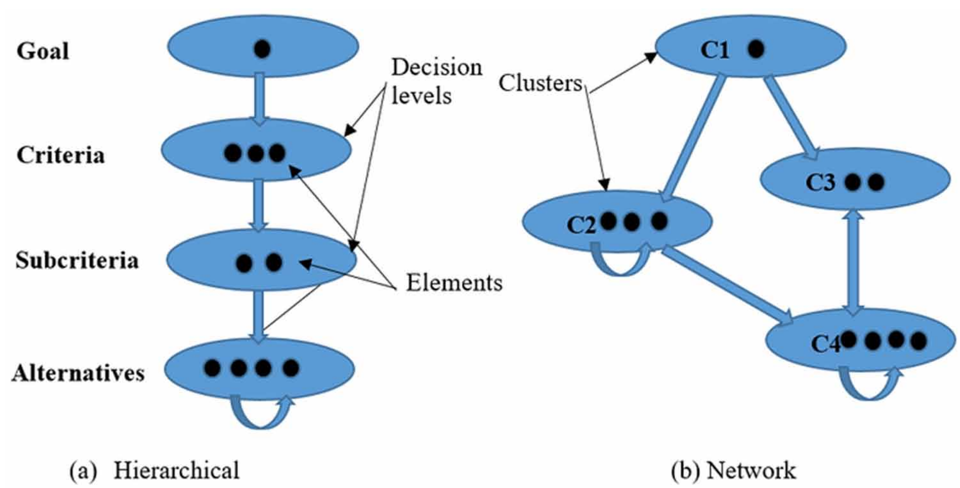

Figure 2. A supermatrix (a) and its submatrix (b)

$$\mathbf{W} = \begin{array}{cc} & \begin{array}{cccc} C_1 & C_2 & \cdots & C_N \\ e_{11}e_{12}\cdots e_{1n_1} & e_{11}e_{12}\cdots e_{2n_2} & \cdots & e_{N1}e_{N2}\cdots e_{Nn_N} \end{array} \\ \begin{array}{cc} C_1 & \begin{array}{c} e_{11} \\ \cdots \\ e_{1n_1} \end{array} \\ C_2 & \begin{array}{c} e_{21} \\ \cdots \\ e_{2n_2} \end{array} \\ C_1 & \begin{array}{c} e_{11} \\ \cdots \\ e_{1n_1} \end{array} \end{array} & \begin{bmatrix} W_{11} & W_{12} & \cdots & W_{1N} \\ W_{21} & W_{22} & \cdots & W_{2N} \\ & \cdots & & \\ W_{N1} & W_{N2} & \cdots & W_{NN} \end{bmatrix} \end{array}$$

(a)

$$W_{ij} = \begin{bmatrix} W_{i1}^{(j1)} & W_{i1}^{(j1)} & \cdots & W_{i1}^{(jn_j)} \\ W_{i2}^{(j1)} & W_{i2}^{(j2)} & \cdots & W_{i2}^{(jn_j)} \\ \vdots & \vdots & \ddots & \vdots \\ W_{in_1}^{(j1)} & W_{in_1}^{(j2)} & \cdots & W_{in_1}^{(jn_j)} \end{bmatrix}$$

(b)

Then, pairwise comparisons of the decision elements are made to evaluate the direction and strength of the relationships. Typically, pairwise comparisons are based on ratio-scale measurements. In pairwise comparison, the decision maker is asked to evaluate the two elements with respect to the common property using the smaller element as the unit and estimate the larger element as a multiple of that unit (Saaty and Özdemir 2005). Pairwise comparisons are then inserted into the supermatrix.

Finally, the limit supermatrix which captures the transmission of all inner and outer dependencies along all possible paths of the supermatrix is computed by raising the supermatrix to a certain power of k. The chosen power k determines the order of the transitivities of the network to be captured. Low values of k may not result in steady state results. In steady state, the priority values do not change any more by increasing the power. For the final results, the steady state priorities are examined. The final results can be in two ways: either each column of the limit matrix is obtained to be equal to each other or not. If the columns are equal to each other, a set of the values in one column is the priorities of the elements. Typically, these values are normalized to sum up to one for each cluster. If the columns are not equal to each other, there exists cycles of limits in blocks. To obtain the priorities, different limits are averaged and then normalized to one for each cluster. For more information on the methodology and its applications, the interested reader is referred to Quezada and Lopez-Ospina (2014), Büyüközkan and Çifçi (2012), Sipahi and Timor (2010), and Kahraman et al. (2007).

AN APPLICATION OF ANP TO REINFORCE AGILE PROJECT MANAGEMENT IN INDUSTRY 4.0 TRANSITION

Industry 4.0 transition requires a fundamental change in multiple dimensions of a company. Some of these dimensions are people, organization, infrastructure, technologies and work processes. Moreover, integration of physical and digital worlds is a required challenge of Industry 4.0. Due to interdependence among the transition dimensions and the need to integrate physical and digital technologies, using agile principles can be effective to achieve a smooth and quick transition.

In this section, a multi-criteria prioritization of project management characteristics will be presented to improve the project management during Industry 4.0 transition using analytical process network approach. Using the prioritized project management characteristics, the project managers can decide which agile framework will better fit to the projects related to the specified domain.

ANP is a technique which is effective to model interdependencies among multiple components. In our prioritization problem, the interrelated dimensions are defined after a thorough literature review as the organizational performance indicators, agile principles, design principles of Industry 4.0, Industry 4.0 technologies and project management characteristics. Using these components first the sub-elements of each component are specified, then the network with relations between the components are constructed and finally the comparisons and calculations are made to obtain the results. The details of the application are presented below:

Step 1: Describe the decision problem.

A company in the Industry 4.0 transition will need to go through many changes which are mostly executed as projects. The principles to be used in the management of various projects may vary depending on multiple dimensions. These are assumed to be the technological domain of the technology the project aims to develop, organizational performance requirements and agile principles. Depending on these multiple dimensions and additional relations among other related factors, the project management characteristics can be prioritized. Finally, the prioritization results can be used as a guide to identify which agile project management framework is more suitable for a project.

Step 2: Set up clusters and their elements.

After a detailed literature review, the clusters are identified as goal, organizational performance indicators, agile project management principles, design principles of Industry 4.0, Industry 4.0 technologies and project management characteristics. Below, the elements of each cluster is defined and discussed:

Cluster 1 – Goal: This cluster has one element, namely improving project management during Industry 4.0 transition.

Cluster 2 - Organizational Performance Indicators: This cluster specifies the possible performance indicators of a manufacturing organization which will take on an Industry 4.0 transition. The below three dimensions that are accepted widely in the literature are selected as the organizational performance indicators in an Industry 4.0 transition (Wang et al., 2016; Schuh et al., 2014):

- Productivity: Productivity is the ratio of increased outputs using less inputs. The major aim of Industry 4.0 is enhanced productivity by the better alignment of business units, better planning, reduced waste through minimization of resources, optimized development processes, optimized operational control, faster detection of issues and defects, etc.
- Customer Engagement and Satisfaction: Today, key to competitive advantage and innovation goes through customer engagement and satisfaction, so it is an important performance dimension. Customer engagement and satisfaction is closely related to increased focus on specific customer needs, increased frequency of collaboration and feedback, higher quality and reduced time-to-market and delivery times.
- Flexibility: Organizations are required to be more flexible due to increased uncertainties and volatilities. Flexibility is improved by the better management of changing priorities and ability to adapt to these changes.

Cluster 3 - Principles of Agile Project Management: This cluster consists of the core agile principles listed in Rumpe (2017) and Ambler (2002) that we find most relevant to Industry 4.0 transition projects.

- Assume Simplicity: Simplicity has a significant value in the management of Industry 4.0 projects. Even though some projects will be intrinsically complex and complicated, assuming simplicity at early stages is indispensable. Due to the nature of Industry 4.0 technologies, some projects might require constant improvements and alterations. Simple software is easier to change for further use. Thus, avoiding complexity by keeping additional features and functions at a reasonable level may facilitate a smoother transformation for companies.
- Embrace Change: During their Industry 4.0 transformation, companies will be exposed to changing environmental conditions, which in turn will lead to continuous revisions of the requirements.

Thus, companies should accept that the project goals and project success criteria might evolve over time.

- Incremental Change: An essential principle when executing Industry 4.0 projects would be to start with a moderate model and improve it iteratively taking the time constraint into account. If companies try to build a perfectly working model at the first place, they might end up exhausted after spending too much time and effort due to the ever-changing requirements and environmental conditions of Industry 4.0 implementation projects.
- Multiple Models: Industry 4.0 implementation will necessitate the interconnection and interdependence of various systems, which in turn makes it impossible to generate an all-around model that can solve any problem encountered during the transformation. Thus, companies should have multiple models in their vault so that they can execute an alternative that best serves the situation.
- Rapid Feedback: Even if there is sufficiently long time to project delivery, this essential principle should be adopted to achieve higher efficiency in software development. As many demonstrations and test runs as possible should be done to let the stakeholders be involved in the process. Shorter iterations may also cause stakeholders meddle with the project, so their interference should be wisely managed.

Cluster 4 - Design Principles of Industry 4.0: No consensus on the Industry 4.0 dimensions currently exists. Different sets of Industry 4.0 dimensions have been reported in the literature. As design principles, we chose the set of elements given below:

- Interoperability is a critical issue of Industry 4.0, which was defined as the capability of systems to understand other systems, the ability of all components (e.g., human resources, smart products, smart factories) to connect, communicate, and operate together (Gilchrist, 2016; Ghobakhloo, 2018). It necessitates "accessibility, multilingualism, security, privacy, subsidiarity, the use of open standards, open source software, and multilateral solutions" (IDABC EIF, 2004; Lu, 2017) to have accurate and efficient processes and can be examined in four levels: operational (organizational), systematical (applicable), technical, and semantic (Lu, 2017). Agile principles can particularly be adopted in Industry 4.0 implementation projects with respect to the latter two levels as they relate to the technical development of IT systems and related software and to information exchange.
- Modularity focuses on the transformation of linear manufacturing and planning, rigid systems and inflexible production models into agile ones (Gilchrist, 2016). It is a crucial aspect of Industry 4.0 as it reinforces the adaptability of companies to changing customer requirements and their flexibility to offer increased product reconfigurations (Ghobakhloo, 2018).
- Decentralization is a key aspect for companies to become more agile (Veile et al, 2018) since it relies on different agents in the value chain work independently. It leads to autonomous decision making that is aligned with organizational goals (Gilchrist, 2016).
- Virtualization can be referred to "the replication of a digital twin of the entire value chain" (Moreno et al., 2017) through real-time analytics and the Internet of Things so that 'smart' manufacturers can have "a complete digital footprint of their existing or new products from design and development phase to disposal and recycling" (Ghobakhloo, 2018).

Cluster 5 - Industry 4.0 Technologies: In the literature, there exist different requirements of technologies for the Industry 4.0 transformation depending on the priorities and the industry specifics. The most cited and common technologies of the various technology requirements are chosen as the elements of this cluster and examined in detail below. These technologies are considered to be installed into a company as projects during the Industry 4.0 transition. Our goal is to investigate and prioritize the project characteristics to manage these technology installation projects.

- Internet of Things (IoT): Internet of things refers to the infrastructure to establish an environment of connected physical intelligent devices and systems. The connectivity is achieved by the internet technology. Machines, information systems, linkage with sensors become connected. This connectivity enables data communication and feedback to improve production and control. It is expected that there will be 26 billion connected devices in 2020 generating multiple trillion dollars of revenue (Brousell, Moad, and Tate 2014). These figures show the enormous potential of IoT to transform and improve the manufacturing environment and the whole value chain in the coming years through real-time machine-to-machine communication, collaboration, integration and automation (Fatorachian and Kazemi, 2018).
- Big Data, Analytics and Cloud Computing: In manufacturing processes, vast amount of data is generated. The big data analysis refers to efforts for processing large amounts of data using the communications, information technologies and high-tech computers with high computing power. Cloud systems, on the other hand, offers high-storage capacity and high-speed computing independent of location by allowing all data to be accessible from any place, at any time quickly (Kang et al., 2016; Veile et al., 2018). In an Industry 4.0 environment, together with connected systems achieved through the IoT and generation of information in the cloud, quick and effective use of data becomes possible (Saucedo-Martínez, 2018). Data generated by machines, devices, products, etc. at different locations can be transferred and collected to anywhere through cloud networks. The collected data can then be aggregated, transformed, mined and analyzed using analytical tools. As a result, the useful knowledge generated can be used for decision-making, optimization of production processes, quality improvement and forecasting, and customization. This enables quick and effective responses to changes and fluctuations, as well as proactive or real-time problem solving (Fatorachian and Kazemi, 2018).
- Additive Manufacturing: It mostly helps to visualize the manufacturing process and ease the production of prototypes. Additive manufacturing is actually not at the back bone of digitalization of the manufacturing processes and it is already embodied in the vertical integration and autonomous manufacturing devices. However, the advantage of easy prototyping and making small amounts of production has tremendous significance for customization, innovation and creating savings by reducing the wastes. Additive manufacturing complements the intelligent manufacturing environment and enhances its goals. Hence, it is frequently mentioned as one of the enabling technology of Industry 4.0 in the literature (Pickett, 2016; Saucedo-Martínez, 2018).
- Horizontal System Integration: It focuses on the whole value chain and aims to align all of the components of the chain to increase the level of collaboration among them. The components of the value chain are the units within the company such as engineering, manufacturing along with suppliers, customers and all of the partners in the supply chain constituting the horizontal level (Liao et al., 2017; Siepmann, 2016; Veile et al., 2018). The system integration refers to introduce structural changes in organization and management of physical objects and in information sys-

tems so that global functioning as a whole becomes possible. The intelligent physical objects and information systems can collaboratively and effectively work together throughout the horizontal level. The information flow is unified and analysis can be done as a whole to achieve the goals of Industry 4.0.

- Vertical System Integration: Vertical systems integration focuses on a specific sector in the chain and aims to integrate hierarchical IT systems related to that sector. An example of the hierarchical level can be the actuator and sensor level to the manufacturing level to the production planning level to the enterprise planning levels (Liao et al., 2017). In this way, end-to-end effective solutions for specific tasks can be achieved. Vertical integration includes connecting all internal systems and interfaces as well as the data exchange between intra-firm hierarchical levels (Siepmann, 2016). For instance, enterprise resource planning systems and manufacturing execution systems need to be connected (Mosler, 2017; Veile et al., 2018).

Cluster 6 – Project Management Characteristics: In order to achieve Industry 4.0 transformation, traditional firms need to install various technologies, a collection of them are listed in cluster 5. These installation/development projects of each technology would have a different set of project management characteristics depending on its scope, components, processes it enables, and size. A set of project management characteristics are deducted from the literature that may affect the type of the project management method (Daneva et al., 2013; Flatscher and Riel, 2016). These criteria are listed as follows:

- Interdependencies: Interdependencies of a project may arise due to various factors listed as follows: (i) cross-cutting multiple business units/technologies related to the project, (ii) due to sequencing of tasks related to a specific process, (iii) due to team assignments, (iv) due to downstream activities
- Stakeholder involvement: It shows to what extent different parties such as customers, suppliers, team members, etc. are engaged into the project, how close and frequent interaction takes place and how much and frequent feedback is taken and used.
- Time/Budget Flexibility: It implies how much tolerance can be given to a deviation from the planned deadline of completion and planned budget.
- Technical debt: It corresponds to the extra redesign effort needed when the project does not have a complete front-end planning but a short-term perspective.
- Volatility/Uncertainty: It implies the expected amount of change projects goes through. The changes can occur due to changing business conditions, technical challenges, human resources or downstream requirements.

Step 3: Determine influences between the components of the network.

In this step, the components are added to the network as nodes and the directional relations between the components are identified. As the components are deducted from the literature, the directional relationships among the components are identified by the expert evaluations. The directions of the influences are illustrated at the network given in Figure 3.

Step 4: Setup the supermatrix and make pairwise comparisons.

The supermatrix having all of the elements in the network on the rows and on the columns is constructed. Elements are grouped based on their clusters in the supermatrix. The general submatrix notation of the supermatrix is given in Figure 4. The notations A, B.., J in the supermatrix refer to the matrices showing the pairwise comparisons of the elements of each cluster. A ratio scale between 1 to 9 is used for the comparisons. The pairwise comparisons are made by two experts from academia with sufficient industry experience. Their individual and collaborative research has appeared in top-tier journals. One of the experts owns a consulting company working on optimization, RFID and Industry 4.0. They have conducted many projects on process improvement, RFID, augmented reality, distribution. The second expert is an academician and holds a professor title. His research is related to technology management, cost management and decision making.

Step 5: Make the computations to obtain the limit supermatrix.

The eigenvalue of each submatrix is calculated and collected in the supermatrix. Then, the supermatrix is raised to its powers in order to obtain the effects of direct and indirect relations in the network. To avoid small priorities drop to 0, we did not choose a high power. The initial supermatrix and the resulting limit supermatrix are shown in Tables 3 and 4, respectively.

Figure 3. The ANP model

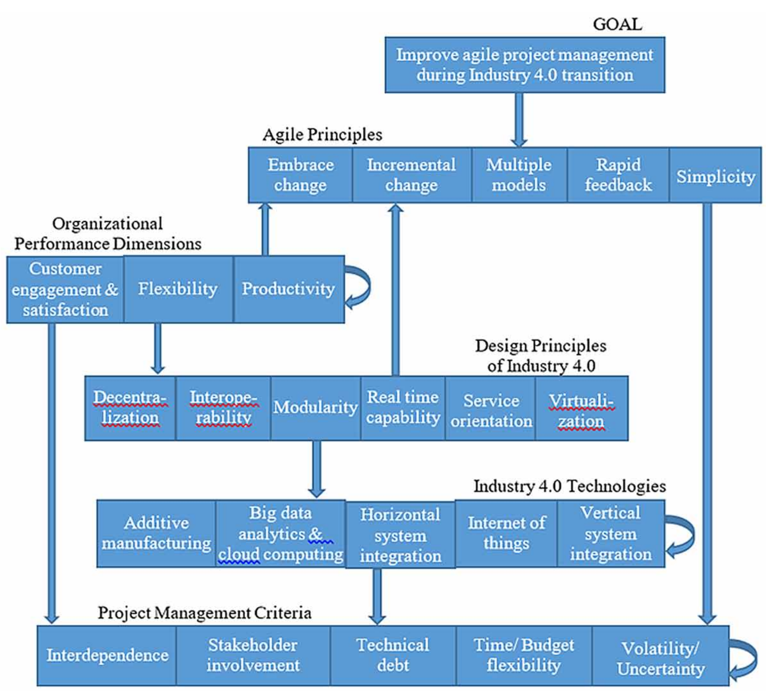

Figure 4. General submatrix notation of the super matrix (I: identity matrix)

	Goal	AP	DP	OP	ITE	CR
Goal	0	0	0	0	0	0
Agile Principles (AP)	A	0	C	E	0	0
Design Principles of Industry 4.0 (DP)	0	0	0	F	0	0
Organizational Performance Dimensions (OP)	0	0	0	G	0	0
Industry 4.0 Technologies (ITE)	0	0	D	0	I	0
Project Management Criteria (CR)	0	B	0	H	J	*I*

Table 3. Initial supermatrix of agile project management characteristics prioritization for Industry 4.0 transition (* CR1, …, 5 columns are not shown, the values of them can be seen in Figure 4)

	Goal	AP1	AP2	AP3	AP4	AP5	DP1	DP2	DP3	DP4	DP5	DP6	OP1	OP2	OP3	ITE1	ITE2	ITE3	ITE4	ITE5
Goal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AP1	0.44	0.00	0.00	0.00	0.00	0.00	0.10	0.06	0.11	0.23	0.08	0.07	0.05	0.06	0.01	0.00	0.00	0.00	0.00	0.00
AP2	0.13	0.00	0.00	0.00	0.00	0.00	0.05	0.03	0.04	0.07	0.02	0.03	0.03	0.03	0.04	0.00	0.00	0.00	0.00	0.00
AP3	0.31	0.00	0.00	0.00	0.00	0.00	0.19	0.21	0.23	0.03	0.10	0.22	0.01	0.10	0.02	0.00	0.00	0.00	0.00	0.00
AP4	0.06	0.00	0.00	0.00	0.00	0.00	0.12	0.09	0.07	0.14	0.27	0.16	0.12	0.05	0.05	0.00	0.00	0.00	0.00	0.00
AP5	0.06	0.00	0.00	0.00	0.00	0.00	0.03	0.12	0.06	0.03	0.03	0.02	0.03	0.02	0.13	0.00	0.00	0.00	0.00	0.00
DP1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.05	0.01	0.00	0.00	0.00	0.00	0.00
DP2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.09	0.00	0.00	0.00	0.00	0.00
DP3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.10	0.04	0.00	0.00	0.00	0.00	0.00
DP4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.02	0.06	0.00	0.00	0.00	0.00	0.00
DP5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.02	0.02	0.00	0.00	0.00	0.00	0.00
DP6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.01	0.03	0.00	0.00	0.00	0.00	0.00
OP1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.21	0.06	0.00	0.00	0.00	0.00	0.00
OP2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.19	0.00	0.00	0.00	0.00	0.00
OP3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.04	0.00	0.00	0.00	0.00	0.00	0.00
ITE1	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.05	0.02	0.02	0.19	0.00	0.00	0.00	0.10	0.00	0.04	0.03	0.04
ITE2	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.11	0.19	0.21	0.11	0.09	0.00	0.00	0.00	0.10	0.00	0.12	0.15	0.14
ITE3	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.11	0.09	0.06	0.26	0.05	0.00	0.00	0.00	0.10	0.00	0.00	0.24	0.09
ITE4	0.00	0.00	0.00	0.00	0.00	0.00	0.23	0.21	0.13	0.17	0.07	0.14	0.00	0.00	0.00	0.10	0.00	0.28	0.00	0.23
ITE5	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.05	0.04	0.04	0.04	0.03	0.00	0.00	0.00	0.10	0.00	0.06	0.08	0.00
CR1	0.00	0.05	0.04	0.09	0.08	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.03	0.05	0.19	0.20	0.23	0.24	0.05
CR2	0.00	0.28	0.44	0.41	0.54	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.10	0.01	0.15	0.36	0.14	0.13	0.12
CR3	0.00	0.16	0.28	0.26	0.13	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.06	0.06	0.05	0.29	0.04	0.07	0.23
CR4	0.00	0.40	0.11	0.10	0.05	0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.03	0.08	0.09	0.03	0.03	0.08
CR5	0.00	0.11	0.14	0.15	0.19	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.09	0.03	0.05	0.07	0.04	0.03

Table 4. Limit supermatrix of agile project management characteristics prioritization for Industry 4.0 transition (the zero submatrices of the limit supermatrix are not shown)

	AP1	AP2	AP3	AP4	AP5	ITE1	ITE2	ITE3	ITE4	ITE5	OP1	OP2	OP3
CR1	0.04	0.04	0.08	0.07	0.18	0.41	0.17	0.42	0.42	0.35	0.44	0.44	0.44
CR2	0.28	0.44	0.41	0.55	0.08	0.28	0.38	0.29	0.29	0.17	0.38	0.27	0.04
CR3	0.16	0.28	0.26	0.13	0.17	0.10	0.31	0.09	0.14	0.32	0.11	0.14	0.17
CR4	0.41	0.11	0.10	0.05	0.45	0.16	0.09	0.06	0.06	0.11	0.03	0.11	0.10
CR5	0.11	0.14	0.15	0.19	0.11	0.05	0.06	0.14	0.09	0.04	0.04	0.04	0.25

SOLUTIONS AND RECOMMENDATIONS

The limit matrix results show the accumulated relations for prioritizing the agile project management characteristics. Our aim to prioritize the criteria is to identify appropriate project management methodologies for the technology development/installation projects during the Industry 4.0 transition. The obtained results related to Industry 4.0 technologies and project management characteristics are given in detail in Table 5.

Considering that Industry 4.0 technologies are mostly integrated with software and IT technologies, we assume beforehand that agile project management practices can be applied for the development of these technologies for a company's Industry 4.0 transformation. There exist various agile project management frameworks as discussed in the Background Section. Using the priorities obtained from the ANP, project managers may decide which agile framework will match the development project management characteristics of the Industry 4.0 technologies.

Some recommendations examining the results can be firstly matching the big data, analytics & cloud computing technology with the Scrum framework. Scrum is a framework where iterative development and stakeholder involvement is strong and these properties are the priorities for big data, analytics & cloud computing technology.

Table 5. Priorities of project management characteristics with respect to the Industry 4.0 technology development and/or installation projects

	Additive Manufacturing	Big data, analytics & cloud computing	Horizontal system integration	Internet of things	Vertical system integration
Inter-dependence	41%	17%	42%	42%	35%
Stakeholder involvement	28%	38%	29%	29%	17%
Technical debt	10%	31%	9%	14%	32%
Time/Budget Flexibility	16%	9%	6%	6%	11%
Volatility/ Uncertainty	5%	6%	14%	9%	4%

In Table 5, it is observable that all the other technologies have a very high priority for the interdependence criterion. This fact is due to the nature of Industry 4.0 technology which integrates the physical and digital technologies as well as aims an end-to-end horizontal and vertical integration. Due to this common property of all technologies, we check the next highest priorities of the technologies. It is seen that for the horizontal system integration and internet of things the next highest priority is stakeholder involvement and both has no time/budget flexibility. These properties seem to be matching to hybrid project management framework where there exists a comprehensive plan but at the same time frequent feedback and iteration of agile principles are used during the project. And hybrid project management is especially appropriate when a project both includes hardware and software development, which is the case for the projects of horizontal system integration and internet of things.

For vertical system integration project, it is seen that together with interdependence, the most important priority is technical debt. Since in Kanban agile project management framework, the visualization of the steps and WIP management are the important elements of the project management. This could help to manage the technical debt for the vertical system integration project.

Finally, additive manufacturing has a high stakeholder involvement, fairly high time/budget flexibility and low technical debt. These properties can be managed effectively using the minimum viable product approach of lean/modular agile project management.

FUTURE RESEARCH DIRECTIONS

There is a general consensus in the literature that Industry 4.0-related research is in its infancy. Different economic environments and cultural backgrounds may require different ways to implement Industry 4.0 projects. Future research could make a distinction between different market environments and overall conditions when evaluating the success of Industry 4.0 implementation projects.

The relevant literature is currently lacking quantitative models. The ANP used in this study can be combined with other MCDM approaches to evaluate how the prioritized criteria and the project management frameworks (i.e. Scrum, Kanban, etc.) fit each other more precisely. Some possible methods to use could be TOPSIS, VIKOR, PROMETHEE and ELECTRE.

A limitation of the current study is that the number of experts consulted is relatively small. This is mainly due to the limited time the authors had and to the fact that making pairwise comparison within the given framework is quite tedious. Yet, future studies could consider consulting a large number of experts in different roles, with varying backgrounds, from different countries, and with differing length of experience in the field to get as broad representation as possible. To make the judgment of experts easier, linguistic fuzzy scales can be employed.

Another limitation of the current study is that the results reported here may not be applicable to all types of organizations. Future studies should definitely consider how Industry 4.0 technologies affect an organization with a special consideration of project teams and managers.

Notwithstanding these limitations, this study contributes to the related literature providing a framework to identify the best fitting tools for different types of projects under specific conditions.

CONCLUSION

Industry 4.0 is a trending topic for both practitioners and academicians. The concepts related to Industry 4.0 is not new but the integration of the communication and information technology in the manufacturing and other areas of physical world is expected to make an enormous change in our world economically, socially and technically. The understanding of manufacturing will go through a new transformation for the third time to construct the fourth era.

The transformation however is not understood well because the concepts and requirements related to Industry 4.0 are still vague and uncertain. There are many different views but no consensus on the list of requirements, roadmaps and benefits. Thus, it is still an emerging area. In this study, the contribution made are two folds. First one is to give a comprehensive view of Industry 4.0 transformation and make a review of the literature. Second one is to create a guideline that will help to identify the appropriate agile project management technique for project managers in the Industry 4.0 transformation. To achieve this, an MCDM method, namely ANP is employed. The results of the ANP show that for different types of Industry 4.0 transformation projects, management criteria have different priorities. Using these priorities, the most suitable agile framework can be specified for the technological transformation projects of Industry 4.0. In our application, we found that the two most important technology projects to be undertaken, namely IoT and horizontal system integration match with the hybrid project management framework, whereas big data analytics and cloud computing is matched with Scrum, vertical integration with Kanban, and finally additive manufacturing technology is matched with the lean/modular project management framework due to different priorities of the three most discriminating project criteria, (i) stakeholder involvement, (ii) technical debt and (iii) time budget/flexibility. The other criteria found to be in similar levels for almost all projects. Interdependence criterion is very high in all projects except for big data analytics and cloud computing technology projects. Priority of volatility/uncertainty criterion, on the other side, is generally low, except for horizontal system integration projects.

ACKNOWLEDGMENT

The authors wish to express their special thanks to the reviewers of this study for their insightful comments.

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Chapter 10
Project Management and Efficiency of the Projects in the Industry 4.0 Era

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ABSTRACT

Using resources without wasting is not only important for traditional operations but also important for projects. At this point, the concept of efficiency which is directly related with the usage of resources comes to the forefront. Efficiency has been important at all times and its importance also continues today, in the Industry 4.0 era. This chapter deals with project management and efficiency of projects in the Industry 4.0 era. In the first section of the chapter the Industry 4.0 concept is explained. In Section 2 the project and project management topics are discussed. In Section 3, efficiency, efficiency measurement and the data envelopment analysis (DEA) are dealt with. In Section 4 project management and the efficiency of the projects in the era of Industry 4.0 are mentioned. Finally, in Section 5 a numerical example is presented.

INTRODUCTION

Due to the globalization experienced in the world, international trade has increased and the effects of crises such as the 2001 banking and the 2007 mortgage have been significant in accordance with this global expansion. These negativities have forced firms to adopt more modern, more flexible and more scientific management approaches and leave the classical management philosophies.

According to these new approaches adopted, manufacturing enterprises should build flexible production systems, considering the level of expertise and the need and the priority of the customers. When doing these, each product or service should continue its activities by considering the production process as a project. In this respect, the concept of project management and the efficiency of the projects gain importance.

DOI: 10.4018/978-1-5225-7865-9.ch010

In the work initiated by Kagermann et al. (2011), which started with the effect of the digital transformation process experienced in industrial production in Germany in 2011, the industry was expressed as 4.0. Afterwards; the German National Academy of Sciences and Engineering (Acatech) published a manifesto in 2013 and shared a new generation of production methods. This revolution, which has also made a tremendous impact outside Europe, is called the industrial internet consortium in America. These approaches, which have basically similar contents, are the cyber physical systems that enable simultaneous information exchange in production processes and create value through the Internet of things.

It is being argued that Industry 4.0 is actually beginning to emerge with the axis shift experienced in global production. The realization of the vast majority of industrial production by the eastern countries has become a threat to the western countries. Countries that want to provide competitive advantage have focused on innovation efforts to decrease the time-to-market of products and services (Hecklau et al., 2016). In the modern sense first project, the Manhattan Engineering Project, was developed in the US during the World War II. With this project, the first atomic bomb was developed and project management concept emerged. Projects are unique, one-time operations designed to put through a specific set of objectives in limited time horizon. Project management is concerned with planning, scheduling and controlling project activities to achieve timely project completion within budget and meeting performance expectations (Fitzsimmons et al., 2008).

In an increasingly complex business world, it is obvious that decisions and projects need to be realized in the light of more professional and scientific data. In this regard, it would be more appropriate to apply Data Envelopment Analysis (DEA), one of the most widely used methods in the literature in project management and project efficiency in the age of industry 4.0. DEA is a linear programming-based method used to evaluate the relative efficiency of decision-making units that are responsible for producing similar outputs by using similar inputs (Kasap et al., 2007). The length of time and accordance of the plan in which projects that are carried out on a long-term basis are important. In this respect, DEA, when implemented with expertise at every stage of the projects being carried out, will be in conformity with the risks and plans carried especially by the long-term projects.

On the other hand, one of the key concepts among the main building blocks of Industry 4.0 is the efficiency of all processes with big data and their analysis. Especially these developments enable industrial growth by increasing productivity in production and therefore faster a production structure having low error rate and high quality with minimum costs has been started (Roda et al., 2018). In addition, with the digitalization, it is seen that the products and services are more customized thanks to these technologies, which allow the changing needs and expectations of the customers to be met faster and more efficiently by the enterprises. In this respect, with industry 4.0, firms that will each become a digital organization should take a holistic approach in the workflows of all processes of the value chain in order to obtain the long-term advantage of digitalization which is started in production. (Buhr, 2017). It can again be said in this point that efficiency measurement and DEA methodology become important in the Industry 4.0 era.

Furthermore, businesses will be faced with massive data as they begin to use the new generation of Internet-based technologies. Those who are successful in analyzing the data will be able to reflect on the competition strategies. Employees with creative and coordinating abilities who are thinking more strategically have begun to be needed (Hecklau et al., 2016). After the availability of the necessary expert staff, businesses will search ways to deal with big data obtained by the Internet of the Things and try to use the data efficiently. Naturally; it will make a sense when the collected data are efficiently categorized and used. In this respect, the concept of efficiency gained importance in the age of Industry 4.0. If we look from the viewpoint of project management, too much data will be available in a project. However; projects can be successful if these data are used efficiently.

This chapter is organized as follows. In the first section of the chapter the Industry 4.0 concept is explained. In Section 2 project and project management topics are discussed. In Section 3 efficiency, efficiency measurement and the Data Envelopment Analysis (DEA) are dealt with. In Section 4 project management and the efficiency of the projects in the era of Industry 4.0 are mentioned. Finally, in Section 5 a numerical example is presented.

CONCEPT OF INDUSTRY 4.0

Industrial revolutions that took place from the historical process to the present have had a great impact on the level of development of societies and countries. Starting with an innovation, every industrial revolution, triggered many economic, social, scientific, cultural and social changes. Throughout the historical process, the muscular power-based production systems have come to a different dimension with the developing technology, which has led to the emergence of new revolutions by changing the relation between production and consumption (Brettel et al., 2014; Polat and Karakuş, 2018).

The Historical Journey of the Industrial Revolution

Before discussing Industry 4.0, it would be helpful to talk about the industrial revolution that have taken place throughout history. In this context, the industry revolution is outlined in Table 1.

The first industrial revolution came into being at the beginning of the 18th century when the production systems based on water and steam power began to be used. As a result of this development, steaming machines developed in the UK and used for commercial purposes for use in weaving looms in the textile sector have become the symbol of the first industrial revolution (McCraw, 1997).

A second industrial revolution emerged at the beginning of the 20th century as the use of electric energy throughout the world became possible. The most prominent feature of this industrial revolution is that it has been standardized by mass production and the transition to efficient production has been achieved. In spite of this rapid development of the living, the consumption has come to a halt due to the two world wars that have lived in the century and therefore the firms have become unable to market the products they have achieved in mass production. This has continued until the 1970s, although it has led to the search for new marketing strategies and the increase in the importance given to innovation (Möller, 2016).

Table 1. Industrial Revolution and Emergence Shapes

1. Industrial Revolution	2. Industrial Revolution	3. Industrial Revolution	4. Industrial Revolution
"Late 18th Century"	"20. Century Heads "	"After 1970"	"Today"
The emergence of water and steam powered mechanical production plants.	The work space that electricity energy makes possible and the emergence of mass production.	The use of electronic and information technology to bring the automation of production to a higher level.	Production systems based on cyber-physical systems and dynamic data processing

Source: McCraw, 1997

After the 1970s, the effect of the wars that had taken place gradually diminished, and automation of production was achieved with the increase of information technology. Parallel to this development, robots have started to be used in the industry. In this context, it is seen that when the production and consumption are examined, the third industrial revolution represents an industrial structure in which the communication and coordination between producers and other stakeholders are strengthened and the consumers in production are also speaking. In this period, instead of producing only what is demanded in the market, an approach that includes the development of products and services for the consumer's wishes has begun (McCraw, 1997).

The effects of the third industrial revolution, which was based on the automation of industrial production, continued until the fourth industrial revolution in 2011, when the digital transformation process in industrial production in Germany was affected. In the whole world, especially in Europe, a new approach - a new production system - was needed. Because of the third industrial revolution, which first appeared mainly in Europe, the eastern countries, especially China with its head, went to advanced levels in production according to European countries. This has become a threat to European countries and a new industrial revolution under the concept of Industry 4.0 has been introduced in Germany to address the dominance of global competition. The first work on this subject was published by Kagermann et al. (2011) in the form of Industry 4.0 principles and content. In Germany two years after Kagermann's work, the German National Academy of Sciences and Engineering (Acatech) published a manifesto to share a new generation of methods. This revolution, which has also made a voice outside Europe, is called the industrial internet consortium in America. These approaches, which are basically similar contents, are based on the cyber physical systems which enable simultaneous information exchange in production processes; objects and services to create value through the internet (Hecklau, 2016; Stock and Seliger, 2016).

Once the concept of the Industry 4.0 has been explained, it is necessary to clarify its main building blocks. Among the developments that constitute the basic building blocks of the Industrial 4.0 concept are as follows (PricewaterhouseCoopers, 2016):

- Big data and analytics
- Autonomous robots
- Simulation
- Horizontal and vertical system integration
- The industrial internet of things
- Cybersecurity
- The cloud
- Additive manufacturing
- Augmented reality
- Mobil devices
- 3D printers / 4D printers
- Smart sensors
- Advanced human-machine interfaces

These developments enable industrial growth by increasing productivity in production so a faster production structure having a lower error rate and higher quality with a low cost can be established. Moreover, new generation production technologies that provide flexibility in production have caused the start of the fourth industrial revolution. It is seen that products and services are more personalized thanks to these technologies, which enable the firms to meet changing customer demands and needs faster and more efficiently with digitalization (Buhr, 2017). Thus, business models have begun to differentiate by having the cost advantage of personalized production systems based on technological possibilities. Again, with the recent industrial revolution, firms that will each become a digital enterprise, it is necessary to take a holistic approach in the workflows of all processes of the value chain in order to achieve the long-term advantage of digitalization that starts in production. Each business function has strategies for restructuring with digital solutions from supply to distribution, from marketing to human resources (McKinsey Company, 2015). However, considering the diversity of resources and capabilities that each company has, an action plan should be developed after analyzing sectoral dynamics and expectations.

All of these things mentioned above have made the concept of efficiency more important. The efficiency ratios that must be known at every stage of production, from procurement of raw materials to end customers. Instead of classical efficiency measurement techniques, more contemporary, more accurate efficiency measurement techniques have emerged. Data Envelopment Analysis (DEA) is one of the such techniques and it is discussed in detail in the next section.

After mentioning the reasons and process of the industrial revolutions, and especially the Industrial 4.0, it is necessary to state what advantages of the last industrial revolution have and how these advantages provide superiorities over previous industrial revolutions.

Transformation Process in Industry 4.0

Industry 4.0 offers significant advantages in terms of countries' development and social welfare, despite the limited opportunities and opportunities to meet increasing human needs. It is possible to list the advantages of this industrial revolution, which provides for the use of intelligent objects through the Internet infrastructure, together with the explanations (Brettel et al., 2014; Geissbauer et al., 2014; Lasi et al., 2014; Stock and Seliger, 2016; World Economic Forum, 2017):

- **Speed:** Along with globalization, firms have started to operate all over the world. In this case, it causes saturation in the markets. In order to get rid of the situation, firms develop innovation strategies. Thanks to Industry 4.0, it is accelerating the introduction of new products on the market using such strategies.
- **Flexibility:** Flexible production structure can be constructed instead of traditional production by using machines that can analyze data in production, make certain tasks by themselves, and make them through an interface with human interaction. It is possible to increase the flexibility by dividing the production process into small value-oriented business units.
- **Productivity/Efficiency:** One of the key building blocks on which Industry 4.0 is based is a zero-defect based on lean production principle. The use of intelligent tools / machines developed to achieve zero error targets provides increased productivity in manufacturing operations. According to estimates, the investments made will be reflected in productivity in the middle term.
- **Cost Advantage:** The use of intelligent devices in manufacturing enterprises will increase productivity by bringing them closer to the target of zero error, as well as cost efficiency by trying to minimize any waste in the production process. In this respect, it can be said that innovations introduced by Industry 4.0 will provide cost advantages.

- **Sustainability:** The goal of meeting the needs of scarce resources and endless human beings, which constitute the basic movement point of economics, is becoming increasingly difficult due to the increase in human population and needs. At this point, sustainability in production has become a major problem. It is expected that sustainability will be ensured in production along with science technologies based on Industry 4.0.
- **Personalization:** Personalized products or services are one of the most common manufacturing strategies used by firms for those looking for diversity with consumer demand and needs at the forefront. However, most firms avoid choosing this competitive advantage because the smallest changes in the production line mean increased costs. In the next generation of production, technologies such as 3D or 4D printers have begun to be used, allowing both consumers to turn into producers and firms to make personalized production at less cost.
- **Decentralization:** In Industry 4.0, the decision-making process within the organization, or the hierarchical structure, is reduced while creating a more organic workflow model, while the key point of action is identified. At this point, multi-criteria decision making methods (MCDMs) gain importance because of their increasing use in modern sense.

Due to the listed benefits of Industry 4.0 it is expected that the number of digital enterprises in industrial manufacturing will increase and the countries will start to investigate on this transformation process.

Industry 4.0 has also some disadvantages. These are summarized as follows (PricewaterhouseCoopers, 2016):

1. Requiring large investments
2. The necessity of developing new service-oriented business models
3. The necessity of designing innovative production processes
4. Requiring strategic partnerships
5. The problem of analyzing the large data that can be encountered
6. Storage of large data
7. Provision of cyber security

Since the concept of industry 4.0 requires the installation of intelligent systems at workplaces, high infrastructure costs occur. In this respect, the cost of transformation to this system is a big problem for the firms. In this process, where automation-related production is increasing, all devices are connected with each other and cyber environments are created, firms need to develop appropriate strategies for this transformation. In this context, new business models with a focus on service and innovation-based production processes are being designed, strategic partnerships are made, and the entire system is required to provide secure cyber safety. On the other hand, equipping all systems with intelligent devices will constantly cause new data flow, which in turn leads to the problem of how these data are analyzed and stored. The lack of specialized staff in areas such as data mining will create a problem for these firms.

It has not been too late to respond to the Industrial 4.0 in the eastern countries, which European countries have developed to break the dominance of production in eastern countries. In this context, the concept of Society 5.0 was introduced in Japan, and studies were started on how digitalization of individuals should be socialized in this work. According to this, society is divided into 5 different categories and technology is not a threat; which facilitates life, provides social welfare and stimulates the economy (Keidanren, 2016).

PROJECT AND PROJECT MANAGEMENT

Project Concept

Projects emerged as a result of the need for change and management. In ancient times, managers saw projects as a simple action. Today, project and project management have a very complex structure. In this case, professional project management is required. In this context, the concept of the project should be explained scientifically.

It is possible to define the concept of the project in many different ways. The project is a study of how resources can be used to achieve optimum for a specific set of specific objectives over a specific period of time. A more specific definition is that which has certain aims and values that can be used for purposes such as meeting certain needs and desires (Cleland and Ireland, 1999). The project is a study which is started and ended, has a long-lasting change within a predetermined period, has its past intentions and goals and is carried out with resources in which various products are obtained through planned application steps. Often a project cannot be repeated as a whole. The work is carried out by a team of interdisciplinary staff who are permanent in the project but temporarily run in the institution where the project is run, within the limits of the planned time and financial resources (Shenhar et al., 2001).

Project is a process that symbolizes change and implements change. Projects can bring a new situation, dimension or vision to the organization, as well as change the products or services of the institution's existing applications. Projects can be classified using different criteria and in order to reveal certain features. Projects can be classified as small medium and large comprehensive projects in terms of their scope (Turner, 2014).

The following factors play a role in determining the scope of the project (Charvat, 2003):

- Projects that have already been carried out in similar fields are known
- Percentage of risks that will prevent reaching the project target
- Changes in resource amounts, depending on time
- The number of cooperating organizations
- Degree of dependency between project activities

Project Management

Project management can be defined as the scheduling and control of project activities to achieve the goals of the projects. According to another definition, 'project management is the art of coordinating and managing human and material resources throughout the project life using modern management techniques in accordance with previously determined objectives, cost, time and quality criteria (Lewis, 1996).

Project management consists of four basic stages (Gido and Clements, 1999):

1. **Project Formation (Formation) Phase:** Projects originate from needs. In organizations, the project idea can be for a variety of reasons. These may be technological reasons, market conditions, renewal needs. The evaluation of project proposals, which define the objectives and scope of the project from the outset, is carried out at this stage and has vital importance for the success of the project.

2. **Project Planning (Identification) Phase:** At the beginning of the most discussed issues in project management is the planning stage. The purpose of the planning is to ensure that the project progresses towards pre-determined targets. At this stage, project organization should be done by using project planning techniques to establish project plan, to provide inputs and to determine alternative plan changes to be implemented when necessary.
3. **Project Implementation (Implementation-Control-Monitoring) Phase:** Following the project plan, it is the phasing of the project in the frame of the planned plan and evaluation of the outputs in terms of quality, cost, duration and objectives. At this stage, the project will be controlled according to predetermined performance criteria. Corrective actions will be planned when deviations from the specified project objectives are encountered during monitoring.
4. **Project Finishing Phase:** In this phase, the project will be completed and the allocated resources (equipment, human power etc.) will be withdrawn, the project organization will be finalized and finally the project will be delivered to end customers.

EFFICIENCY AND DATA ENVELOPMENT ANALYSIS

Efficiency Concept

Nowadays, enterprises have to compete with many competitors with the influence of globalization. Increasing numbers of competing businesses have forced businesses to produce better quality products at cheaper prices. This necessity has made the concepts of productivity and efficiency more important for the enterprises and they are now forced to use their resources more efficiently to get the maximum outputs with minimum inputs or to reduce the amount of inputs while maintaining the same number of outputs.

It is possible for enterprises to operate efficiently, through continuous quality control and process improvement. In this line of business, the company strives to continue its activities more efficiently and more productively by making efficiency measurements and they also detect faults from the data obtained.

Various concepts related to each other (technical efficiency, scale efficiency, price efficiency) have been put forward in order to better express the concept of efficiency in the studies carried out up to the day, and these concepts are called as efficiency types in the literature.

- **Technical Efficiency (Input Efficiency):** Firms operate in an environment where complex and intense competition conditions are affected by various factors. It is only possible for firms to succeed in these conditions, but only if they can produce the maximum and highest quality outputs in the most efficient manner using the inputs (labor, raw materials, technology, etc.) they use in production (Battese, 1992). Technically active DMUs; (González and Miles, 2002), which is expressed as the theoretical limit of the highest production quantities that can be achieved with the optimal input composition in the production of a product.
- **Scale Efficiency and Return by Scale:** In order to get the closeness to the most efficient scale size when performing performance measurement, it is called the scale efficiency. Scale efficiency is seen as a consequence of the losses made by the inability to produce at the optimal scale and is thus regarded as the success of production at the appropriate scale (McAllister and McManus, 1993).

- **Allocation (Price) Efficiency:** Operators operating in an increasingly competitive environment must therefore determine the optimal input composition, considering the prices of the inputs, in such a way to minimize the cost. The success that the business has achieved when selecting such input combinations is called the allocation efficiency. This efficiency is also referred to as the price efficiency because the efficiency is measured taking into consideration the prices of the resources as understood from the definition (Ye and Mo, 2002).

The basis of economic activities lies in the use of scarce resources more efficiently and more productively. Therefore businesses must carry out their activities as far as efficiently possible. This is why efficiency measurement is crucial for businesses. Different methods for efficiency measurement have been developed and the most commonly used method is the Data Envelopment Analysis (DEA).

Data Envelopment Analysis (DEA)

DEA is a performance measurement technique developed by Charnes, Cooper and Rhodes (1978), which is used to evaluate the relative efficiency of decision units in organizations (Azadeh et al., 2011). Efficiency measurement is the evaluation of the results of the use of resources at a specific time and in the form according to the intended results. The results obtained by a decision-making unit are achieved when the target unit coincides with the targeted results, while the unit is not efficient when not overlapping. The meaning of the efficiency measure is how close the actual results are to the targeted results. In addition to the concept of efficiency, the concept of relative efficiency should be addressed. Relative efficiency is a concept that compares the success of decision units in achieving the targeted results in a given timeframe or the success of a decision unit in achieving the targeted results over time (Charnes et al., 1978).

At first, DEA was started to be used for efficiency measurement of non-profit organizations. Later it was used in the measurement of the performance of multinational or multi-branch firms and in the measurement of efficiency of firms operating in the profit-oriented service and production sectors. In recent years, a wide application area of DEA can be found in operations research field (Norman and Stoker, 1991).

DEA is an approach developed to determine relative efficiencies. With this approach, the following conclusions can be reached (Cooper et al., 2006):

- Efficient organizational decision-making units
- Inefficient organizational decision-making units
- The excess resource amounts used by organizational decision-making units
- Organizational decision-making units are required to produce output levels that need to be generated by the current input levels (level at which output should be increased)
- Units of organizational decision-making units that constitute the reference set

DEA has bi-directional capability for input and output. Input-oriented DEA models investigates how the most appropriate quantity of input should be in order to be able to produce a specific quantity of output. On the other hand, output-oriented DEA models investigate how much output composition can be obtained with a given input composition (Charnes et al., 1981).

Efficiency value of the best-performing decision-making unit is 100 while that of the other decision-making units varies between 0-100, which aims at measuring how efficiently decision-making units use resources to create an output set (Ramanathan, 2003).

Decision-making units having similar organizational structures should be selected in order to implement the DEA method. In order for the efficiency of decision-making units to be measured, the input and output variables of these units must be specified. It is desirable to have a large number of inputs and outputs variable so that the DEA model can be used effectively. Selected input and output elements must be used for each decision unit. If the number of selected inputs is m and the number of selected outputs is n, at least m + n + 1 decision units are a necessary constraint in terms of the reliability of the research. Another constraint is that the number of decision-making units taken into consideration must be at least twice the number of variables (Boussofiane et al., 1991).

DEA Models

DEA models are examined in two groups as "input oriented" and "output oriented". While the input and output models are basically similar, the input DEA models search for the most appropriate input composition to be used in order to produce a particular output composition most efficiently. The output-oriented DEA models are investigating how much output component can be obtained with a given input complex. Charnes, Cooper and Rhodes (CCR) and Banker, Charnes and Cooper (BCC) models are most frequently used in DEA models. These models can be set up in two different ways as input-oriented and output-oriented. If the control over inputs is low or if it is an output-oriented model; if there is little control over the outputs, or if an input-oriented model is to be established. In the input-oriented models, to generate the output, use at least the input; while in output-oriented models, it is tried to produce the most output with the current input (Charnes et al., 1981). In this chapter we use the CCR model. Therefore, this model is explained in the following paragraphs.

- **Charnes, Cooper and Rhodes (CCR) Models:** The CCR models first introduced in 1978 were applied by Charnes, Cooper and Rhodes with a nonparametric approach in evaluating the research efficiency. The CCR models are used to calculate relative total efficiencies based on the assumption that all decision units are operating at the optimal scale under a constant fixed return assumption on a scale and are interested in evaluating the total efficiency and estimating those that are inadequate from the sources (Sinuany-Stern et al., 1994; Wu, 2009). CCR models will be examined in two groups as input oriented and output oriented.
- **Input-Oriented CCR Model:** Models that investigate how much the input composition should be reduced to achieve this output level most efficiently, without changing the output level in the input-oriented model. The mathematical expression and general formulation of the input-oriented CCR model is as follows (Charnes et al., 1981):

$$E_0 = \max \frac{\sum_{r=1}^{s} u_r y_{ro}}{\sum_{i=1}^{m} v_i x_{io}}$$

Constraints:

$$\frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1, \text{(j= 1,2,…..n)} \tag{2}$$

$$v_i, u_r \geq \varepsilon \text{ (r=1,2,….s) ve (i=1,2,….m)} \tag{3}$$

Here,

n: Number of decision units (j = 1,2, ..., n)
s: Number of outputs (r = 1,2, ..., s)
m = number of inputs (i = 1,2, ... m)

- **Output-Oriented CCR Model:** Models that investigate how much the output composition should be increased to enable operation with this input level without changing the input level, and the difference between this model and the input model is to minimize the ratio of the weighted input to the weighted output. This model can be formulated as follows (Charnes et al., 1981):

$$E_0 = \min \frac{\sum_{i=1}^{m} v_i x_{io}}{\sum_{r=1}^{s} u_r y_{ro}} \tag{1}$$

Constraints:

$$\frac{\sum_{i=1}^{m} v_i x_{ij}}{\sum_{r=1}^{s} u_r y_{rj}} \geq 1, \text{ j=1, 2, …, n} \tag{2}$$

$$v_i, u_r \geq \varepsilon \text{ r=1, 2, …, s; i = 1, 2, …, m} \tag{3}$$

DEA Application Steps

It is important in terms of the results to be followed and application of some steps in order to reach the correct results by the DEA which finds application area in profit oriented and non-profit oriented institutions. The steps required for the implementation of the DEA are given below (Ramanathan, 2003):

- Choice of decision units (observation set)
- Selection of input and output variables
- Availability and reliability of data
- Measurement of efficiencies with DEA
- Finding efficiency values
- Determination of the reference set
- Target setting for inefficient decision-making units
- Evaluation of results

Advantages and Disadvantages of DEA

- **Advantages of DEA:** DEA is a convenient method for determining the best boundary values, helping individual Decision Making Units (DMUs) to create the best organization and to analyze new data in this direction to produce new managerial and theoretical ideas. Charnes et al. (1978) have explained the advantages of using this method in their study as follows:
    - Determines the source of inefficiency by determining the decision unit.
    - Provide the optimum input composition as a single total value over periods to produce the desired output.
    - Contrary to average density, it gives results based on individual observations.
    - Helps to identify units that will form a reference to DMUs.
    - It can use multiple input and multiple output set in calculations.
    - It does not require that the production relationship is restricted to the functional form.
    - Can determine the most appropriate criteria for the relative development of each DMU.
    - DEA is a method that can handle many inputs and outputs.
    - DEA does not need a functional form that relates input and output except linear form.
    - Decision-making units whose activities are calculated by means of DEA are compared to those who have relatively fully efficiency.

Inputs and outputs can have very different units. In this case, there is no need to use various assumptions and transformations to measure input and output in the same way.

- **Disadvantages of DEA:** There are some disadvantages as well as the above advantages of the DEA method. Several arguments have been put forward in some investigations regarding the disadvantages of the method.
    - DEA is very sensitive to measurement errors as it is based on maximum border efficiency (Roll et al., 1991).
    - DEA is insufficient in terms of evaluating absolute effectiveness even though it is sufficient to measure performance of DMUs. It also does not allow the use of statistical test tools because it is a non-parametric method (Ramanathan, 2003).
    - Due to the fact that there are no random faults in the DEA method, the measurement methods and the roughness in the data cannot be extracted and therefore the related problems are reflected in the results (Cooper et al., 2000).
    - Since the efficiency values in DEA are obtained by solving a certain number of linear programming problems, it may be difficult to evaluate the implementation and results for some-

one who does not have technical knowledge in situations where there are more than two inputs or outputs (Ramanathan, 2003).

- Resolution of large-scale problems takes time unless appropriate package programs are used according to the DEA method (Ertay et al., 2006).
- The productivity results obtained in the research made by the DEA method are relative. There is no absolute productivity criterion. For this reason, the coverage of the data set is of particular importance. Interpretation of the results, interpretation of the results by input and output included in the analysis, accepted approach and analysis also differ (Berger ve Humphrey, 1997).
- It is very sensitive to measurement errors (Matthews and Ismail, 2006).

EFFICIENCY OF THE PROJECTS IN THE INDUSTRY 4.0 ERA

There are many studies focusing on project management and/or efficiency of projects in the literature. A brief discussion of the selected studies from the literature is made in the following sentences. Six-Sigma project selection (Kumar et al, 2007), project and project management efficiency (Dweiri and Kablan, 2006; Bouras, 2013; Serrador and Turner, 2015; Sundqvist et al, 2014), projects efficiency prediction (Tsvetkov, 2012), automotive project efficiency (Niebecker et al, 2008), effectiveness of associated projects (Vitner et al, 2006), information technology projects (Asosheh et al, 2010), project control methods efficiency (Vanhoucke, 2011), efficiency of new product development process (Swink et al, 2006), project performance system design (Hoffman et al., 2010), project efficiency with Data Envelopment Analysis (Hong et al, 1999), construction projects efficiency (El-Mashaleh et al, 2010), determination of project management risk factors (Raz and Michael, 2001) and industry firms efficiency (Sanchez and Perez, 2002) are some examples of this literature.

The industrial revolutions have passed from mechanization, electricity and IT phases before reaching the Industry 4.0 era. Then as now, the developing technology and competitive market dynamics need innovation and risk management. By the given conditions, project efforts have contained more risks and opportunities. Because of that, it has been needed to manage the projects professionally and efficiently. It is natural that most of the projects are multi-faceted, interconnected each other and have multiple alternatives, outputs and inputs and realized subject to many constraints. This situation has a key role in the digital transformation. Namely, the efficient operations are essential at each step of all projects for the digital transformation. Therefore, it seems that it is needed to increase the flexibility of all steps of projects to achieve the digital transformation. In the smart factories, which occur with digital transformation in industries, the yield and production amounts are increasing. However, the principles of the last industrial revolution should be integrated into the all of value chain of these smart factories. In this case, efficiency is required at each stage of the process. In fact, the process of acquiring smart plants through the process of digital transformation from the classical industry is a project and this project needs to be carried out efficiently (Jeffrey, 2007; Tonchia et al, 2018).

On the other hand, companies in today's trade conditions carry out many projects simultaneously. For example, from the supplier selection to marketing, each phase is a project. The selection and prioritization of these projects is of vital importance for firms. Because, the efficient execution of the projects directly affects the subsequent project. In addition, it is the use of scarce resources that make production processes a project and mandates efficient execution. So that the distribution of firms' scarce resources to production processes is a project in itself. In this regard, the project of efficient allocation of scarce resources; it has a key role in achieving firms' strategic goals (De Reyck et al., 2005; Kaiser et al., 2015; Isikli et al, 2018).

With the innovations introduced in Industry 4.0, the management type of projects gains additional importance. As mentioned earlier in this chapter projects are activities whose all stages are defined in detail. It is essential that the activities at every stage, from the design of a project to the end, are carried out efficiently. If each stage is inefficient in a project, it is probably to face with some problems. Depending on this situation, problems such as resource waste, cost increase and excessive time usage arise. These issues remove the benefits of Industry 4.0. Professional and contemporary efficiency measurements should be made at each stage of the project to avoid such situations. On the other hand, the duration of the projects, the results and the outputs are required to be interdisciplinary, since they are certain one-time activities. The simplest example of this is an efficient supply chain. Optimality of interdisciplinary work is vital for projects in this case.

Firstly, during the design phase of the projects, the most efficient ones can be taken as a reference by comparing similar projects that have been done before. It may be desirable to carry out the project using better input quantities such as time, cost, and resource than the best reference project. In this case, it is essential to perform efficiency measurements on each field of production process. Efficiency measurement must be made not only in the design stage of the projects, but also in all stages of project flow and therefore it will be possible to know accessing level of aims. Such measurements will provide status analysis by giving objective information about performance. It is aimed to save money and time by using innovations such as intelligent systems/machines introduced by Industry 4.0. Efficiency measurements to be made within the project process will show the potential benefits to be achieved. When the projects are concluded, the efficiency measurement will determine the extent to which the objectives are achieved, and the success or failure will be controlled. As a result, it will be clear how efficient it is at the current state. Finally, DEA is a useful method that produces more accurate results, which are more commonly used than other efficiency measurement methods. Efficiency measurements made using the advantages of DEA would provide a significant advantage for firms.

A NUMERICAL EXAMPLE

Cappadocia Life Builder (CLB) is a leading company in the construction sector. It is currently carrying out a big project focusing on building 200 smart apartments in ten different cities of Turkey. The projects are identical in all cities, but the contractor firms are different in these cities. Naturally; each project produces similar outputs by using similar inputs. The expected due date is 2 years; starts in January 2016 and ends in December 2018. Furthermore, according to the agreement made between the shareholders it is required to utilize from 3D printers in some part of the project since it is partly supported by the public funds. Therefore, CLB decided to build the roof of the apartments using the 3D printers and requested its contractors to comply with this condition as well as all other terms and conditions of the agreement. The rest of the data including inputs, outputs and the DMUs are given in Table 2.

The cities are arranged in alphabetic order as Antalya, Ankara, Bursa, Diyarbakır, Erzurum, İstanbul, İzmir, Kayseri, Nevşehir and Samsun. The contractor firms managing the projects in these cities are named as CF_1, CF_2, …, and CF_{10} respectively. There are two inputs and two outputs: Input-1 is the "number of staff" and Input-2 is "total cost". First input includes managerial team, engineers and workers and

Table 2. Data of CLB company

DMUs	Input-1	Input-2 (million$)	Output-1 (million$)	Output-2 (%)
CF_1	200	17,8	40	91
CF_2	203	20,2	55	92
CF_3	197	19,3	39	88
CF_4	202	18,5	37	81
CF_5	201	19,0	38	83
CF_6	210	25,0	62	94
CF_7	208	23,0	59	93
CF_8	172	18,1	38,2	90
CF_9	225	18,9	39,4	91
CF_{10}	203	19,8	40,1	80

all other auxiliary staff. The second input comprised of all (fixed and variable) costs and all expenses made during the project. The cost of the 3D printers is also included in Input-2. Output-1 is the "total revenue" and Output-2 is the "quality rate". The first output represents the revenue gained by selling all apartments. The second output is the indicator of quality of the buildings reflects the opinions of the experts in this field and translated into numerical based on their judgements. At the end of two years CLB made a detailed control and compared the efficiency of the contractors before delivering the projects. Calculate the efficiency of all contractors and find the efficient and inefficient ones.

- **Solution:** The problem can be solved by using linear programming, specifically the DEA. We can model this problem using the input oriented CCR model (in page 11 of this chapter). This is the rational representation of this model. We take its equivalent; the linear programming form and solved the problem with this model. The linear programming form of the input oriented CCR model is given below (Doğan, 2015):

$$Min\theta$$

$$s.t.$$

$$\sum_{j=1}^{n}\lambda_i x_{ij} \leq \theta_o x_{io}, \quad i = 1,\ldots,m$$

$$\sum_{j=1}^{n}\lambda_i y_{ij} \geq y_{ro}, \qquad r = 1,\ldots,n$$

$$\lambda_j \geq 0, \quad j = 1,\ldots,n$$

This model can be solved by using different softwares such as EMS, LINDO, PIM-DEA and Microsoft Excel. In this chapter we utilized from EMS (Efficiency Measurement System). After solving the model in EMS, we obtained the efficiency measurement scores. Table 3 gives these scores and efficient / inefficient firms.

It can be seen from Table 3 that four firms are efficient (CF_1, CF_2, CF_6, CF_8,) and six firms are inefficient (CF_3, CF_4, CF_5, CF_7, CF_9, CF_{10}). Efficiency scores of the efficient firms are 100% and inefficient firms are smaller than 100%. It can be interpreted that the efficient firms use their resources more rationally than the inefficient ones. As a result; it doesn't matter whether a firm uses traditional or advanced systems; efficiency and/or productivity concepts always maintains their importance. It is also valid in the Industry 4.0 era.

CONCLUSION

Projects are one of a kind and one-time operations designed to perform a specific set of objectives in a limited period. Therefore, management of projects is different from classical operations management and it requires much more attention. A project is any activity with a defined set of resources, goals, and time limit. Project management can be defined as the application of knowledge, skills and techniques in project activities to meet project needs. Project management is related with planning, scheduling, and controlling project activities to complete the project timely and efficiently. Efficiency is simply the ratio of outputs to inputs and it is related to resources used in a production environment so efficiency measurement is an important indicator for firms. Efficiency which is one of the sub-dimensions of performance has always been important throughout the history of industrial evolution. Although technological improvements make it possible to speak about artificial intelligence, the internet of things, robotic production systems, big data or data mining; namely the Industry 4.0 era, efficiency still maintains its importance. No matter it is a classical production system or a project, every process using inputs and producing outputs should

Table 3. Efficiency measurement scores

DMU	Efficiency Score (%)
CF_1	100,00
CF_2	100,00
CF_3	91,34
CF_4	87,10
CF_5	87,58
CF_6	100,00
CF_7	99,63
CF_8	100,00
CF_9	94,18
CF_{10}	83,67

be subject to efficiency measurement. Furthermore, it is not significant whether a project is conducted in old times or in the Industry 4.0 era. It is clear that efficiency measurement can give valuable information for any firm. At this point, a powerful method for measuring efficiency becomes important. Data Envelopment Analysis (DEA) is one of the such methods and it is widely used with this aim.

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KEY TERMS AND DEFINITIONS

BCC Models: These models are named after Banker, Charnes and Cooper (1984) and take into consideration variable returns to scale (VRS).

CCR Models: These models are named after Charnes, Cooper and Rhodes (1978) and take into consideration constant returns to scale (CRS).

Data Envelopment Analysis: A non-parametric linear programming model used to measure relative efficiency.

Decision Making Units: The entities whose efficiency are measured.

Efficiency: It is the ratio of output to input and also used interchangeably with productivity.

Efficiency Measurement: Measuring efficiency of a decision-making unit relative to other units.

Project: It has specific aims and values which can be used to meet specific needs and expectations.

Project Management: Project management is concerned with planning, scheduling and controlling project activities to achieve timely project completion within budget and meeting performance expectations.

Chapter 11
KANBAN Optimization in Relationship Between Industry 4.0 and Project Management Approach

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ABSTRACT

The aim of this chapter is to arrange KANBAN shelving in order to calculate the optimum order quantity of the materials supplied for the TV main boards in an electronic factory and to minimize the stacking of material waiting in the production area. To optimize this problem, a mathematical model is developed and solved in an optimization program. In addition, a number of proposals have been submitted under an Industry 4.0 to manage deficiencies in material following. The performance measures of both cases were compared, and the results evaluated. Due to the shortage of material following the next step of the problem, the company has been recommended to apply radio frequency identification (RFID). With the project management approach, all the critical information needed to manage materials, such as the materials themselves, production processes and stock information, has been clearly updated to keep the entire process under control.

DOI: 10.4018/978-1-5225-7865-9.ch011

INTRODUCTION

Supply chain is a whole consisting of the product required by the customer from the supply of raw materials necessary to produce the product held until all the operations and the flow of information delivered to the customer. The supply of the necessary materials is a very important part of this process. The material needed for production must be available at the required time, place and amount required. This understanding in production is known as just-in-time production and is born with a lean production philosophy. Lean manufacturing practices have been seen in the industry since the early 1990s. The key features of lean manufacturing are their focus on tight integration in the production process, continuous improvement and value adding activities while avoiding waste (Kolberg & Zuhlke, 2015).

In the just-in-time production, which is popular with the Toyota Production System, requires a stock level of zero value (Sanders, Elangeswaran, & Wulfsberg, 2016). Extra stock is also seen as one of the seven largest wastes of lean production. Stocks have an important place in terms of the profitability of the business and the continuation of production. But the costs of stocks, which are too much or too low, can cause loss or damage to the business.

In an operation of an enterprise, production in a normal push system is not based on real demand, but on the contrary to the demand forecast. In the pull system, production is based on real demand. Ordinarily, an operation of production should only be undertaken when requested. Demand must originate from a customer who must establish a production order. This means that every subsequent operation must initiate the operation of the previous operation. Extra stock in the business will lead to unsold merchandise, and in addition to production, maintenance and so on. Additional costs will arise (Monden, 2011). Marchwinski et al. (Marchwinski & Shook, 2007) describe the pull system as follows: “The next operation in the pull system conveys to the previous operation what material is requested, the amount required, and when and where it is needed through the Kanban card. Nothing is produced by the supplier until the customer specifies a need. It is clear from this that the best way to implement the pull system is the Kanban system. In this study, in order to minimize the amount of stock in the production area and to optimize the order quantities in the business, the drawing system from lean manufacturing techniques and therefore the Kanban systems were utilized.

The aim of this study is to calculate the optimal order quantity of the materials supplied for the television. Motherboards in an electronics factory, and also to arrange the Kanban shelves to minimize the amount of material waiting in the production area. In doing so, it will also be supported by Radio Frequency Identification (RFID) application, which is based on continuous radio frequencies and will provide follow-up to the physical locations of the materials. Within the context of the Industry 4.0 concept, the availability and traceability of materials are increased in production and used as an input of information that adds value in stock management systems, so that decision makers and project managers can be made faster decision making process.

LITERATURE REVIEW

Lean Manufacturing and Industry 4.0

Lean production involves a production system for the organization to learn continuously. The Toyota Production System (Womack & Jones, 2003) has its origins and means doing more with less. It is intended to reduce unnecessary steps and variations in the business process by eliminating wastes perceived as any action of non-value-added products or services. At the outset, it has been emphasized to remove wastes such as reprocessing, unnecessary processing steps, material or human movement, waiting time, extra inventory and defects that require over production. Today, product development covers the different aspects of production, starting from the first stage of the product life cycle to the stage of distribution from procurement to production.

When the application process of lean production is concerned, various frameworks are discussed. In general, the successful implementation of any management practice is often based on organizational characteristics. Most commonly, associated with lean manufacturing are: bottlenecking (production softening), cellular production, competitive benchmarking, continuous improvement programs, cross-functional workforce, cycle time reductions, focused factory production, just-in-time / continuous flow generation, lot size reduction, maintenance optimization, new process equipment / technology, planning and scheduling strategies, preventive maintenance, process capability measurement, traction system / Kanban, quality management programs, rapid change techniques, reproduction process, safety improvement programs, self-directed working teams, total quality management (Shah & Ward, 2002).

Industry 4.0 is the fourth industry revolution to implement cyber-physical systems (CPS), technologies for the internet and the future, and intelligent systems that promote human-machine interaction paradigms. This provides identity and communication for every asset in the value stream and leads to massive personalization in IT-enabled production (Lasi, Fettke, Kemper, Feld, & Hoffmann, 2014). The term first started in the Hanover Fair in 2011, followed by the establishment of a working group led by Siegfried Dais (Robert Bosch GmbH) and Henning Kagermann (Acatech) (Kagermann, Helbig, Hellinger, & Wahlster, 2013). The internet of things and services allows the entire plant to create an intelligent environment. Digitally developed intelligent machines, warehouse systems and production facilities enable integration based on end-to-end information and communication systems throughout the supply chain from incoming logistics to production, marketing, outbound logistics and service. Industry 4.0 also enables better co-operation between employees and business partners.

Although there is great interest in the concept of Industry 4.0 worldwide, no one is officially recognized for it. Integration of complex physical machines and devices with networked sensors and software for the prediction, control and planning of better business and social outcomes (Industrial Internet Consortium, 2016) or “a new value chain organization and management throughout the life cycle of products” (Kagermann & Helbig, 2016), or value chain organization can be considered as a common term for technologies and concepts (Hermann, Pentek, & Otto, 2016). For this reason, the Industry 4.0 concept can be perceived as a strategy to be competitive in the future.

The integration of both lean manufacturing and Industry 4.0 areas are an important research area to be explored extensively. With the advent of integrated production with computers, there has been speculation that factories of the future will function autonomously without the necessity of human operators. In the mid-eighties, during the Kanban period, Scheer et al. stated that individual stations demanded material from the upper production unit in case of a minimum standard reduction, and Kanban expressed that the process can work both manually and computer-assisted (Sheer, Mattheis, & Steinmann, 1987). Proving that such a statement is not feasible in a practical scenario, it has led to the concept of lean automation in which robotic and automation technologies are used to achieve lean production. Toyota Production System (Ohno, 1988) is based on two columns, just in time and autonomously. Autonomy refers to automating processes to include manual processes; when a problem arises, the equipment should automatically stop and allow errors to travel along the line. When only one defect is detected, human intervention is necessary. For this reason, automation in production has been played an important role since the beginning of lean production, and Industry 4.0 can be considered as progress on this field.

Hermann et al. (Hermann, Pentek, & Otto, 2015) identified four key components of industry 4.0. These key components are as follows:

Cyber-Physical Systems (CPS)

Industry 4.0 is characterized by an unprecedented link called the cyber-physical systems (CPS), the database maintained and updated by the internet or the participants, which can be thought of as systems that bring together the physical and virtual worlds (Akanmu & Anumba, 2015). In addition, cyber-physical systems are the integration of computation with physical processes. Embedded computers and networks monitor and control physical processes. This monitoring and control usually performs feedback cycles that the physical processes affect the calculations, and vice versa (Lee, 2008). In the production context, this means that information about the physical workshop and the virtual computing area is synchronized at high speed (Lee, Bagheri, & Kao, 2015).

Internet of Things (IOT)

The Internet of things has become popular in the first decade of the 21st century and can be seen as an initiator of Industry 4.0 (Kagermann, Wahlster, & Helbig, 2013). Nolin and Olson (Nolin & Olson, 2016) explained that IOT envisions a society in which all members can access a full-fledged Internet environment that is self-organizing, self-managing, intelligent technology, and always and everywhere.

Internet of Services (IOS)

There are strong indications that services are made easily accessible via web technologies, and that a service network (IoS) based on an ideology has emerged that enables companies and private users to bring together, create and deliver new services (Wahlster, Grallert, Wess, Friedrich, & Widenka, 2014; Andersson & Mattsson, 2015). It can be assumed that Internet-based marketplaces will play an important role in future industries (Hofmann & Rüsch, 2017). From a technological point of view, concepts such as service architecture (SOA), software as a service (SaaS) or business process outsourcing (BPO) are closely tied to IOS, Barros and Oberle (Barros & Oberle, 2012), which suggests a broader definition of the term service. “A commercial transaction, in which a party has temporary access to the resources of another party to perform a prescribed function and a related benefit.

Smart Factory

People, machines and resources communicate with each other as if they are in a social network with each other. In a smart factory, products find their way independently of production processes and are always easily identifiable and discoverable. This follows a cost-effective but highly flexible and individualized mass production idea. Spath et al. (Spath, et al., 2018) have pointed out that employees are expected to take more responsibility, act against decision makers, and monitor their duties, rather than driving forklifts, for example. In the same context, some critics note that the automatic and self-regulating nature of intelligent fabrication can lead to serious job demolition. However, almost no reliable study supports this fear (Hofmann & Rüsch, 2017).

Lean Automation

Lean Automation introduces the idea of combining automation technology with Lean Manufacturing (Kolberg & Zuhlke, 2015). The term emerged in the mid-1990s shortly after the Computer Integrated Manufacturing (CIM) summit (Groebel, 1993; Schling, 1994). While science has not shown much interest in Lean Automation in the last decade, there are new solutions within Industry 4.0 that combine automation technology with Lean Manufacturing, described below.

The digitization of the Kanban system has been known for several years. Traditional, physical cards for order-based production control are replaced by virtual Kanban (Lage Junior & Filho, 2010). Depending on the application called e- Kanban system, missing or empty boxes are automatically recognized by the sensors. The e- Kanban system sends a virtual Kanban to trigger the charge. Using Information and Communication Technology (ICT), the lost Kanban no longer causes a defect in production control, as long as the inventory in the production application matches the actual inventory. In addition, it is easily possible to adjust the Kanban depending on batch size, process or cycle time changes (Dickmann, 2007).

In 2013, Würth Industrie Services GmbH & Co. KG. KG has introduced the optical ordering system (iBin) for Kanban boxes (see Fig. 1). A camera in the mode detects the charge level of the panel and the iBIN reports the status wirelessly to an inventory control system. In addition, iBin can automatically send orders to suppliers. As a result, buffer stock can be reduced and spare parts can be programmed to order (Würth Industrie Service, 2017).

METHODOLOGY

The reels brought to the Kanban shelves from the warehouse are renewed every two days. The reason for this is that the operator does not want to keep only a certain amount of stock in the warehouse in the production area. At the same time, the fact that material diversity is too high also increases the workload of the warehouse. After analyzing the causes of the problem with the fishbone diagram, the most stock producing materials were selected in the production. Pareto analysis method was used in the selection of these materials.

Firstly, 72 pieces of material with the most stock information and most used in production were taken from the operation in which the study was carried out. The cumulative totals of stock quantities and percentage ratios of these stocks are calculated by listing the stock amount information for each material code and material.

In order to analyze and solve the problem it is important to be able to see the current situation in operation and to create a future situation by looking at this current situation. For this purpose, the current state of the stock quantities in the production area and the desired future state are drawn by the value stream mapping method. Value Stream Mapping (VSM) is a basic tool for describing how we can use various lean techniques by analyzing all the processes that the system we are working on, adding value, or not adding value.

Figure 1. Inside the box iBin system
(Adapted from [Würth Industrie Service, 2017])

After investigating the cause of the problem, the production stocks were analyzed by Pareto analysis and value stream mapping (VSM), and then the existing Kanban system in operation was examined and a calculation of the Kanban mentioned in the application chapter was carried out. This was found to be insufficient for the calculation of the Kanban system and material order quantities, so a mathematical model was developed for the optimization of material order quantities. The aim of this mathematical model is to improve the operation of the system by determining optimum material order quantities. The model was created and run in Lingo 9.0. The generated model is a very targeted model and the aim and scoring method is used to find the weights of the targets in the model. The analytic hierarchy process (AHP) method was considered primarily for these weights, but the scoring method was used because this method is not suitable for two targeted problems. The results of the mathematical model were tested in the ARENA system simulation program and the results were interpreted. After all the results have been found, some suggestions have been made to the operation such as RFID application under Industry 4.0.

APPLICATION

System Definition

The problem addressed in this study is to minimize the waste of material in the production area of an electronics factory. It occupies an area of 1 million square meters with 16 thousand employees. Companies engaged production in Turkey and is a large-scale company with shares in foreign markets both in the domestic market. The factory offers products in consumer electronics, white goods, digital products, information technology, LED lighting and defence fields. The factory has a production capacity of 87 thousand products per day and the production numbers change seasonally. In the high season of production, television production is up to 1 million adjectives and these products are exported to 54 European countries as well as the domestic market.

The problem addressed is on the production lines of the television motherboards of the plant, which are also found in the electronics factory. In this factory, motherboard and power cards are produced. These cards vary according to the final product and differ according to different models in the same product group. So the diversity on the cards is quite high. Motherboard and power card productions are the process of placing necessary components on the electronic card. Figure 2 shows the motherboard production scheme.

SMD Materials (Surface Mount Technology) and Set Operation

Surface Mount Technology (SMT) is a production method where the elements placed on the printed circuit board are soldered directly on the surface. SMD materials (Surface Mount Device) are materials used in surface mounting technology and are very small in size (see Fig. 3). This is why it is not possible to produce with perforated PCB technology (see Fig. 4). The most common SMD materials used in printed circuit boards; resistors, capacitors, coils, fuses, diodes, BJT transistors, MOSFETs and integrated circuits. The dimensions of the materials can range from 0.4 mm x 0.2 mm to 4.5 mm x 3.2 mm.

Problem Definition

The SMD materials used in the production of TV motherboard card are supplied in the form of reels as described in the previous section and are processed by attaching them to the SMD type machines in the line. The amount of product required for certain periods in TV motherboard card production is provided by dispatching to the warehouse production area. Despite the fact that the products shipped are in the form of reels, the material requirement information from the production to the warehouse is in the form of total material number. In this case, the number of reels for which a production is shipped does not take place within the knowledge or need of production.

The problem addressed in this context is that the material stocks in the production area are out of control of the company. The inability to control the production stocks causes the excess material dispatched from the warehouse to be lost for the failure of production. The lack of systematic movement of production stocks causes the supply engineer who manages the material to be unable to access the actual

Figure 2. Motherboard Card Production Flowchart

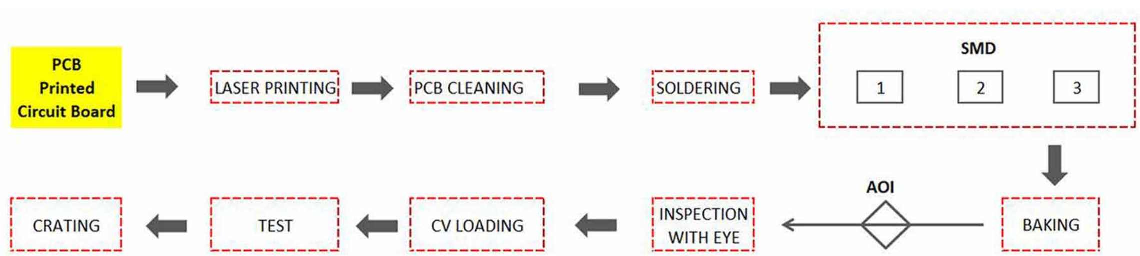


Figure 3. Kanban reels for SMD (Surface Mount Device) materials
(Adapted from [Mini-Circuits, 2018])

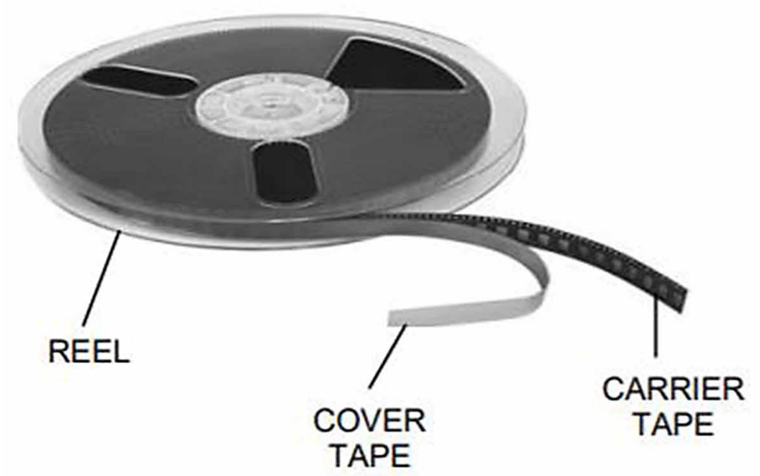
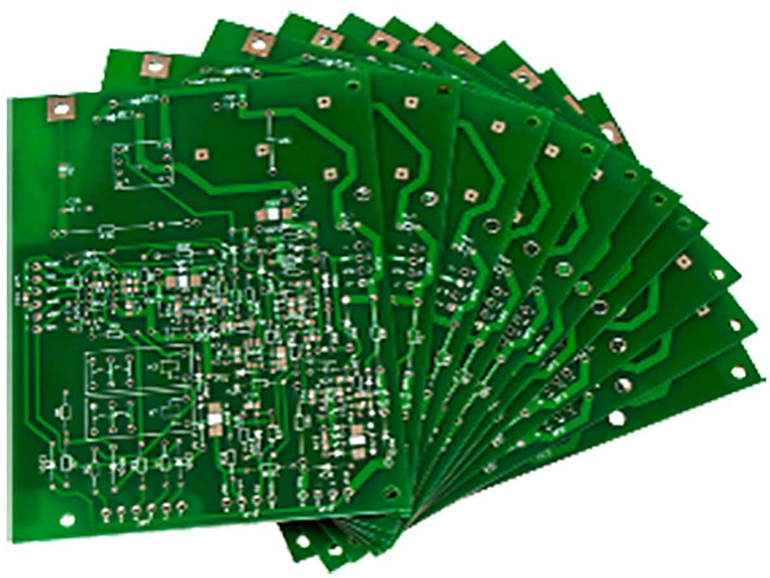


Figure 4. PCB (Printed Circuit Boards) materials
(Adapted from [Chen P., 2018])

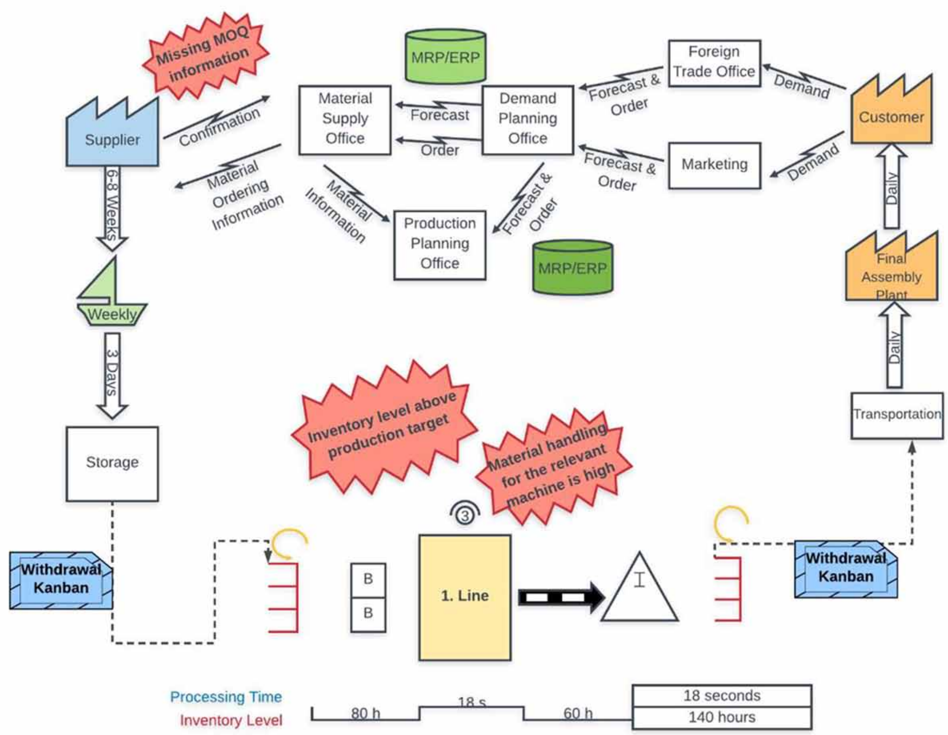


information about the material and cause the material to be short on the reels. As a result, the problem can be summarized as the production stocks are unnecessarily large and often the amount of material in the production cannot reach the production rate.

The main purpose of the problem is to reduce the amount of stock in the production environment. Factors related to the materials on the Kanban shelves or on the line are caused by the excessive amount of stock in production. Therefore, in the solution phase of the problem, the materials to be worked on were first selected. Pareto analysis method was used when material selection was made. 72 different materials were analyzed to select materials by Pareto analysis. All of the materials analyzed are SMD materials used in surface mounting technology.

Value stream mapping (VSM) is a lean manufacturing technique for analyzing how the desired production process works. Through this technique, all processes that add value or not add value are revealed. In addition, possible benefits such as lower production times and lower inventory levels can be clearly seen and are useful for detailed comparison of "before" and "next" scenarios. According to the value flow in Figure 5, Demand Planning Unit on Demand Forecasting and Orders from Foreign Trade and Marketing units informs production planning and procurement teams via ERP software and through SAP for business use and more generally for product groups. Upon this information, about 4 months of MRP horizon about how much of each item is needed in the system in terms of procurement crews seen. Procurement teams also make decisions such as opening orders, pulling forward orders, or moving forward according to this situation. The orders placed are based on the total needs, and the dimensions of the reels are ignored at this stage. During the creation or verification of the order information, the supplier does not receive material related any reel size information of reels, and therefore the order quantities are determined without using this information. The materials are brought from the supplier at a very long supply period of 6 to 8 weeks, usually by ship. If the material must arrive very urgently, and if the weight is appropriate, it is supplied by air, and if it is from Europe, it is supplied by road. The material arriving at the business warehouse enters the electronics factory after a 3-day customs and quality approval process. According to necessity, materials are withdrawn and placed on the Kanban shelves of the booth next to the production lines.

Figure 5. Current Situation Value Stream Mapping



The TV motherboards from the production line are sent to the final assembly plant with an inventory level of at least 60 hours. The final product, televisions, which comes out from the production line is distributed to the customers. The reason for this high level of inventory is that it is produced in two separate factories and that the final assembly is the customer and the electronics factory is the supplier. It is important to maintain this level of inventory so that any incompatibility between plants does not affect production at the final assembly plant.

In Figure 6, some improvements are made on the existing system without any changes to the processes in the future state value stream. First of all, during the order confirmation, the reel dimensions will be learned from the suppliers so that the material ordering process is more effective. In this way, it will be determined as order opening parameter in the used SAP system. The amount of the Kanban will be revised so that the production inventory level is reduced and no incompleteness occurs at the material feeding points on the machine. In this case, the 40-hour production inventory level will be the target stock life span. This will ensure that there is no more material in production. Improvements and situations in the Kanban system are explained in detail in the following section.

Improvement of Kanban System

At the establishment where the production of TV cards is made in operation, there is a shelf of Kanban at the beginning of each assembly line (see Fig. 7). The materials needed for TV card production are supplied as reels. On the Kanban shelves, the necessary reels are provided for production from the warehouse. These shelves ensure that operators working in production can easily reach the reels. Each Kanban shelf has an informative card on it. On this card, which material reel is in the box, the size of the reel, the supplier company and so on information exist.

Figure 6. Future Situation Value Stream Mapping

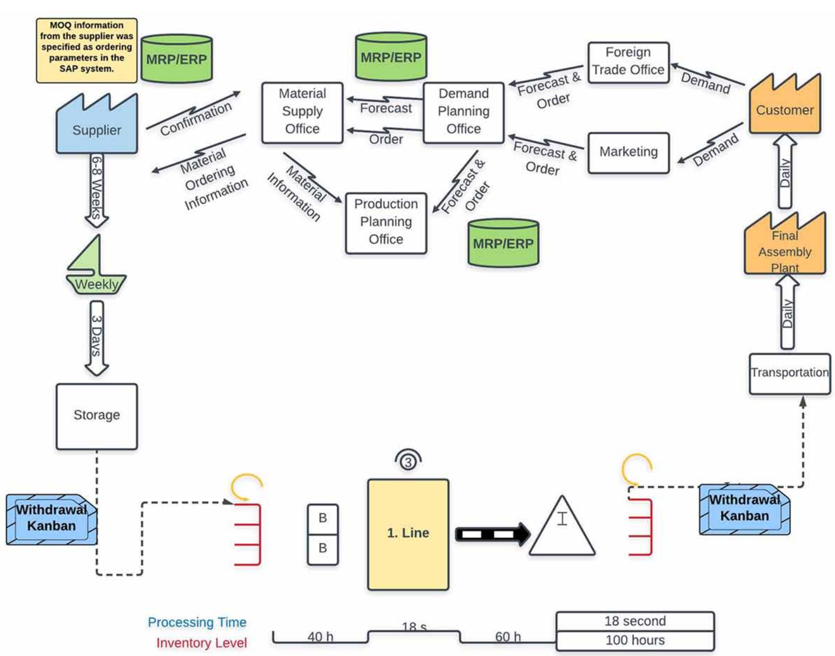
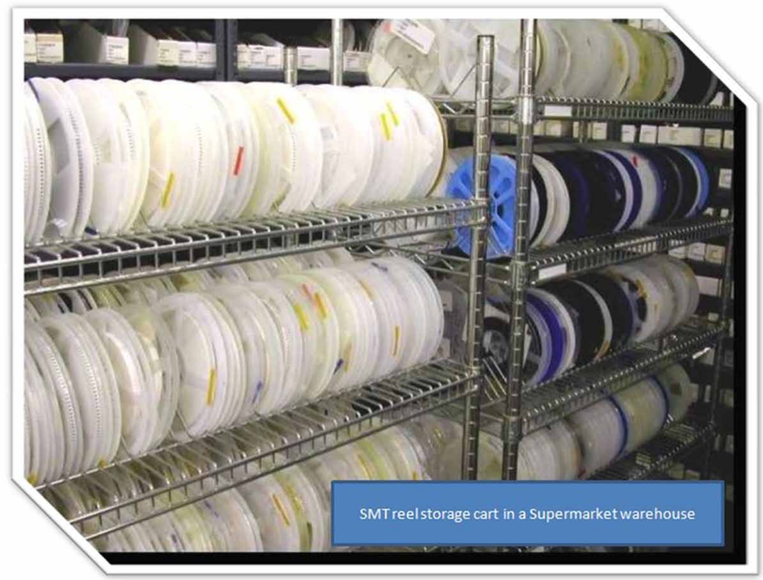


Figure 7. Kanban shelves
(Adapted from [Ferenc, 2018])



In addition, the number of positions that must be inserted in each line, and a unit of finished product, ie the amount of usage per motherboard card, and the amount of production information per hourly card that on line have been given. At the same time it is seen that there are 50.000 pieces of material in a reel. Based on this information, 40 hours of material on the lines are needed, assuming a 40 hour run time and a 1% waste rate.

The amount of the material of this material was found as follows:

$$Kanban\ Quantity = Daily\ need * Stock\ lifetime \tag{1}$$

There are two situations encountered in production. This shown through the 300448484 code material. The stock of each material found in the Kanban shelves are kept in operation 40 hours in the production area. This material was taken for the 40 hours holding lifetime, the needs and the ideal amounts of Kanban quantity were calculated. The need of the material and the size of the reel in the current situation according to equation 1;

number of positions in the line = 23 pieces

amount of the daily material requirement in 40 hours = 395.920 pieces

piece of material in a Kanban reel = 50.000

material requirement is in the field of production = (23 x 50000) – 395920 = 754080 pieces amounts of Kanban reel = 395920 / 50000 = 7,92 $\cong$ .8 pieces

The first line must have 8 reels. Since 15 positions are empty because the number of positions in the line is 23. Therefore, the operator has to fill the empty positions by dividing the rollers in his hand. This leads to a risk of quality problems in the material as well as to the loss of shredding. The number of materials more than the need for production is 4080 pieces. Another encountered situation is the number of reels taken from the warehouse according to the number of positions in the line and the size of the reel; on the first line, 23 reels have been pulled from the warehouse. However, this time the material requirement is in the field of production even though it is not 754080 pieces. To talk about the risks of this situation; it can be seen that the materials in production are systematically only in the field of production. However, it is not possible to see on shelf is available. In the meantime, material can not be seen on which machine it is. In addition, if a model change is made in the production line at this same time. This material can not be used in the model to be installed, the material is sent to the area called the setup area. This area is the area where many reels have been used with many unfinished materials. In this case, the material in the area is observed by the engineer who manages the material, but material losses are encountered because it is very difficult to find reels in the very large production area.

There are material types encountered in both cases, but as mentioned, there are risks in both cases, and the problem is that the materials actually come in reels and that the dimensions of the reels do not match the material usage information in production. For this reason, the Kanban system created with the same reel dimensions will bring the same problems again. In the following section, a mathematical model has been developed with the dimensions of the reels being determined according to the current production constraints and the targeted performances, and the results are discussed.

The established model has two aims. The first is to minimize the inventory of the production area by preventing the production from taking more than 40 hours of material from the warehouse; and the second is to minimize the change of reel at the material feed points of the machines within a period of 40 hours.

The number of reels shipped to the lines is often equal to the number of positions previously mentioned. It is necessary to renew the reels feed points 6 and 7 in the lines.

In a Kanban calculated according to necessity, it causes confusion in production because the position restriction is not observed. For this reason, the number of reels fed to the lines in the new case amounts to at least the number of positions on the machine. At the same time, with the current reel dimensions all positions would be transported to the production area where too much material was not needed. Therefore, a mathematical model has been written which can accommodate the two objective functions and offer different solutions according to the weights given to the goals. Previously, in order to avoid missing positions, the number of materials shipped was 26,677,708 pieces, while the number of materials shipped to meet their needs was 3,337,708 pieces. However, in this case, since 498 positions were empty without reels, the continuity of production was not achieved. According to the obtained results from the mathematical model, 9,394,708 pieces of material are produced without any position being rolled and all needs are met. According to the obtained results in this study, a 65% improvement in production stocks has been achieved.

The mathematical model assumes that the materials have equal consumption rates from the feed points of the machines. But this can change in real life, and the reels on the same machine can be done at different times. This is because the amount of use per unit of material is not the same in more than one position that requires the same type of material on the sorting machine. The mathematical model was developed under the assumption that the amount of material used per unit of machine is constant. In order to incorporate this variability into the system and to test the results obtained from the mathematical model, the ARENA system simulation program results were interpreted.

DISCUSSION AND PROPOSAL

The inability to measure the speed of use of the materials still brings with it shortcomings for the system. Although the results from the created model improve the current situation, different technologies should be included in this system for sustainability. The following suggestions have been made to the company since the follow-up of the materials is the critical point in this system.

Real Time Inventory Support of Machines

Therefore, another system recommend to the company is to include intelligent machines in the processes.

Figure 8 shows the adaptation of intelligent machines to the system and the operation of the Kanban system. When you enter the PCB sorting machine, the machine collects the data on how much material is being spent. These data are transferred to the warehouse via internet connections and necessary materials are prepared in the warehouse. The warehouse can be seen from the data that the shelves of the Kanban are empty and how much material is taken. In the interest of this information, the warehouse supplies the necessary materials for the production area. Thus, the materials are taken to the relevant area when necessary and at the required amount. Another advantage of this system is that the materials used in production that are recorded simultaneously and more systematic monitoring of how much material goes and also how much is going to be made. In this case, the actual inventory level will also be reflected to the inventory level in the system simultaneously.

Material Tracking With RFID

2.7 million reels are moving in the production area per year and the size of materials are very small compared to the production area. Therefore, it is very important to follow the physical as well as the numerical follow-up of the materials. Production areas and warehouses have different characteristics.

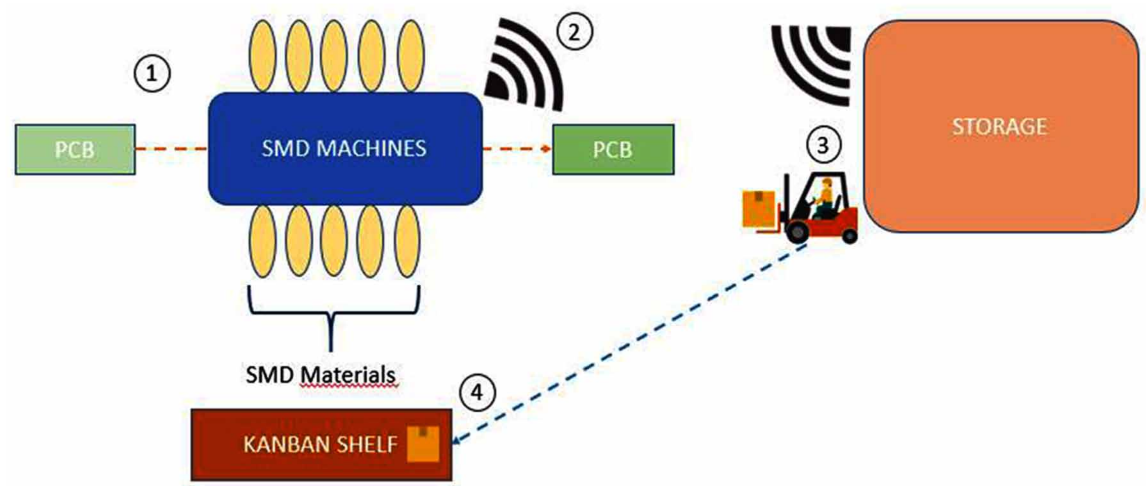
In the warehouses;

- Inventories are provided with addressable and individual location,
- Stock movements are barcoded and systematic,
- Single location discipline of single material.
- There is a regular counting possibility,
- The main purpose is inventory accuracy,
- There is no movement outside the system,
- Stock addresses represent that there is no movement outside the system -based and clear area.

On the other hand, in production areas;

- A wide range of unallocated and non-locally distribution of materials is realized,
- Systematic changes are available,

Figure 8. Movement of materials to the Kanban with intelligent machine



- Loss of material in a large area,
- There is a difficulty in recognizing materials other than label reading,
- Unplanned losses exist.

When these characteristics are taken into consideration, the safety of the materials is not provided in the field of production, and as a solution, so it can be suggested that to follow up the materials physically with RFID (Radio Frequency Identification) system.

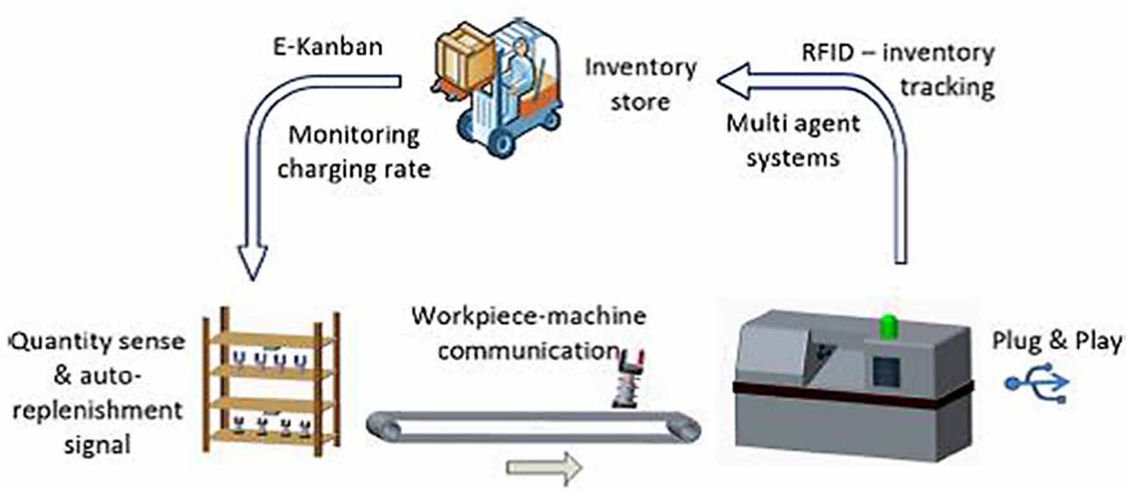
The performance measures of both cases were compared and the results evaluated. Due to the shortage of material following the next step of the problem, the company has been recommended to apply RFID and the methods that can be adapted to the company by investigating the subject have been determined. As it is well known, with the creation of the Industry 4.0 concept, companies, and R&D departments are working to integrate many related systems into their structures. It is planned to be supported by the Radio Frequency Identification (RFID) application, which is based on the radio frequency of the improved process and which will follow the physical locations of the materials (see Fig. 9) (Sanders et al. 2016). Thus, the availability and traceability of the materials within the production can be increased and used as an information input which adds value to the stock management systems. The calculations and improvements are made according to the current data of the system but the production quantities are constantly changing according to demand forecasts and customer orders. Therefore, the ideal reel dimensions and the amount of the Kanban of the changing materials also vary. With the project management approach, all the critical information needed to manage materials, such as the materials themselves, production processes and stock information, has been clearly updated to keep the entire process under control and create a “Plan for Every Parts” file for the sustainability of the work done. Thus, the procurement engineer will manage all the parameters affecting the supply forms, production processes and warehouse methods of all materials from this single database. Any changes in the process will be reflected in this database and the improved process will continue to exist under all variabilities.

CONCLUSION

Inventory management is a factor that must be taken into account in all stages of production and supply. Inventories constitute a large part of the costs when operating. At the same time, holding too much inventory may cause wastes, and having fewer stocks in hand can also cause the level of customer service that can not be met. Inventory management becomes a more important process when it is thought that waste and customer satisfaction are also important in terms of lean production systems.

In this study, an analysis of the stocking system and stock amount which constitutes a big problem in the operation has been made and problem oriented solution model was created. With the solution model, the optimum order quantities required for the material are found for the operation of the electronics company. In production, the shelves of the Kanban which constitute the pull system were created. With these solutions produced, the amount of stock in the production area has been reduced. In addition, inability to follow the items that are still considered problematic and a number of suggestions were made to the firm for the sustainability of the provided Kanban application. One of them is intelligent machine technology to provide real time inventory support for machines, and another is to integrate RFID (Radio Frequency Identification) system technology into the factory because of the physical nature of the materials and many other advantages. In this way, it is ensured that the systematic movements of materials are continuously monitored physically, making sure that they are correct. At the same time, all units will be able to perform material follow-up with real-time information transfer. Transferring the amount of material and usage information to the project managers will also help to establish the projects on real data. Competition in the international market is very high. Simplify production namely lean production for such a market will make a profit for the company. This context is directly proportional to the quality of information transfer to reduce the cost of keeping the unnecessary stocks together with the cost and quality of materials which directly affects the quality of the product. The higher the reliability of the data, the healthier decisions will be made at the supply point.

Figure 9. Radio Frequency Identification (RFID) technology application related to KANBAN System within Industry4.0
(Adapted from [Sanders, Elangeswaran, & Wulfsberg, 2016]).



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Chapter 12
The Project Management of Industry 4.0 Strategy for Software Houses

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ABSTRACT

Nowadays, Industry 4.0 is becoming a strategic issue for software companies. Because of fast digital conversion, they should review their visions and strategies. In this study, a project management framework is proposed for software companies considering Industry 4.0 as a future strategy. Global ERP firms try to find a good integration of ERP and Industry 4.0 applications. A global ERP firm's solution partner is used as a case study in this chapter. The study includes: the development of an internet-based portal application that integrates all their business partners (customers, suppliers); a collaborative project management software; and an industry 4.0 portal. The benefits of this study after applying in the software house are explained.

INTRODUCTION

Software companies, including global ERP firms' solution partners, must be involved in industry 4.0 applications, because in the near future their customers will ask industry 4.0 applications. If they do not satisfy their customers about industry 4.0, they will lose some of their customers. Therefore industry 4.0 strategy is vital for them. On the other hand, industry 4.0 software companies need information gathered from ERP systems. It is very important to manage industry 4.0 projects collaboratively for successful customer industry 4.0 applications of software houses.

Industry 4.0 is an important strategy not only manufacturing companies but also software houses. According to a study, German companies from different sectors are expected to invest 650 million Euros into Industry 4.0- related technologies and applications in 2015. (Bitkom, 2015). But Erol et al. (2016) state that companies have substantial problems to grasp the idea of Industry 4.0 and relate it to their specific domain.

DOI: 10.4018/978-1-5225-7865-9.ch012

Lot sizes are getting smaller. Therefore, a greater level of customization for manufacturing companies is necessary. The customers push the ERP software vendors beyond classical ERP. Industry 4.0 solutions can integrate agile supply chains both vertically and horizontally. The manufacturing companies need to be smarter and agile.

The rest of the paper is organized as follows: Literature review is explained in the next section.

How to manage industry 4.0 strategy for software houses section explains the proposed framework. In the case study section, the proposed methodology is detailed. Further research directions are discussed into Future Research Directions section and results are evaluated in Conclusion Section.

BACKGROUND

There is no scientific research regarding a software house's industry 4.0 strategy.

IT solution providers are developing internet-based applications to enable integration with their external counterparts. With the development of cloud technology, the solutions offered in the internet environment become unlimited. When examining existing solutions, there are some specialized applications such as CRM, B2B.

Oztemel and Gursev (2018) reviewed the industry 4.0 related technologies in literature. They explain some leading countries' investments and activities. For example, China spent approximately $200 billion on research and development, the second-largest investment by any country. (McKinsey, 2017). France, the second biggest economy of European Union, started "New Industrial France" initiative in 2013 to be an innovation leader country and to push the technological frontier to create the products and the uses of tomorrow (DEF., 2016). United States, Japan, Germany, (the origin of Industry 4.0 concept, Kagermann 2013), South Korea are aware of Industry 4.0 and start similar projects. In Turkey, TUBITAK (Turkish Science and Technology Research Council) funds the original and value-added industry 4.0 projects.

Moghaddam and Nof (2017) stated a collaborative control theory to provide a framework of the collaborative factory of the future. Wollschlaeger et al. (2017) studied the impact of IoT (Internet of Things) and CPSs (Cyber-Physical System) on industrial automation from an industry 4.0 perspective, used a survey of the current state of work on Ethernet time-sensitive networking (TSN), and shed light on the role of fifth-generation (5G) telecom networks in automation. Preuveneers and Ilie-Zudor prepared a survey and had an analysis of emerging trends, research challenges and opportunities in Industry 4.0.

Ellialtioglu and Bolat (2009) proposed a conceptual framework for building supply chain strategies to meet marketplace requirements and to give an insight into the managers of supply chains.

The Agile methodology was explained with Agile Manifesto in 2001. (Larson & Chang, 2016)

Kaur and Singh (2016) reviewed critical success factors in agile software development projects in India. Whitney & Daniels (2013) study the primary causes of IT project management failure and complexity. Khalid analyzed the application issues of SME' cloud computing.

Schumacher et al. (2016) define a maturity model for assessing industry 4.0 readiness and maturity of manufacturing enterprises. The first group of dimensions "Products", "Customers", "Operations" and "Technology" are formed to assess the basic enablers. In addition, the other groups of dimensions "Strategy", "Leadership", Governance, "Culture" and "People" allow for including organizational aspects into the assessment.

Erol et al. (2016) proposed a 3-stage model for the transformation of industry 4.0 in manufacturing firms. The first stage is "envision." The involvement of top management and commitment is approved and shared with the employees in this envision stage. The external experts explain the industry 4.0 and the importance of doing it in a collaborative way. The second stage is "enable." The roadmapping of industry 4.0 is prepared in the enable stage. The roadmapping is prepared for short-term, mid-term and long-term. Internal and external success factors are identified. They used 4 perspectives; market, product, process, and value network.

The last stage is "enact" stage. The preparation of transformation is done in this stage. The proposals of Industry 4.0 projects are formed again in this stage. The output of the stage is roadmaps for every project.

Chesbrough (2006) proposes a practical definition of business models and offers a Business Model Framework (BMF) that illuminates the opportunities for business model innovation.

Albers et al. (2016) study spring coiling production process and prepare a procedure with value-added partners, for intelligent condition monitoring quality control system. The intelligent quality control system focuses on the initial phase of an industry 4.0 project.

HOW TO MANAGE INDUSTRY 4.0 STRATEGY FOR SOFTWARE HOUSES

A vision defines the future directions of the companies and a strategy explains the roadmap. Nowadays, software companies need to include industry 4.0 strategy for sustainable growth and to achieve their vision.

A vision of software house should be prepared by involving employees. In addition, it should be shared with all employees. A SWOT Analysis is very useful to focus and define strategies. Strategy maps are very useful to find out KPI's (Key Performance Indicators) for industry 4.0 strategy. After defining industry 4.0 strategy, the software house should start strategic project(s).

Industry 4.0 contains many concepts and expertise such as cloud computing, cyber physical systems, internet of things, big data, etc. Therefore, it is very difficult for a software company to serve its customer with all types of components of industry 4.0. It may outsource different services (including some software) and various hardware components. The software company can provide the other services.

How the project management framework of Industry 4.0 Strategy for software houses is managed is demonstrated in Figure 1.

Define Vision and Share It

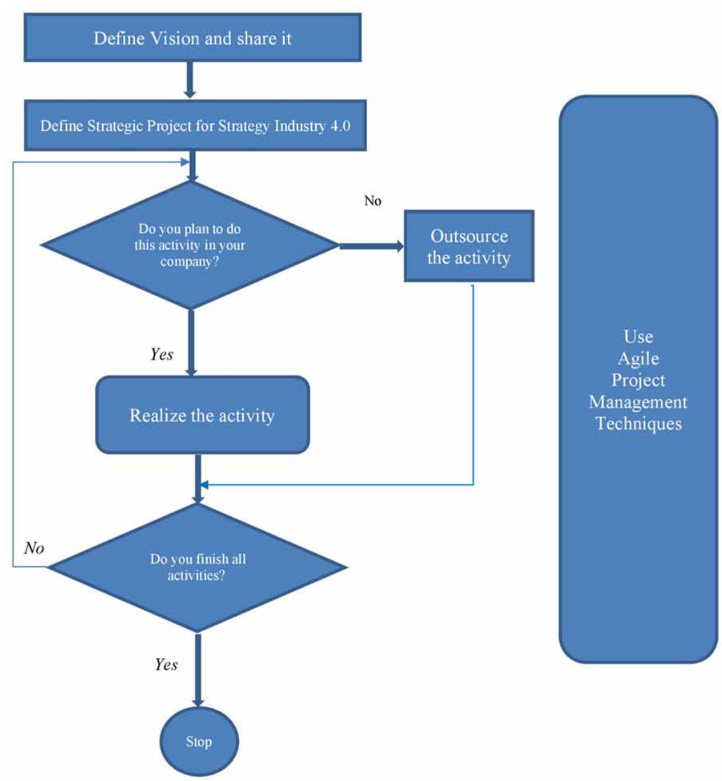
First, the software house should define its vision. Because it shows the focused target and it may affect almost every activity of the firm in the future. The vision should be both difficult to achieve and realistically accomplishable.

The vision should be shared with the employees and explained to them clearly. If the employees are involved in the stage of defining the vision, their motivation will be increased and there will be a synergy.

Define Strategic Project for Strategy Industry 4.0

One of the strategies of a software house is to be an industry 4.0 supplier for present and potential customers.

Figure 1. The project management framework of Industry 4.0 Strategy for software houses



Then, the company should select proper strategic projects according to the conditions of customers and its own realities and starts by using agile project management techniques for this strategy. Industry 4.0 strategy may change frequently, because it has been getting new concepts and technologies. Companies may give up even some technologies.

Make or Buy Decision

Since industry 4.0 includes dozens of applications, a software-house needs to determine which applications to be developed and which applications to be outsourced according to its strategy and constraints. These constraints can be human resources qualifications, capital, financial advantages, other areas to be focused on etc.

If the company is a solution-partner of a global ERP firm, it can use industry 4.0 portal and other solution partners such as cyber-physical-system expert firms. It is easier to decide on make or buy decisions after a cost-benefit analysis. However, the firm should not outsource its confidential or critical processes and products.

A cost-benefit analysis may be required to make or buy decision. The analysis is used for estimating the strengths and weaknesses of alternatives. A common unit of measurement should be defined in order to reach a conclusion.

Realizations of the Activities

Activities are managed according to the agile project management techniques.

Because of fast changes in these technologies, the company should be aware of and prepare action plans according to different scenarios.

The process ends after all activities are finished.

CASE STUDY

Different software houses are visited for this study. MBIS Software Company is selected for this case study, because:

- It is SAP's first "Gold Partner" in Turkey.
- It has implemented 500 projects in 350 companies from various industries such as automotive, mining, food, machinery manufacturing, metal, pharmaceutical, chemical, health care, cement.
- The company has ISO 9001 Quality and ISO 27001 Information Security system certificates.
- The firm has applied many solutions, especially SAP solutions in hundreds of domestic and international companies from all industries and from all sizes.
- It has a large industry-specific expertise obtained from projects that were implemented in various industries.
- It offers process design, end-to-end information systems design, industry 4.0 project consulting, hardware, and infrastructure services to customers wishing to have a digital transformation.

With the SAP S / 4 HANA system, the SAP solution family, which comes in a different dimension, forms the backbone of a transformation story from the ground up with Hybris, Leonardo (industry 4.0 platform of SAP) and the SAP Cloud Platform.

Define Vision and Share It

The vision of the MBIS is, "To be the first SAP solution partner of the customers in Turkey, in neighbor countries and in South East Europe."

The vision is explained to the employees and shared by top management.

Define Strategic Project for Strategy Industry 4.0

The project is selected according to the total number of employees, distribution of employees, their competency, their expertise. After a feasibility study, the project is selected.

The selected strategic project is:

- First, an agile project management software development both their own use and customers' use. It is called Jimarin,
- Applications called Wega Port consisting of Customer Web Gate and Supplier Web Gate.

Make or Buy Decision

The company selects a solution partner, which is an expert about cyber-physical-systems for manufacturing applications. The company realizes other activities, itself.

Realizations of the Activities

Jimarin project is finished. Jimarin (www.mbis.com.tr/en/products/mbis-jimarin-en):

You can follow your internal affairs with e-mail systems of your company through the Jimarin Management Portal. In the same way, you can follow up your projects or investments from Jimarin on a process-by-project basis. Because it is a cloud-based software, it does not put you at the cost of additional hardware. As you are connected to social media tools, Jimarin can be linked to the portal; Follow your work, assign tasks to your employees, and organize your meetings. Jimarin is a management instrument at your elbow from every medium you visit. With Jimarin's staff, you can analyze their performance according to the resolution period of your tasks so that you can see the places that are in trouble more easily. With the advanced dashboard structure, you can see the vital values from the admin console more easily with graphs, and this structure also allows you to customize with detailed reports. Instead of losing time in your electronic mail for your company, employees and departments in different folders you create in your e-mail box, you can organize your company into Jimarin and follow your work, assignments, and projects from one screen to another. Gymnastics helps you achieve immediate results with notifications.

Another project is Wega Port (Çetin et al., 2017):

When examining existing solutions, we see specialized applications such as CRM, B2B, SRM.

The companies that use these portals have great advantages in terms of cost and in terms of efficiency if they are combined in a single platform. Thus, both companies that use these systems get solutions at a reasonable cost and very fast, as well as allowing IT companies to develop new solutions for all users in a cloud environment.

There are areas of expertise in such solutions. For example, human resources, procurement, financial management, task follower.

This process leads to different solutions which are independent of each other on the internet. Companies are also using many portals and mobile apps at the end of the day. Another portal for suppliers, another portal for customers, employees, customs brokers, and other portals for transporters.

Considering the use of these ports is two-sided, it can be seen that there is actually an integration problem for the other side. For example, a company using a purchasing portal intends to build a portal of all its suppliers. But the purchase of the firm means the sale of the other company. However, the CRM system used by the supplier company is not integrated with this portal.

These needs have been taken into account when developing the WEGA product. This product enables all business needs to be met on one platform and integration with other cloud solutions.

The portal environment to be developed will have the ability to collect data from company systems and devices. In this way, for instance, the management of the transport operations with the data coming from the vehicles will be provided. Thus, WegaPort will include IoT functions.

WegaPort will be integrated with the SAP Leonardo IoT platform. The Portal application we are going to develop will have an advanced level of Industry 4.0 capabilities. In this way, data collected via WegaPort will be processed by machine learning, big data or predictive analytics tools.

Functional Components of WegaPort

Our product will include the following modules in the first place:

- Customer / Dealer Portal
- Supplier Portal
- Service Portal
- Forwarder Portal
- Customs Broker Portal

Generic Components of WegaPort

While our product creates all this portal environment, it will also present some basic features to all users.

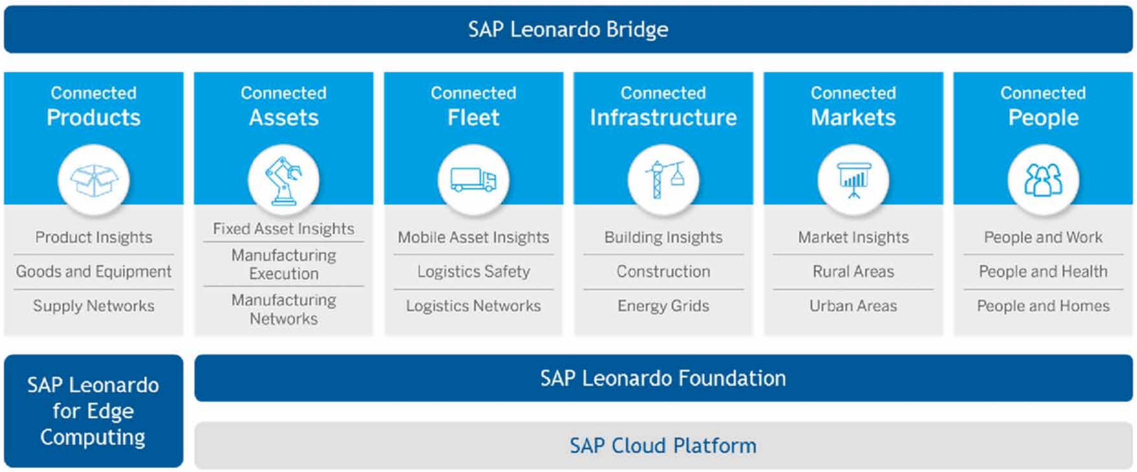
- **Notification Management Module:** Indicators produced in the system will be conveyed to the relevant person as a notification.
- **Instant Messaging:** Messaging between system users will be possible.
- **Questionnaire Module:** Surveys to business partners such as customers, vendors, forwarder will be managed by this module to improve business processes.
- **Audit Module:** Monitoring the interlocutors that the firm receives services from, in certain periods, loading and grading of evaluation results into the system, functions like follow-up of the work list will be managed with this module.
- **IoT Integration Module:** The data from the "things" will be transferred to the system via this module.
- **Business Intelligence Reporting Module:** The data in the system can be converted into business intelligence reports, which can be generated dynamically by the user.
- **Work flow Management Module:** The workflow module will be used in flows where the need for approval is required. Users will be able to define their own workflows.
- **Mobile Access Module:** IOS and Android-based mobile devices will be able to access and use the system.
- **Security Module:** The security module will be used to provide information security in the collaborative environment created.
- **SAP Leonardo Integration Module:** The data will be integrated with the SAP Leonardo solution for analysis and forecasting. This integration will be established by means of this module.

SAP Leonardo is a technological platform developed by SAP AG, the world's leading business solution provider, that connects objects and business processes. The structure of the platform is shown in Fig. 2.

SAP AG, managed to connect the business processes, MBIS will integrate the WegaPort platform to the IOT world with SAP Leonardo Platform.

The basic functions of the Leonardo Foundation are as follows and in Figure 2:

Figure 2. SAP Leonardo (https://blogs.sap.com/2017/07/14/sap-leonardo-live-2017-frankfurt)



- Supports all message protocols required for object linking
- Enables management of devices by taking security protocols into account
- Supports other technologies required by the IOT world (Data Streaming, UI, Geo-mapping, Predictive Analytics etc.)

DETAILS OF WEGA PORT

1. Customer Portal

Dealers, customers, sales staff will be able to create orders from users in the role. Tracking created orders includes the ability to track financial situations. The features of this module can be summarized as follows:

- Order Management Functions
- Credit and Risk Management Functions
- Delivery Tracking Functions
- Invoice Tracking Functions
- Business Intelligence Reports (Orders / Deliveries / Invoices / Financial Status)

The functions of the Customer Portal are detailed below:

a. Admin Functions

- User management
- Role-based authorization
- Site theme and ad area management
- System access log analysis
- Translation: The requested languages are entered into the dictionary to enable the system to work in other languages.

- SAP integration settings

b. Order Functions

- Product listing
- Order entry
- Create basket
- Copy order
- Create order from template
- Order list
- Order credit check
- Order payment
- Contract listing
- Creating orders from a contract
- Order confirmation

c. Delivery Functions

- Delivery list
- Delivery receipt confirmation

d. Billing Functions

- Invoice list
- Sales reports
- Payment: Direct payment by credit card

e. Reporting

- Current status reports
- Extract
- Open document listing (all FI documents such as check, collateral, etc.)
- Listing of accredited documents
- Inventory report
- Price report
- Sales performance report
- Sales staff, affiliated dealer performance report

f. Notification Management (Announcement / Warning)

- Automatically send mail to the user
- Order confirmation workflow
- Send a SMS to the user
- Customer complaints and suggestions entry

g. Document Management

- View product documentation
- Display contract documents
- Display delivery related documents (Quality certificates)

h. Survey Management

- Defining the survey
- Periodic survey repetition
- Analysis of the survey results

2. Supplier Portal

The role of the dealer / customer / salesperson in the role includes the ability to open orders, track orders, track financial situations. The features of this module can be summarized as follows:

- Order management functions
- Credit and risk management functions
- Delivery tracking and traceability functions
- Invoice tracking functions
- Business intelligence reporting

3. Service Portal

- Service request management
- Maintenance / service activity management
- Service costs follow

4. Forwarder Portal

- Through this portal, it is aimed to carry out the transactions of the companies or users involved in transportation operations.
- Freight forwarding planning functions
- Drivers' goods reception-transport-goods delivery functions
- Vehicle tracking functions

a. Shipping Service Process

The entry of loading request to the system: The upload request will be entered as a transport order in the system. Different methods will be used to create transport orders.

- Web service integration
- Mobile application for IOS and Android

- Manually via Portal
- **Loading Requests Planning:** The created loading requests will be optimized and transport documents will be created in the system.
- **Load-Driver Assignment: Load** requests will be assigned to driver and license plate. The driver will then be able to see the load assigned to him on the mobile phone application.
- **Accepting the Load:** The load will be accepted by the car driver with the mobile application. In the cellular phone, the work order related to the load request will be marked as received and the status in the system will be updated.
- **Delivery of The Load:** Load will be recorded in the system by taking a photograph at the moment of delivery to the buyer.

Coordinate information of the hand terminal will also be recorded in the system during freight delivery.

- **Vehicle Tracking:** The collection of the data from the vehicles will be integrated with SAP Leonardo platform. The following functions will be used on this platform:
- Vehicle location tracking and traceability for nonconformities
- Automatically calculating the arrival time of the load and informing the receiver
- Automatic alarm generation according to predefined warning points by the users according to the data taken from the vehicle

b. Portal Functions

The portal will be designed for manufacturers. This portal will have the following functions:

- Create goods order
- Automatic Load order creation service (for creating automatic load order for external systems)
- List or change load order
- Goods tracking system on the map
- Billing report (load associated)
- Status report
- Load handing photos display page
- Alert system: Send an e-mail to the interested parties after delivery.

c. Mobile Functions

With the Android-based application to be developed, drivers will perform the following functions:

- To be hold assigned freight list
- Load acceptance
- Unloading approval
- Cargo delivery confirmation
- Taking and loading photos
- Signing the loading acceptance by pen on the device

5. Customs Broker Portal

It is aimed that the customs firms carry out the transactions related to the import / export processes.

- Customs files management function
- Import / export costs management function
- Document preparation function

MBIS industry 4.0 team also applies the framework and the developed software in a manufacturing firm successfully.

The benefits of MBIS after the study:

- The clear and shared vision with employees
- Well-defined strategy and strategic project related to industry 4.0.
- Successful industry 4.0 software products and continuous improvements in these products
- Better image
- Increased sales
- New R&D projects

FUTURE RESEARCH DIRECTIONS

A global ERP firm's solution partner is used successfully as a case study in this paper. The framework can be converted to a decision support system including some recommendations. These recommendations can be derived from literature and industrial experts.

A study for determining the maturity level of software houses may be another area. After clustering the software houses, the right directions can be prepared for the managers of software houses.

CONCLUSION

In this study, a project management methodology is proposed for software companies' industry 4.0 strategy. The framework is applied in a global ERP firm's solution partner and the results are satisfactory.

For the software companies, Industry 4.0 and its transformation are a must strategy. The top managers should evolve their company in the right way and continuously. The author of this study has not seen a research regarding a software company's industry 4.0 strategy.

The benefits of this study after applying in a software house:

- Clear and shared vision with employees
- Well-defined strategy and strategic project related to industry 4.0.
- Successful industry 4.0 software products and continuous improvements in these products
- Better image
- Increased sales
- New R&D projects

The developed framework can be used as a part of Industry 4.0 strategy. It can also be used for other types of projects.

ACKNOWLEDGMENT

This research was supported by MBIS Software Company. They provided the necessary data and information for this study.

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KEY TERMS AND DEFINITIONS

Strategy: One of the ways to achieve to the vision of a company. Some examples are innovation focused growth, merging, industry 4.0, productivity by using lean manufacturing etc.

Vision: A vision is a picture of the future of an organization. It should be both hard to achieve and realistically accomplishable.

Section 2

Management of Industry 4.0 Projects

This section describes how projects related with Industry 4.0 can be successful by using agile approaches. This section handles management of Industry 4.0 projects from theoritical and academic perspective.

Chapter 13
A Managerial Perspective for the Software Development Process:
Achieving Software Product Quality by the Theory of Constraints

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ABSTRACT

The companies will become the center of business with the Industry 4.0 revolution implementing IT integration, cloud-based applications, data management, rapid decision-making operations, etc. These transformations can be realized with an effective project management, and project managers have a big role in this context. The quality of the software is very important for Industry 4.0, given that it can be as strong as the weakest link in a chain. Collaboration between producers and customers plays an increasingly important role in software processes where agile applications have recently been proposed. In this chapter, for the success of the project manager, Theory of Constraints is applied to remove the problems that may be encountered with the implementation of the agile methods during identifying the problem and determining its solution. The proposed solutions to uncover the reasons not reaching the targeted quality and removing the obstacles will be a guide for software project managers.

INTRODUCTION

In today's digital revolution, the structures that define Industry 4.0, such as autonomous robots, smart factories, cybersecurity, cloud computing, system integration etc., are entirely combined with software (Hermann et.al, 2015). Highly qualified software product affects the systems directly to be operated accurately. For this reason, software developers play a major role. Rapid changes in technology and customer requirements require frequent releases of software products. To respond to this problem, agile

DOI: 10.4018/978-1-5225-7865-9.ch013

methodology is generally proposed while developing software (Sun and Schmidt, 2018). All software projects in which the agile approach is used begin with discussions on user stories and continue with opinions on release planning and iteration planning (Cockburn, 2007). Software is a teamwork, and the development of a coding standard is an experience to be constituted by the cooperation of team members. Developers should agree on coding standards, and it is one of the major responsibilities that developers have to realize during the development (Wang, et.al. 2008). During setting the coding standards, it is important to consider the industry standards that is appropriate to the product being developed.

Any interface that is mostly used in an Industry 4.0 project may also be required to use by other systems. An organization may use more than one web services, and these services are probably provided by different systems. It is required to know which services are ready to use. This structure is called as 'service-based architecture' and, is widely used by Industry 4.0 projects (Erl, 2016). Thus, a legacy database where it belongs to another company is accessible. For example, the person in charge of a transport company can follow the highway passes and petrol purchases of the trucks that are dispatched. The company can only access the data of other companies by knowing their structure and semantics. However, it is also important to know the renewal time of instruction, if the data to be used is in the batch processing architecture (Tamrakar, et.al, 2017). In order to change a system or to develop a new system, the routine entities existed in the organization must be organized as existing legacy assets. Industry 4.0 solutions provide solutions and services through the cloud for the integration of data, people, workflows and legacy systems (Rennunga et.al., 2016). Product control systems are transformed into open databases and transparent interfaces by service-oriented architecture. Versality is a very important content of smart factories as one of the four fundamental rules of big data (Abaker, et.al., 2014). The standard interfaces and application modules should be able to change in a short time; continuously coming data can also vary its type. Moreover, different simulations will not only save time, but also reduce cost during product development. Moving the simulations done in real programming languages to the hardware environment will also contribute to success (Gokalp, et.al, 2017).

The new industrial products will soon be the combination of communication networks and physical systems to form a single entity. This is called as Cyber-Physical System (CPS), which is an important characteristic of Industry 4.0 (Kagermann. et al., 2013). In the future, the production demands will be supplied by CPSs in other words by smart factories. These processes will be accomplished by standardized and mobile factories, open interfaces, which confirm industrial standards, and plug and procedure methods. All these transformations require agile, flexible, openness to change and efficient approaches. Seamless, modular and extendable systems, and the integration of the used software with the current technology will be emphasized (Chen, et. al., 2017).

A web-based visualization ensures the integration of all devices in a system, then the relations between the terminals are monitored. This new technology called as 'smart grid communication' is an Internet of Things (IoT) protocol integration. It sends the values such as temperature, vibration, humidity, operations, weather, and meters to a substation control system (Prasad, 2014). From here, cloud computing and grid monitoring can mutually be carried out. Systems connecting nations have widely begun to use beginning at the second half of 2010. These are IoT and cloud services as new communication tools that constitute Industry 4.0. Thus, the importance geographical distribution has been removed. The standards will become more important when the transition into smart grid technology and the integration of legacy systems are provided (Faheem, et.al.,2018). For example, the creation of a competitive environment in the energy sector will lead to more economical use of resources, and the integration of distributed energy resources will be possible. This means new standards in the communication. As a result, more information can be circulated around the world with more diverse customer services (Nagasawa, et.al. 2017). Web-based communication causes secured communication problem. Different protocols perform the integration of various communications and worldwide frameworks are used to provide Cyber Security. The management of Cyber Security risks as one of the future smart grid communication issues needs to be solved (Atkinson, 2018). In 2016, a cyber-attack to Ukraine Power Grid took place and caused major damage to the IT system. So, it comes into prominence that the software be must be prepared and reviewed carefully and thoroughly. No obstacles should arise in the Industry 4.0 digital world.

The usage of continuously renewed technologies by Industry 4.0 makes necessary to choose the agile methods. Deficiencies in determining customer requirements precisely and accurately by the customer require that the software of the product be developed in small pieces and made available to the customer (Wiegers and Beatty, 2013). According to the use cases given by the authors, sometimes the customers cannot fully transfer their requirements to the analysts, and sometimes the analyst does not fully understand the customer's requirements. This, in turn, fulfills the requirement of continuous cooperation with the customer as one of the first four rules of Agile Manifesto. In other words, the customer is at the focus of agile approach (Apke, 2013).

Since, Industry 4.0 have been arisen from social changes and development of new information technologies, the creation of new possibilities on information society affected both manufacturing and project oriented organizations. Radical changes will be required in the management of future projects such as to implement big data and analytics, to build Industrialized IoTs experience, to use mobile devices as the interface, to automate the operational works, to enable teams to think more strategically, to move software systems to the cloud.

It is necessary to accomplish the target at each stage of the project, in other words to provide quality, during software development process. There are many problems that limit the quality of the software and hinder the achievement of the target (Lee and Xia, 2010). Lea and Xia emphasized the significance of the software used for industrial products of the day and future and stated that the method to be developed is important.

In Industry 4.0, project managers will be the main leaders of projects possessing significant strategic importance for the future of companies. Thus, the roles of project managers will also change. Firstly, project teams will be distributed and team members from different cultures will communicate each other. Distributed project teams will grow continuously and, the software product will tend to be generated more similar to human beings because of different cultures. Secondly, innovation will become more and more important at projects. The effect of this transformation will be to work with smaller teams and, the teams will focus on particular goal. Moreover, operational tasks will be gradually automated. Therefore modernized operations will be performed instead of hierarchical forms. Thirdly, because of the new technologies such as sensors, it will be required to analyze huge quantity of data to adapt the business processes to the data analytics of products and services. In addition, more flexible processes will decrease the time to market of production and the customer will conform to the requirements of the market. Fourth reason, change management must be implemented extensively for the combination of the Industry 4.0. Therefore, the customers who resist the changes will moderate for the innovations. Finally, project teams will need higher skills than those required in the past to achieve the best results. The experiences of the project manager with contemporary technologies and projects are significantly important and difficult to be acquired. Accomplishment of the project manager is evaluated with the success of organization for both the entire system and its components. In this case, it is possible for project manager to adopt the principles of agile approaches. When integrated with the tools of Industry 4.0, it will be possible to overcome the operational weakness about the project management. This is resulted by increasing the efficiency of project management without consuming development time and decreasing project management team flexibility. As the development team performs the analyzes rapidly, the changes in requirements will easily be able to adapt to production processes, and costumer requirements will be compensated (Frankl and Paquette, 2015).

Standish Group is a research advisory organization that focuses on software project performance. The organization defines one of the 10 main reasons for the success of their software projects as agile processes in product development (Project Smart, 2014). In today's economy, the solution of constraints in the structure of agile is very difficult. Previously, the constraints of the projects were determined by IT units. The decisions of the IT team were resolved by the software team being the same persons. The complicated problems are now being defined by the project managers and the project management department is also consulted to make decisions to evaluate the financial status. This change has also required the agile approach, that is, to take decisions in parts. This structure controls the agility of the organization's constraints. Theory of Constraints (TOC) helps to think about root cause of the bottlenecks (Bulat, 2015). If there is a 10 months budgeting process limiting, the product development cycle will be decided according to this financial situation. Budget constraints require observation to invest in ambiguous and unpredictable markets. It is important for the team making decisions about the sprints of the product to provide the competitive advantage.

In this study, TOC is used to support the agile software development approach. Although agile methods have many advantages, they can also reduce the productivity of the product because of their weak properties (Bergland, 2016). To apply TOC principles is an alternative way to identify the possible problems of agile approaches. All problems of the development method are found by using TOC. These are called as quality constraints of agile method. The criteria that should affect the performance of the product while determining the requirements are analyzed with the TOC. In the following section, TOC and related works are explained firstly. Then TOC is implemented to remove the obstacles that restrict the quality of the software product used by any smart factory that develops the Industry 4.0 product. The study is completed with the conclusion section.

GOLDRATT'S THEORY OF CONSTRAINTS AND THINKING PROCESS

Theory of Constraint is a management philosophy that aims to achieve continuous improvement by managing constraints. According to this philosophy developed by Dr. Eliyahu Goldratt in the early 1980s and first applied in manufacturing systems, the constraint is the main obstacle that restricts the profitability of a company and every system has at least one constraint. Everything that slows down the system or hinders the achievement of the goal is a constraint.

The goal of many businesses is to provide efficient service and achieve profitability because of this service. According to Goldratt, efficiency should be defined at the enterprise level and increased with the operational improvements. The thinking system is used in performance improvement and is very useful tool in terms of revealing the connections of elements that are not connected or are separated from each other. At the same time, it helps different perspectives and helps to identify unit, understand and prioritize the common goals and issues. Some constraints prevent highly important performances from developing and produce high impacts while others create small effects. Constraints that has a high level of effect in the development of the system are defined as "root cause" or "root problem". It will enable administrators to use the time effectively by focusing on the root problems with high level of effect and by identifying and addressing these problems since constraints with a high level of effect will cause performance to fall behind time for all organizations. (Onursal, Birgün and Mızrak, 2018).

The TOC, which was first applied to manufacturing systems, is a form of management that improves performance by eliminating each constraint systematically and then by identifying and destroying other constraints. The first step is to determine the bottleneck (constraint) and its cause for progress to be sustainable. Because this bottleneck restrains the output of the entire process or system and therefore the entire system must be analyzed from a holistic point of view. Once the constraint is identified, the work for increasing the capacity is initiated. At this stage, all other related operations should be rescheduled according to the constraint. All related operations should be directed to maximize the constraint and capacity as a chain is only as strong as its weakest link. The capacity of the constraint should be increased with new investments, new regulations within the enterprise or new managerial/technical approach etc. applications. When this source is eliminated to be constraint, it should be checked whether new constraints are occurred in the system. Usually, at least a new constraint occurs. Works done by returning to the first step with this method, called the 'Five Focus Steps', are indicators of *continuous improvement* efforts in the system by returning to the first step. (Onursal, Birgün and Yazıcı, 2018).

The examination of the cause and effect of each activity to find the constraints is based on a question-and-answer technique. In the TOC, the method defined as Logical Thinking Process (TP) is used for problem-solving to find constraints and to improve the system. The accurate and effective use of Logical TP provides inevitable access to root causes and provides effective solutions to root problems (McMullen, 1998).

Each Logical Tree structure presents the cause-and-effect relationships within the analyzed problem with diagrams and figures. The method (Dettmer, 1997) uses Current Reality Tree (CRT), Conflict Resolution Diagram (CRD) /Evaporating Cloud (EC), Future Reality Tree (FRT), Prerequisite Tree (PRT), Transition Tree (TT) tools.

The TP includes examining the constraints that limit the performance of the system, suggesting solutions, finding preconditions of solutions, and eliminating the difficulties that can be encountered during implementation (Birgün, et al., 2011). TP is a tool in use for all processes and problems, regardless of the situation, and are based on win-win principle (Taylor and Thomas, 2008). When Logical TP is applied, answers of the following three questions are sought in order: "What will change?", "What will it turn to?" and "How will the transformation take place?"

The aim of the question *"What will change?"* is to find the fundamental problem that prevents improvement of the organization's performance. CRT is an analytical approach that uses effect-cause-effect relationships with the purpose of determining root causes, which seek out the answer to this question and reveal undesirable effects. The *"root problem"* or problems in the system, which is the weakest link of the system and must be removed from the system, are identified through the creation of CRT. The CRT also provides a means to investigate the nature of the root cause. The CRT should be read ascending order by using if-then expressions in a logical layout (Taylor and Thomas, 2008). The creation of the CRT is the first step of implementation.

Consistent, clear, practical solutions for the root causes are sought with the question *"What will it turn to?"*. In order to determine what the wrong methods that prevent development should be transformed to, first the EC and then the FRT is used (Akman and Karakoç, 2005). EC is a method where the basic requirements are defined by the proposed ideas to remove the root problem, the conflict between the solutions is revealed, and the injections are made to destroy this conflict (Aytekin et al., 2012). The

EC is a TP tool (Taylor and Thomas, 2008) that enables conflict to be centered while the fundamental problem continues and directs the search for a solution by challenging the underlying assumptions of the conflict. Two opposing demands contradicting each other, a need behind each demand, and a general goal that both needs try to meet are identified. Then the assumptions behind the connections between the goal and the need, and between the need and the demand are exposed. This immediate contradiction is usually the same as the one underlying the CRT. According to Goldratt, managers sought solutions that compromise both needs proportionately while solving these contradictions. According to Goldratt, this approach is very useful for solving the problem without a compromise solution (Mabin, 1999). EC is read from left to right.

Desired effects can be combined with injections, and logical cause and effect relationships and future outcomes can be improved. With this technique, the future reality tree is created. According to Goldratt (1993), the FRT, when applied, is the Thinking Process that leads to the generation of a solution that changes the desired effects with the undesirable effects, without creating destructive new innovations, (Taylor and Thomas, 2008). The FRT (Kim, Mabin and Davies, 2008; Dalci and Kosan, 2012) is a proficiency-based structure for showing how the changes decided on the current situation will contribute to the desired outcomes and the cause-effect relationship between the changes to be made in the existing system and the consequences that might occur. The FRT allows the picture of a strategy, vision or plan for an organization to be seen. It tries to determine the benefits of the proposed change, the negative effects it will have, and how to remove these effects. The effectiveness of the activities to be found out rationally with the FRT can be tested and the worsening of the current situation is precluded. The CRT becomes a FRT by using the if-then logic, which will reasonably indicate that the desired effects can be achieved once the injections have been applied (Taylor and Thomas, 2008). The FRT is read ascending order by using if-then expressions in a logical form.

The starting and ending points of the system are determined by the questions *"What will change?"* and *"What will it turn to?"*. The phases created between the start and end points answer the question *"How will the transformation take place?"*. For this question, Prerequisite Tree and Transition Tree methods are used (Dettmer, 1997). The PT is used as a template to plan the implementation of new procedures (Taylor and Thomas, 2008). With the same logic used for the EC, it is used to identify and solve critical factors or obstacles encountered for achieving the goal (Mabin and Balderstone, 2003). It sets out the conditions necessary to achieve the goals set forth by the FRT (Husby and Swartwood, 2012). All ideas in the CRT are applied to create this diagram.

The Transition Tree provides a detailed plan for the implementation of the activities required to achieve the goal (Aytekin et al., 2012). The aim of the TT is to implement the change (Mabin and Balderstone, 2003). It is a cause-and-effect chain designed to reveal processes step-by-step from identification of undesirable effects till the completion of change (Akman and Karakoç, 2005). The TT structure allows the explanation of the diagram of the FRT to be understood by everyone (Kıncal, 2007). While the FRT is a strategic tool; TT is an operational or tactical tool. Through the creation of the TT, improved injections are implemented in the EC and FRT, and tactical action plans are prepared for strategic plans (Yüksel, 2011).

The TOC is a management technique that is used to analyze and solve business problems in a wide variety of fields. Manufacturing systems (Rahman, 1998; Ünal, Tanış and Küçüksavaş, 2005); maintenance management (Pophaley and Vyas, 2010); healthcare management (Phipps, 1999; Womack and Flowers, 1999; Yükçü and Yüksel, 2015; Sadat, Carter and Golden, 2013; Groop, Ketokivi, Gupta and Holmström, 2017); mental health service (Ritson and Waterfield, 2005); logistics (Escobar, Vega and

Zamora, 2016); procurement logistics (Kapustina, Chovancová and Klapita, 2017); cold chain logistics (Onursal, Birgün and Yazıcı, 2018); reverse logistics (Yang, Min and Zhou, 2009); food supply chain (Oglethorpe and Heron, 2013); order management (Kirche, Kadipaşaoğlu and Khumawala, 2005); distribution systems (Sukalova and Ceniga, 2015); sales process (Onursal, Aydın and Birgün, 2018); hotel management (Dalcı and Koşan, 2012); overtime problem (Yeşil, Gültekin and Birgün, 2016); invocing system (Taylor and Thomas, 2008); call center (Birgün, Öztepe and Şimşit, 2011); airline sector (Polito, Watson and Vokurka, 2006); software development process (Akman and Karakoç, 2005); trademark registration process(Birgün, Erol and Ceylan, 2018); market orientation (Gupta, Sahi and Chahal, 2013): symposium arrangement process (Birgün and Kolbaşı Onursal, 2012) and also infant feeding education (Trickey and Newburn, 2012), are examples of variable fields where solutions of the problems are sought by TOC.

DEVELOPING THE SOFTWARE WITH HIGH QUALITY USING TOC PRINCIPLES

In this study, the measurements related to the introduction of a high-quality software product is defined through TOC (Anderson, 2003). Therefore, the objectives of software are defined by classifying them according to the constraints during the development of product. It is accepted that one of the agile software development methods has been used. Thus, the specified constraints can be removed by improvements made during the cycle, and the possible poor quality of the developed product can be repaired. The creators of different software methods had a meeting and agreed on "Agile Manifesto" in 2001, and it was considered as core value of agile software development (Sommerville, 2011). The implementation of the agile principles leads to a visible improvement in the value stream. This can be explained by the following four basic standards of the Agile Manifesto: "individuals and interactions, working software, customer collaboration and responding to change" (Fowler, 2006). All principles of agile manifesto must be accepted in order to have successful agile development. On the other hand, weak links may also exist in agile development. Each principle can be addressed in different methods. Disparities occur where there are no connection between the practice of agile method and general agile principles. Since general agile development method focuses on frequent interaction with stakeholders, possible weak link may be to interact with stakeholders. Stakeholders include customers, product manager, sponsors, and all other people related with the project. But, most of the agile methods don't interact with all stakeholders in detail, they concentrate on different deployment activities. This is a possible bottleneck. Such disagreements considered as a high level bottlenecks of agile development method can be addressed indirectly by other principles such as TOC.

The TOC application to the software development process with the agile method has been performed by the following 5 steps. (Goldratt, 1993).

Step 1 - Identifying the Constraints: Identification of constraints has been carried out together with software project team, user and management. Constraints and their causes are shown in Figure 1 with their CRT root causes.

Step 2 - Exploding the Constraint: The work that others can do is not to be defined as a constraint. In other words, it is necessary to integrate the tasks performed by the different teams and subtract them from the constraints of the team. Because the cooperated working principle of the agile approach should be applied. It is also important that people in the system do not have too many connections. More people and their large number of contacts will also adversely affect product development.

Step 3 - Subordinating Everything to the Constraints: Agile managers should not assign jobs to team members when performing tasks. The agile method requires people to take their own decisions within the organization. The manager should be able to make decisions about improvements, and to evaluate the capacity of the team, and to create value. In short, the manager should focus on continuous improvements and observe how people use their knowledge and skills. This is directly related to the management of constraints.

Step 4 - Elevating the Constraints: Elevating the constraints should be noted that additional staffing is the last resort for eliminating constraints. Training, automation, faster working environments should be provided to deal with the constraints.

Step 5 - Not allowing a Recession to Constitute a Constraint: Once a constraint is removed, a reanalysis should be done to ensure that new constraints are not occurred in the system, and these first 4 steps must be repeated for each existing constraint. This cycle is the path that leads to continuous improvement.

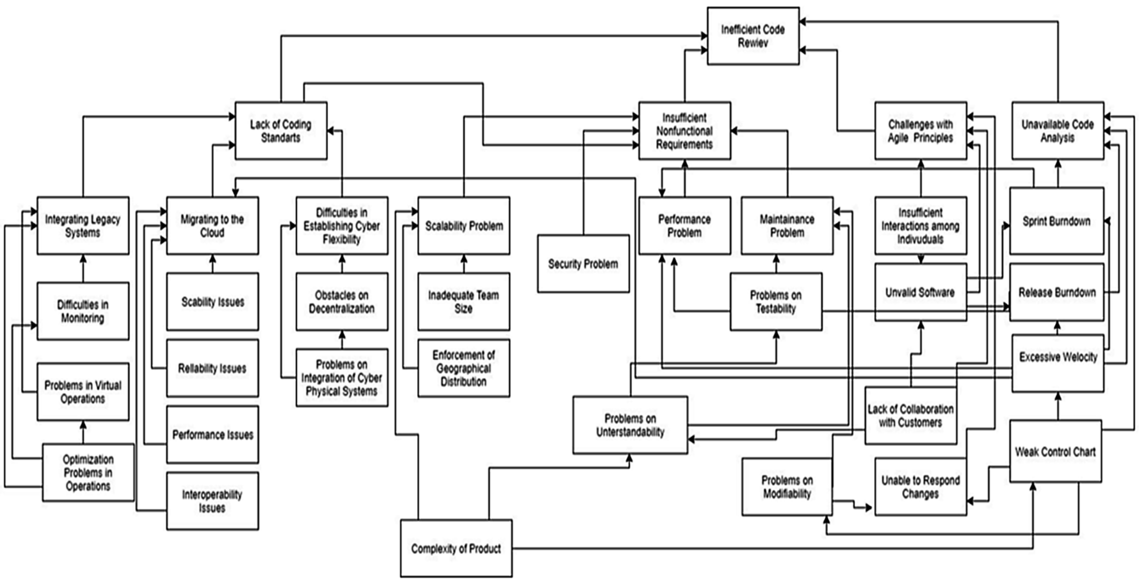
Schragenheim and Anderson (2003) suggested that TOC is founded on the notion that a value chain is only as strong as its weakest link. This weakest link is known as the constraint. Weak links may exist in agile software development. They accepted a software development constraint like that: “a software developer is responsible to work 8 hours per day”. Since software developing requires to be flexible for developers in working hours, the authors tried to answer the question “how the software developer as a resource could be protected and exploited?” They elevated the capacity constraint of software developers by improving the constraint until it was no longer the constraint. They proposed that the manager can choose to hire more developers or to introduce shift working, or to use a better developer. Finally, bottlenecks in software production were identified by measuring the trend in inventory at each step in the process.

Constructing the CRT

The first step in the Thinking Process of TOC is the creation of the CRT. The aim here is to find out the root problem. It is possible to distinguish factors that cause a software to fail into four basic categories. These categories, which also affect each other, are defined as lack of coding standards, insufficient non-functional requirements, challenges with agile principles and unavailable code analysis. Although the root problems are categorized, they are in tight interaction with each other and solutions are proposed in the same way, one within the other. Figure 1 shows the CRT for insufficient code review. Software review process is an endorsed process that improves the quality of the software product and reduces software development time and costs.

Software reviews are widely used in industrial applications, and defined as techniques that are used to examine software products against deviations from development standards. The code review process helps the code reviewer and software developers to gain expertise. Researches show that code review produces software with fewer defects. On the other hand, insufficient code review results with the failure of software product. The fundamental reasons of this failure caused by agile processes are explained in detail in the following.

Figure 1. Current reality tree for software product quality



The most essential root problem is to develop an invalid software that doesn't meet the requirements of the developed product. The essential cause is that customer's requirements can't be transferred to the other side i.e. analysts. One of the reasons of this problem is that the customer doesn't know what s/he wants clearly, which is an undesired scenario to be avoided. Because the inefficient transfer of the customer's requests in this way will make the results of the implementation vague. In some software projects, the end users of the product say that they don't have enough time for the clarification of the requirements. They prefer to stay out of the agile development process by suggesting that what they request from the product are specified by the related department. It is natural that the results obtained from the requirements which are detected in this way will fail (Wiegers and Beatty, 2013). Because the acceptance test criterion which is one of the most significant criteria in the success of a software product are detected and written by analysts in the analysis stage of the requirements and it is accomplished with the release of whole or a part of the product (Braude and Bernstein, 2010). Another cause of an invalid software is that the analysts that collect the customer requirements don't understand them accurately. Here, the conceptual modelling which is the first solution of the problem in high level won't be well designed. After the analysis and design phases are completed, the code which will be written by developers won't give the target solution.

Although the analysis and design phases of the software development process are completed perfectly, various problems can be encountered in software team as another failure criterion. The problems that the working team encounter are the most vital problems of the software development with agile approximation. Because, the failure of one person in the team is the failure of the team. The team is responsible for each sprint with its all members. Neither the software team nor the test team is responsible for a fault occurred during the development process; no matter where the failure comes from, it is the failure of the team.

Another criterion which causes developed product to fail is that the members of different teams don't work conformably, and the parts of the product can't be integrated with each other. The adaptation problem of developers to different software tool uses can cause the developed product to become problematic due to the invalid software root cause. The main reason of this is that it takes long time for people to break their habits in some occasions. Actually, what lies behind the problems of agile principles are the communication difficulty between all people who contributed to the project and the problems in the management of daily operations.

The other reason of failure is that if the project team is incompatible, they don't like to share the accomplished work with other people, which may cause the unwillingness of team during work. On the other hand, the customers that fear making dynamic decisions will bring the failure problem alongside. Some customer won't want to get in contact with agile team. Since all of these criteria won't meet the requirements which will be coming up, it will enhance the possibility of throwing the product to be developed to the trash.

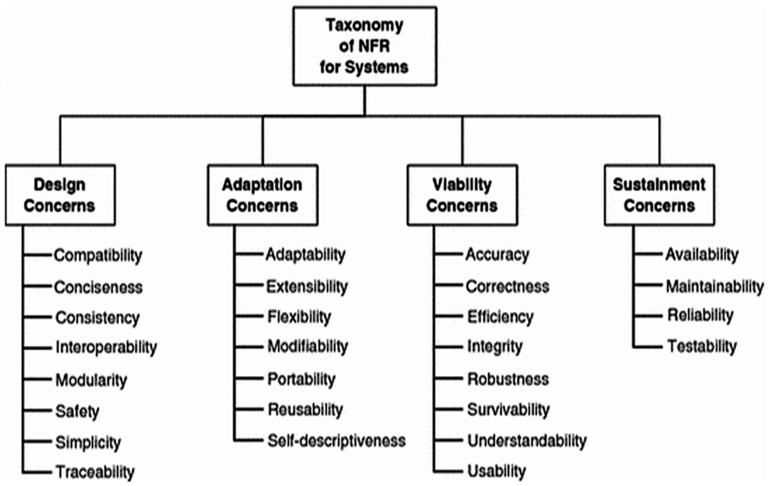
In some projects, it is seen that the product's contact with the customers is not ceased even if the product's date is expired. This means that the maintenance phase of the product is not observed, which is evaluated as a minus point for the success of the organization. The maintainability of the product is at least as significant as the development of the product.

Another difficulty is the reflection of problems on daily operational proceedings to the software. The first reason of this problem is the documents and test tools which have been uploaded previously. The visualization of the requirements effectively which have been determined during identification of the requirements is an important factor that affects the success of sprints in agile methods. One method to realize the visualizations is UML (Unified Modeling Language) diagrams (Fowler, 2012).

Implementation of all software tests automatically is the problem that agile method may encounter during the development of the application and it constitutes one of the reasons of insufficient nonfunctional requirements. In case of making all black box tests completely via automatic tools when testing the functionality of the application, some critical cases may be ignored. Black box tests control the nonfunctional requirements of the software product *(Figure 2)* and can be implemented on every level of the software test. On the other hand, the white box tests control the internal structure of the software i.e. how it works. These tests start from small code units and keep going with integration, system and acceptance tests to the whole of the software (Crispin and Gregory, 2008). The nonfunctional requirements should also be tested on every level on which white box tests are applied. Via white box tests which control to what extend the functional requirements are met, it is controlled what to do in a software. But, it not significant how the code has been written in black box tests; the nonfunctional requirements of the product and how well it must be done are identified and the identification controls are fulfilled via black box tests. In a software project that implements an agile method, it is planned that the required changes to be met constantly. Whether this criterion is accomplished or not is controlled via modifiability test of the software (Figure 2). These controls are related to the challenges with agile principle root cause and insufficient nonfunctional requirements root cause.

One other problem of agile approach is the practice deficiencies on functioning product. The criteria that causes this might either be unwell planned budgeting or giving up on the decisions too early. Inexperienced product owners and scrum masters might cause the current system to fail. Therefore scrum masters and product owners take up two main roles which are responsible for separate areas of the projects in Scrum that is one of agile methods. Both are significant for the project and it can be the same person in some projects. While the scrum master functions as a bridge between the product owner and the development team, the product owner focuses on customer's demands and business value of the product. These roles that exist in the natural structure of the agile methods complete each other and contribute to the ensuring that the interactions between people are made properly and correctly. The

Figure 2. Nonfunctional requirements taxonomy



scrum masters who is responsible for the management of the processes ensures keeping the collaboration with customers by carrying out the information trade. The product owner who manages the product backlogs is responsible for managing everyone such as customers, end users and stakeholders to the unproblematic implementation of the software product.

When the problem is evaluated from the point of view of the product to be developed, Industry 4.0 projects are big data projects in which the utilized data grow continuously (Nagode, Mantha, Licht, et.al, 2015). The growth of big data increases with cloud computing. The increase in the volume and the variety of the data has caused changes in traditional storage methods. The flow of data which has been performed only structurally till then now has turned into unstructured format with big data concept of today's problems. The data that cannot be categorized with the relational database needs to be generated, captured and processed faster at the same time. Major challenge which should be overcome here is to design appropriate cloud platforms to create when faced to a growth ratio more than expected. Procedural planning of the project should be achieved in such a way that no problems should be encountered in transferring, processing and withdrawing data to the cloud environment. This points out not only the data storage method but also the significance of infrastructure to be built. On the contrary, the scarcity problem of the resources will lead to great obstacles by creating digital strategy loop. Software architects need to cope with these, choose appropriate technology, make right planning and carry out scheduling. When they all combined, it ensures deciding of the enterprise resource planning and software architecture i.e. it creates manufacturing enterprise system. The infrastructure which has been planned like this will be able to make more meaningful data analysis to make the access to the real-time data easier and make sure that big data analysis results are interpreted in a more meaningful way. The realization of all innovations and the entrepreneurial project management can be achieved with the vision of the project manager. The other two main characteristics of the big data are the velocity and the value. Transfer speed becomes vital when the data streams from multiple sources and the data type changes constantly. The size of enterprise is important when building a business model. Since diverse and fast data withdrawal is fulfilled from large datasets, value is an important aspect of big data. To understand how the value is obtained plays a great role in detecting target users of the product.

Through the examination of the CRT, it is revealed the root causes that need to be evaporated as lack of collaboration with customers, complexity of product, cyber security, integration of cyber physical systems, and optimization of operations. These root causes will be eliminated with the help of EC.

Evaporating Cloud

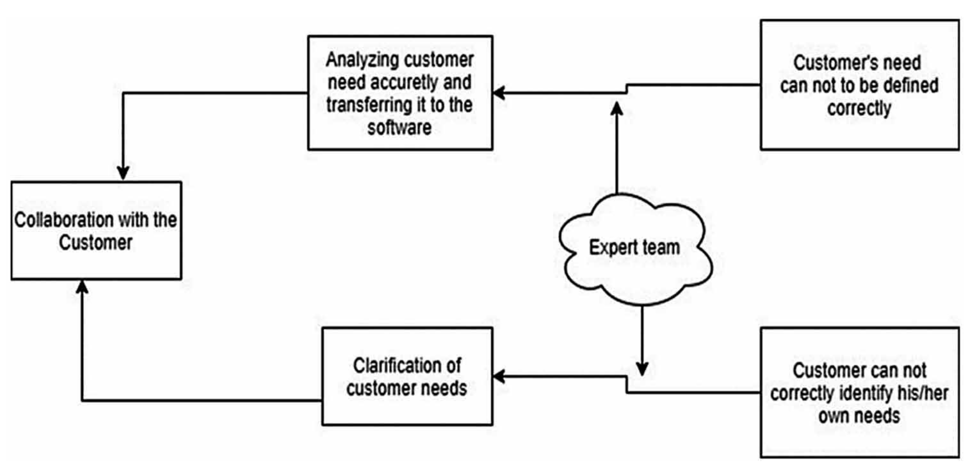
EC is the consulted method for removing the problem. At this stage, root causes uncovered in CRT are removed by evaporation through EC. Injections and possible conditions made related to removal of root causes are briefly described below.

Failure to provide the necessary communication with the client is the main root cause that causes project to fail. If the client cannot express his/her needs fully or when he/she expresses it, but if the analyst cannot fully understand these needs, and therefore misquotation to the software is the most basic failure cause of all projects.

Although the customer usually knows what s/he wants, but s/he may not be able to fully explain his/her request. Demands of the customers may change throughout production. If a specialist team, that has a clear understanding of the client's language; that will find out what the customer really wants by making him/her speak by asking subtle questions that the team has gained due to their experiences; that will make the customer more aware by revealing some conditions and thus, will get more accurate and real information from the customer by making him/her determine his/her needs correctly, is employed, then it will be possible to remove uncertainties.

The other factor is that, although they accurately describe customer needs, analysts cannot reflect it correctly to the software because of being inadequate to understand it. There is a need for analysts who can understand all these needs and changing demands correctly, evaluate them correctly and transfer them to the project team correctly. An expert team will also remove this problem. Therefore, working with a team of experts will be injected and the root cause will be evaporated by not cooperating with the customer. As a result, it is possible to produce a valid software in cooperation with the customer in every sprint of the project, as the agile approach requires (Figure 3).

Figure 3. Evaporating Cloud for strong collaboration with customers



Products usually have a complex structure. For this reason, it needs to be well understood and properly managed. It is very important that *the products in the complex structure* are planned correctly in terms of time and cost. Failure to manage sprints correctly is one of the biggest obstacles to achieve success (Figure 4). A project manager's good understanding of the product and the assignment of an experienced and disciplined team leader will ensure that the plans and control charts are properly organized and managed effectively and thus that the sprints are successful.

Sometimes, the problem may arise from the appointment of an insufficient project manager. In this case, the distribution of the project to the teams will not be coordinated correctly. If the right person is selected as the project manager, this problem will be solved, and the project will be carried out correctly and effectively with the right coordinated teams. In summary, product management will be successful with the correct selection of the project manager and the appointment of the right team leader in the same way. In the meantime, adaptation of teams is also crucial for a successful product management. The inconsistency and lack of communication between the teams are also the reasons for project to be invalid. The project manager must ensure that teams work in coordination and interaction with each other with the correct management policies. Thus, success in product management will increase by ensuring that teams work in collaboration.

Another root cause is *the lack of optimization*. As it can be seen in Figure 5, the fact that the team is not an expert or that the existing system cannot be understood correctly causes this root cause.

The most important factors that prevents optimization are the lack of expertise of the employee team and the inability to understand the legacy infrastructure correctly. The lack of expertise of the team leads to lacking or misinterpretation in understanding the requirements, thus misrepresentation of them to the software, and at the same time not having a full command of technology. Technology, especially computing technology, is developing and changing very fast. Existing systems and personnel should be able to meet this change. For this reason, it is necessary to renew the systems or make new investments to make them compatible with contemporary technology. Existing systems need to be understood and used correctly. For example, the presence of systems that can interface with new systems may make it easier to adapt to new technology, or new technology may be caught up without investing too heavily. If

Figure 4. Evaporating Cloud for product complexity

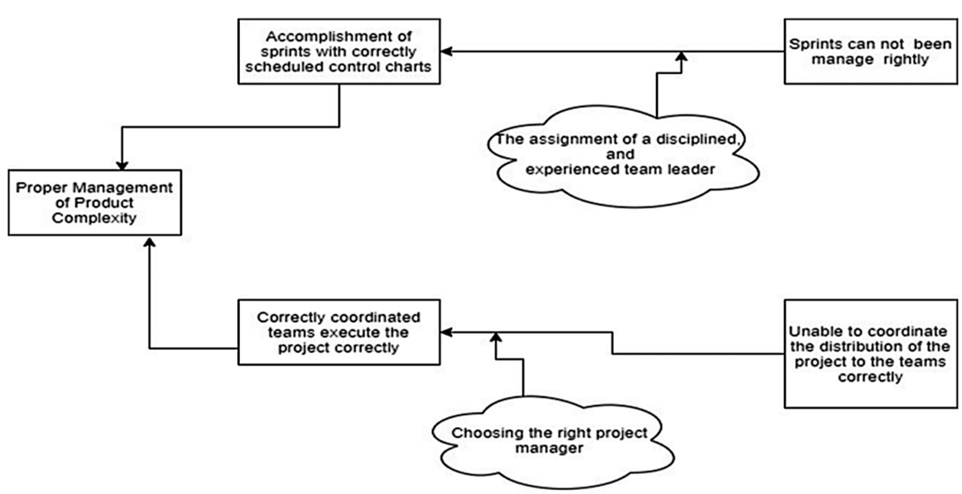
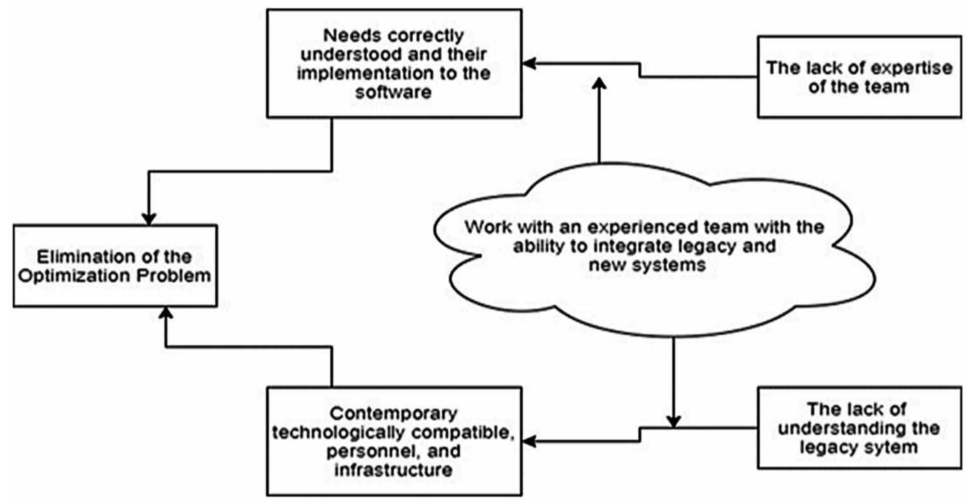


Figure 5. Evaporating Cloud for optimization



a competent and experienced team that can integrate old and new systems is employed, contemporary technologically compatible infrastructure and personnel will be obtained, moreover the needs will be understood correctly, and they will be implemented to the software correctly. As a result, a team with the qualifications given above needs to be injected into the system to evaporate the optimization problem.

Another root cause for the development of an invalid product is integration of cyber physical systems. Interaction problems between distributed tools and machines cause problems incompatible working of the systems running in distributed environments.

The staff working in different environments, especially when the international environment is discussed, can do the same thing in very different ways. For example, misunderstandings arise in environments with different characteristics of culture, language, etc., or there are wording differences in environments with the same language and culture. In order to prevent misunderstandings and to perform standard procedures, it is necessary to eliminate such conflicts before the project by providing trainings and making necessary meetings. Thus, it will ensure that teams work in collaboration.

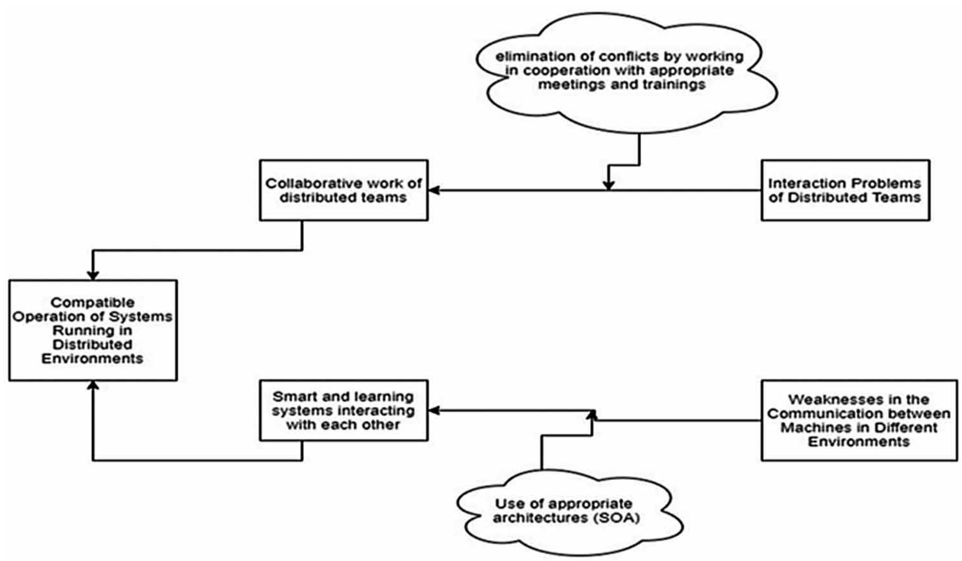
The communication of the machines with each other can be strengthened by writing the service-oriented architecture. This enables the use of smart and learning systems that interact with each other by providing a structure that allows cloud usage.

Compatible working of the systems in the distributed environment, in other words the integration of the cyber systems, will be achieved with the improvements made with the injections suggested in the following (Figure 6).

The gaps in software and infrastructure insufficiency occurred in consequence of lack of design and the lack of necessary tests are the most important obstacles for providing *cyber security*.

The security issue must be taken into account during the design phase. The security of the software should be checked by testing where security is not included in the design. If these processes fail to be done by people proficient in their jobs, there may be situations that can cause very significant losses. To avoid this situation and to be able to produce secure software, a serious and disciplined team of experts should be employed, and the tests should be carried out sensitively. By investing in infrastructure that will provide secure communication and create protocols, it will be possible to obtain systems that

Figure 6. Evaporating Cloud for integration problems



communicate securely with each other by overcoming infrastructure insufficiency. The obstacles for providing security and the injections made are shown in Figure 7.

Creating the FRT

The third step in the TOC Thinking Process is to create the FRT. The FRT is used to show that the desired effects can be achieved after applying the proposed injections. The root causes and injections explained above can be summarized as given in Figure 8.

- ***The accurate selection of the project manager.*** As in any project, especially in projects where the complexity of the product is high, choosing the project manager accurately is a factor that increases the success of the product management. Being at the right quality of the project manager ensures that the project is understood correctly and thus the size of the project teams to be established and the team members and team leaders are selected in the right manner, that the project plans are carried out effectively, the distribution of the projects to the teams is properly coordinated and carried out effectively and the distributed teams are working in a coordinated manner, as a result, product management is carried out correctly and effectively. In addition, correctly constructed and operated plans will ensure that sprints and releases are successful and a valid code analysis is done. This will open the path to sufficient nonfunctional requirements.
- ***Appointment of a disciplined and experienced team leader.*** An experienced team leader will ensure proper management of sprints. Properly planned control charts will ensure that the sprints are properly carried out and are successful. A good understanding of the task and the desired changes over time and the correctness and completeness of the tests can be achieved with a disciplined team leader.

- ***Working with a team of experts.*** The most important reason for the success of a project is to understand very well what the client wants. When a team consisting of experienced and expert analysts is established, customer requests can be correctly understood and analyzed and deployment to the product can be done correctly. In addition to this, expertise will reveal exactly what customer wants by questioning the customer, who cannot explain exactly what s/he wants. Moreover, some requests that the customer is not aware of will also be exposed. Thus, the customer can be involved in the production at the beginning of the project and as a result, a valid product can be produced by cooperating with the customer in every sprint according to the agile principles.

The expert software team's ability to integrate old and new systems will ensure that legacy systems are understood and used correctly and thus the problems in optimization of operations can be overcome. In this way, the problems experienced in the virtual platform will be eliminated and monitoring will be easier.

The gaps in software occurs in consequence of lacks in the design and incomplete necessary tests. Working with a specialized test team that will ensure tests to be done sensitively will provide development of a reliable software.

- ***Use of appropriate architectures.*** The use of appropriate architectures such as SOA-Service Oriented Architecture, cloud applications and appropriate infrastructure will eliminate the interaction problems of the machines in different environments. This will enable the integration of cyber physical systems through smart and learning systems that interact with each other. Thus, the problems of decentralization will be eliminated and flexibility is ensured.
- ***Making appropriate meetings and giving necessary trainings***. Real or virtual meetings should be held and trainings should be given in order to remove the lack of interaction between distributed teams, lack of communication, use of different code, language, etc. This way teams will be able to

Figure 7. Evaporating Cloud for providing cyber security

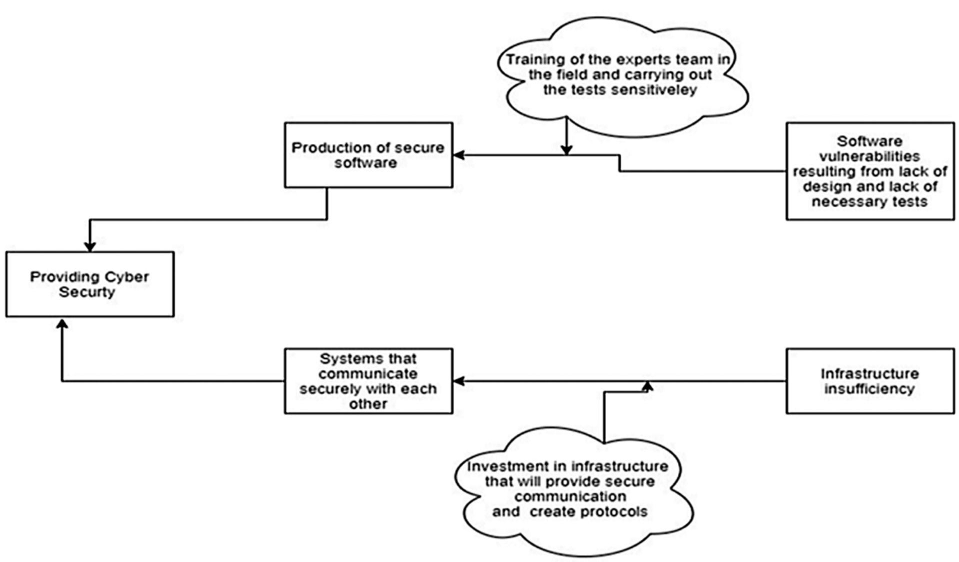
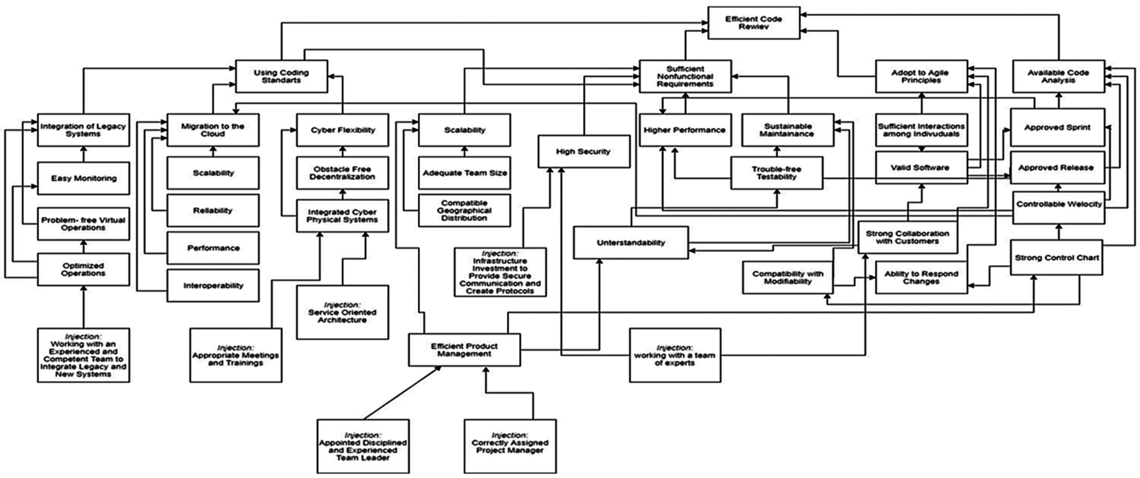


Figure 8. Future Reality Tree for a successful product quality



negotiate with each other, use the same language in coding, and standardization will be supplied and teams will be able to collaborate. This will solve the decentralization problem.

- ***Infrastructure investment that will provide reliable communication and create protocols.*** Infrastructure insufficiency prevents systems from communicating securely with each other. It will be possible to provide security with necessary and adequate infrastructure establishment.

If the injections presented above are fulfilled, a successful and valid software product will be obtained.

CONCLUSION

Software developers are required to develop fast and accurate code in Industry 4.0, where both the market expectations and the demand for functionality of the software increase. Agile approach is important in the software development to provide flexibility in adaptation to ever-changing conditions and to rapidly fulfill customer requests. Whether they are classical products or products that are developed with agile approach, they have to interact and communicate with other products while taking their place in the digital world. However, when the product is intended to be produced correctly and on time, it often results in failure. In this case, if any software is faulty, it will create a “domino effect” on the systems in which it interacts. This impact means big costs and global failures.

The Theory of Constraints is an analytical approach that provides continuous improvement by removing constraints and main problems that affect the performance of a system. It is a management philosophy that allows root causes to be found and removed to improve performance. In this study, TOC TP (first 3 steps) is used to determine the basic problems for the production of valid software and to suggest solutions and remove them. The study investigated the reasons why a software product developed in an agile environment and considered to be used in the Industrial 4.0 smart systems might be invalid. It is found that the basic problems arising in general as “lack of coding standards”, “challenges with agile principles”, “unavailable code analysis” and “insufficient nonfunctional requirements” are in fact derived from the root causes of “lack of collaboration with customers”, “complexity of product”, “cyber security", "integration of cyber physical systems" and "optimization of operations". These root causes lead to many undesirable effects and the output to be invalid.

With TP's FRT tool, the necessary interventions have been made for system to run better and for the output of valid product and undesired situations have been removed. These interventions are; the use of specialized teams for software or for designing and testing, the implementation of necessary infrastructure investments, the use of appropriate architectures, providing the necessary training to the employees, and the integration of teams and meetings. However, it is important for the project manager and team leader to be selected and appointed accurately in order to carry out and manage all of these.

The study we are presenting here is a template limited to the common problems faced by software companies and their solutions. We recommend that software companies encourage senior managers in their companies to conduct research under such a template for their projects and encourage them to undertake studies that will contribute to the identification of problems specific to their own companies. Measuring the benefits obtained in terms of time, cost and quality in such studies will lead significance of the subject to come in sight clearly.

An application of the model presented here can be performed in a software company and the results obtained can be compared with the results of the study. It is possible to do this work in different sectors, for example for different production subjects.

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KEY TERMS AND DEFINITIONS

Agile Manifesto: Uncovering better ways of developing software by doing it and helping others do it.

Constraints: Restriction on the degree of freedom in providing a solution, including effective global requirements such as limited development resources or a decision by senior management.

Continuous Improvement: The ongoing improvement of products, services, or processes through incremental and breakthrough improvements.

Cybersecurity: The protection of internet-connected systems including hardware, software, and data from cyberattacks.

Grid Computing: A distributed architecture of large numbers of computers connected to solve a complex problem.

Legacy Systems: Outdated computer systems, programming languages, or application software that are used instead of available upgraded versions.

Nonfunctional Requirement: Specifies criteria that can be used to judge the operation of a system, rather than specific behaviors.

Root Cause: A factor that caused a nonconformance and should be permanently eliminated through process improvement.

Service-Based Architecture: A style of software design where services are provided to the other components by application components through a communication protocol over a network.

Software Code Review: An ongoing practice during the development phase in which software developers attend a series of meetings and review code to identify bugs and defects before testing.

Thinking Process: Enables to create breakthrough solutions by identifying, challenging, and correcting unexamined assumptions.

Value Stream: The set of all steps from the start of value creation until the delivery of the end result to customer.

Versality of Big Data: Reflects how useful the data is, in different scenarios, and in applications for different sets of stakeholders, despite invariably having been created for a certain purpose.

Chapter 14
Critical Success Factors in the Transition Processes to Industry 4.0 Projects

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ABSTRACT

In today's competitive industrial world, sustainability and competitive advantage of companies depend mostly on their capability of adaptation to changing business requirements. The Fourth Industrial Revolution, driving from the progress in new technologies has been profoundly changing the dynamics of most industries. Hence, companies are getting prepared to move from the Third Industrial Revolution to the Fourth Industrial Revolution. The purpose of this research is to define critical success factors in the transition processes to Industry 4.0 projects. It is important for the effectiveness of the transition process to Industry 4.0. In this study, a literature study was conducted to identify the critical success factors in the transition processes of Industry 4.0. and, the survey instrument, a questionnaire form, was designed. The results of this research show that big data management is the most important success factor of Industry 4.0.

INTRODUCTION

The world has become different as fast as it has ever existed since the First Industrial Revolution. In recent years, Industry 4.0 has become popular as a result of searching methods to control operations more effectively. As a result, companies are getting prepared to move from the Third Industrial Revolution to the Fourth Industrial Revolution. Determination of the factors affecting the success of companies in this transition process and realizing the effects of these factors have become the major interest for researchers in terms of the effectiveness of the transition process to Industry 4.0.

DOI: 10.4018/978-1-5225-7865-9.ch014

Industry 4.0, which was first announced in 2011 at the Hannover Fair in Germany, has been a topic of constant consideration since then by academics, practitioners, politicians and government officials around the world. Kagermann et al. (2013) has defined the Industry 4.0 concept as a new trend in automation and data transfer in production technology encompassing cyber physical systems (CPS), the Internet of things (IOT), cloud systems, and the concept of smart factory. To summarize the system briefly; the digital copy of real objects is created in virtual world with the help of the pyramid physical systems created in the established smart factories. With the internet of objects, products are coordinated in communication with each other and with people (Sung, 2018). Industry 4.0 will reduce the responsibility of enterprises to adapt to new business trends. Issues such as sudden demand increases in the market, short-lived products, complex product structures, and supply chains that exceed the country borders are the trends putting pressure on enterprises.

Implementing Industry 4.0 systems is a complex, lengthy, and expensive process. As a result critical success factors in the transition processes to industry 4.0 projects become very important for companies. The aim of this study is first of all to identify the critical success factors of the Industry 4.0. Furthermore, perception of Industry 4.0 has been investigated in this research. First, a literature review was carried out to determine perception of Industry 4.0 and the critical success factors in the processes of the firms located in Turkey. The second section in this chapter presents relevant literature, research framework, and the hypotheses of the research. The third section provides research methodology, results, and findings. Finally, the last section provides conclusions.

LITERATURE REVIEW

Industry 4.0

Oesterreich and Teuteberg (2016) and Herman et al. (2016) emphasized inadequacy of academic studies about Industry 4.0. According to more than 2000 companies, digitalization levels of companies are increasing rapidly. At the end of this transformation process, it can be said that all successful industrial companies will be digital companies. This digitality can be explained as the products will be both physically and virtually visible and contain innovative services. At the same time, digitized enterprises will work in harmony with digital ecosystems, including the common technologies they have established with their customers and suppliers (Tupa et al., 2017).

According to a study conducting by McKinsey in 2015, companies are not able to continuously know new emerging technologies. Mckinsey conducted a survey of 300 leading companies in manufacturing. According to results, 48 percent of these companies are ready for Industry 4.0, and 78 percent of participating companies stated that they are in preparation for this new process (Sung, 2018). As a result, critical success factors of the Industry 4.0 projects is very important for firms.

Industry 4.0 refers to new technological improvements where the internet and other technologies such as embedded systems are defined as the main characters of Industry 4.0. They provide the integration of physical objects, labours, intelligent machines, production lines and processes, and also create a new model of intelligent, internet connected and agile value chain. (Leyh et al., 2017). Industry 4.0 is the digital copies of real objects that are created in virtual world with the help of cyber physical systems in the smart factories. With the internet of things, products will be in communication with each other and with labour Also, products and labour will be well coordinated. Thus, production and process monitoring in the cyber physical system will be achieved by utilising internet (Sung, 2017). In other words, Industry 4.0 is the linking of people and objects with any communication technologies or services at all times in all platforms (Wagner et al., 2017).

Industry 4.0 Critical Success Factors

The instrument for Industry 4.0 critical success factors used in this study was developed by Kocak and Diyadin (2018) to investigate and determine critical success factors in the processes of transition to Industry 4.0. In their research after literature review, they have determined critical success factors. Then, these factors were evaluated by decision makers of a German company, a global producer in the textile sector that has initiated the Industry 4.0 processes. According to Kocak and Diyadin (2018), the success factors affecting the enterprise's process of transition to the industry 4.0 are strategic vision, organizational structure, horizontal integration in value chain, vertical integration, information system and technology infrastructure, smart factories, big data management, qualified workforce structure and security.

In this research, nine factors are used as the critical success factors. These critical success factors are strategic vision, organizational structure, horizontal integration in value chain, vertical integration, information system and technology infrastructure, smart factories, big data management, qualified workforce structure and security (Kocak and Diyadin, 2018).

Strategic Vision

Industry 4.0, technology-based production capabilities in the business process paradigm brings a change (Schumacher et al., 2016). As a result, Industry 4.0 is not only a technology investment, but also has new business models that should be regarded as a business strategy. In this sense an Industry 4.0 vision integrated with business strategies should be created and implemented.

Three basic qualities of the strategic roadmap to be created must be determined (Schumacher et al., 2016):

- Technology-assisted for new conversion to provide a continuous planning and analysis infrastructure,
- Vision, strategy and projects related to Industry 4.0 to function in a holistic structure,
- All activities of the industry 4.0 transition period for monitoring and management.

Organizational Structure

Industry 4.0 is characterized by an unstable changing environment, and is compatible with the organic design of company, which is characterized by decentralization, empowerment, few rules and procedures, horizontal communication, and collaborative team work. This kind of design is more suitable for innovation strategy and changing environment. As a result, while establishing organizational structure, a manager should remain in the organic paradigm of design for industry 4.0. It is not rational to suggest one single structure for industry 4.0 as organizations ought to design flexible structures according to their needs and situations. No single approach is suitable for companies (Shamim et al., 2016).

Horizontal Integration in Value Chain

Cross-company data integration is based on data transfer standards. This is a precondition for a fully automated value chain (from supplier to customer, from management to shop floor). According to Wang (2015) integration of various IT systems used in the different stages of the manufacturing and business planning processes that involve an exchange of materials, energy, and information both within a company (e.g. inbound logistics, production, outbound logistics, marketing) and between several different companies (value networks). The horizontal and vertical integration enable real time data sharing, productivity in resource allocation, coherent working business units and accurate planning which is crucial for connected devices in the term, Industry 4.0.

Vertical Integration

Industry 4.0 is marked by a technical integration of Cyber-Physical Systems in manufacturing and logistics processes as well as the use of the Internet of Things and Services in industrial processes. New technologies will have miscellaneous impact on value creation, work organization, downstream services, and business models of companies. At the forefront of all Industry 4.0 developments, the concept of a Smart Factory plays a significant role in shaping the vision of a new industrial age (Kagermann et al., 2013).

Information System and Technology Infrastructure

Industry 4.0 integrates physical world and virtual world. Thus, technologies are used by firms for this objective. For example, simulation, automation, enterprise resources planning programs, and various software have been used by companies. Furthermore, companies need RFID, sensor, cloud, robotic technologies, big data management for Industry 4.0. As a result, companies should firstly provide suitable infrastructure.

Smart Factories

One of the basic elements of Industry 4.0 is smart factory. There are smart products and smart machines in the smart factories. Computer aided design; enterprise resources planning, digital systems, and machine data collection must exist in smart factory. According to Gilchrist (2016) smart factory, is the principle of Industry 4.0. Smart factories cannot work on an independent substance. The literature review shows four main elements of Industry 4.0, namely IOT, Smart Factory, Cyber-Physical Systems and Internet of Services. Communication between machines and Smart Products are not regarded to be independent of Industry 4.0 factors. Because machine communication between machines is a provider of IOT, and Smart Products are a component of Cyber-Physical Systems (Bartodziej, 2017; Hermann et al, 2015). There is a requirement for the connection of smart factories and smart products because it will create developments in the industrial processes within production, supply chains, material usage, and product lifecycle management (Gilchrist, 2016). Smart Factory plays an important role for strategies of Industrial 4.0 (Kagermann et al., 2013). The Internet of Things as a new developing term enables different technologies and approaches to communicate with each other and connecting physical objects with each other by internet (Pereira and Romero, 2017).

Big Data Management

Industry 4.0 integrates value chain and digital infrastructure of firms. Thus, all necessary data may be collected easily. On the other hand, cloud systems can ensure exact time information management and it can manage big data confidently. As a result, fast response for data processing and management of data flow can be achieved. Consequently, Industrial Internet and cyber security support big data management.

Qualified Workforce Structure

Qualified employees are needed by organizations that aim to be smart because intelligent systems can be used by highly skilled employees (Shammim et al., 2016). On the other hand, there are various intelligent systems in Industry 4.0. Physical workforce decreases as intelligent workforce increases. In industry 4.0 employees should have variety of skills and heterogeneous knowledge. Future labour force is expected to have mostly cognitive abilities (52%), systems abilities (42%), and complex problem solving abilities (40%). Furthermore for information and communication technologies (ICT), those skills and workers possessing fundamental abilities are needed. Increased digitalization and automation involved employees with professional ICT. These employees have the ability to make coding, develop implementations, administrate database, and analyse Big Data. Basically, ICT features do not only help firms making an effort in their business for smart systems (Quintini 2014). According to Grundke et al. (2017) increasing automation and digitalization of operations, employees that have ICT ability, soft ability of autonomy will be necessary.

Security

The most difficult factor of Industry 4.0 is the IT security risk. IT-security constitutes the technological cornerstones for further manufacturing and achievement (Bartodziej, 2017). Industry 4.0 will integrate several data with each other, and this real time integration will give room to security infringement and missing data (Sung, 2017). According to Frost and Sullivan (2017) raising data density with Industry 4.0 and the fusion of operational technology and information technology brings with cyber security. Changing technology, enhancing new technologies and automation, hacker attacks, and the poor safety prevention in the cyber market are precisely considerable (Weber and Studer 2016).

RESEARCH METHODS

Sample and Data Collection

A survey instrument was developed to investigate the Industry 4.0 success factors and perception of Industry 4.0. This construct is composed of nine items drawn from earlier studies The study was conducted in 31 companies operating in Turkey.

Measurement of Variables

Industry 4.0 Success Factors

For Industry 4.0 success factors, the instrument used in this study was developed by Kocak and Diyadin (2018). The importance level of the critical success factors were evaluated using a scale of 1-10.

Perception of Industry 4.0

In the second part of the questionnaire, questions are related to variables for evaluating perception of Industry 4.0. Based on the literature, 20 items are determined for perception of Industry 4.0 (Schumacher et al., 2016). The respondents are asked to evaluate their Industry 4.0 perception using a five point Likert scale. In this scale, (1) indicates strongly disagree, (2) disagree, (3) neither agree nor disagree, (4) agree, and (5) strongly agree.

HYPOTHESES, ANALYSIS, AND FINDINGS

Reliability of Measures

When measuring Industry 4.0 perception a five point Likert scale was used then and reliability of this factor was analysed. Internal consistency of the study's constructs is measured by Cronbach's Alpha. It was found 0.869. Because of this research's value of Cronbach's Alpha is bigger than 0.70, measuring of data is reliable (Hair et al., 1998).

Findings Related to Industry 4.0 Critical Success Factors

In the first part of the questionnaire, variables related to Industry 4.0 critical success factors take place. As the search of previous publications is accomplished, 9 dimensions are determined. Table 2 illustrates the findings of 9 critical success factors dimensions. The averages of the ratings and percentage of this point are shown in Table 1.

The average points received for Industry 4.0 critical success factors are shown in Table 2.

From the highest to the lowest point critical success factors are listed as follows:

1. Big Data Management (8.61)
2. Smart Factories (8.48)
3. Strategic Vision (8.35)
4. Security (8.22)
5. Information System and Technology Infrastructure (8.12)
6. Organizational Structure (7.68)
7. Qualified Workforce Structure
8. Horizontal Integration in Value Chain (7.19) / Vertical Integration (7.19)

Table 1. Findings Related to Industry 4.0 Critical Success Factors

Industry 4.0 Success Factors	Average points	Level of place	Percentage (%)
Strategic Vision	8.35	3	83.8
Organizational Structure	7.68	6	77.4
Horizontal Integration in Value Chain	7.19	8	64.5
Vertical Integration	7.19	8	64.5
Information System and Technology Infrastructure	8.12	5	67.7
Smart Factories	8.48	2	80.7
Big Data Management	8.61	1	87.1
Qualified Workforce Structure	7.52	7	71
Security	8.22	4	80.6

The highest rated factors are big data management, smart factories and strategic vision in this research. As a result these dimensions affect Industry 4.0 success more than other dimensions.

Findings Related to Perception of Industry 4.0

In Table 3, the perceptions of the firms related to Industry 4.0 are illustrated. The averages of the points are calculated. The frequency of level of Industry 4.0 perception is determined according to these answers.

As shown the Table 2, companies believe that to achieve success in industry 4.0 integration, it is necessary that vision, strategies, and projects operate in a holistic structure (4.42). This result indicates importance of strategic visions on Industry 4.0. Most of the companies agree that Industry 4.0 is a technology investment for companies (4.42). Most of companies disagree that Industry 4.0 will reduce qualified labour in enterprises (2.84).

Analysis of Relationship Between Company Characteristics and Industry 4.0 Critical Success Factors With Company's Industry 4.0 Perception

Industry 4.0 is most common and most affected in electric - electronics industry and automobile industry because these industries are technology-intensive industries. As a result in this section these sectors are compared. As shown Table 3, the sample consists of firms from three kinds of industries including electric - electronics (67.7 percent), automobile (6.45 percent) and others (25.8 percent).

A SPSS software program is used to analyse the findings of the research. Relationships between company characteristics and Industry 4.0 success factors are analysed by employing independent t test.

Relationship between firms' sectors and Industry 4.0 success factors is examined by 9 Hypothesizes. This hypothesizes are listed as follows:

H_1: There are differences between electronics-automotive sector and other sectors in strategic vision.
H_2: There are differences between electronics-automotive sector and other sectors in organizational structure.

Table 2. Findings Related to Perception of Industry 4.0

Industry 4.0 Perception Factors	Average points
Industry 4.0 should be seen as a long term management strategy including all managements and requiring new business models.	4.32
To achieve success in the industry 4.0 integration, it is necessary that vision, strategies and projects operate in a holistic structure.	4.42
Industry 4.0 is a technology investment for companies.	4.42
Industry 4.0 is a management strategy that creates cultural change.	3.93
With Industry 4.0, a change from a product focused management model to a service focused management model is targeted.	3.55
The major problem of companies while applying Industry 4.0 is the lack of digital culture and education.	3.81
For Industry 4.0 success, continuity after applying Industry 4.0 is required.	4.32
It is necessary to integrate various information technologies in order to provide information, material and energy flow between the internal and external processes of logistics, production and marketing of the enterprise and other managements and customers in the value chain such as suppliers.	4.16
In industry 4.0 transition processes, beginning from production processes until distribution processes, coordination and integration are required in all processes.	4.32
The transition to Industry 4.0 can be done at the departmental level.	2.97
The integration of the internal environment into Industry 4.0 is more difficult than the integration of the external environment.	3.03
The Industry 4.0 efficiency can not be done without integrating the external environment into Industry 4.0.	3.55
The success of Industry 4.0 is directly related to the successful implementation of Enterprise Resource Planning (ERP).	4.03
Using smart systems in factories makes the transition to Industry 4.0 easier.	4.26
For the success of the industry 4.0 integration, it is necessary to use big data effective and real-time use of decision-making and management activities in all processes and new business models.	4.03
Industry 4.0 will reduce qualified labor in enterprises.	2.84
Industry 4.0 will provide labors with more opportunities to participate in individual responsibility, leadership and decision-making processes.	3.74
The industry 4.0 will improve the quality of work together with labors quality.	4.06
Providing cyber safety effect on Industry 4.0 success directly.	4.16
Industry 4.0 that requires data collection and processing activities is also important for companies in the process of data warehousing and security of transaction.	4.10

Table 3. Sectors of the sample organizations

Sector	Percentage (%)
Electric - Electronics	67.74
Automobile	6.45
Others	25.8

H_3: There are differences between electronics-automotive sector and other sectors in horizontal integration in value chain.
H_4: There are differences between electronics-automotive sector and other sectors in vertical integration.
H_5: There are differences between electronics-automotive sector and other sectors in information system and technology infrastructure.
H_6: There are differences between electronics-automotive sector and other sectors in smart factories.
H_7: There are differences between electronics-automotive sector and other sectors in big data management.
H_8: There are differences between electronics-automotive sector and other sectors in qualified workforce structure.
H_9: There are differences between electronics-automotive sector and other sectors in security.

Hypothesis 1, Hypothesis 2, Hypothesis 3, Hypothesis 4, Hypothesis 5, Hypothesis 6, Hypothesis 7, Hypothesis 8, Hypothesis 9 are tested to explain the difference between two variables and t-test is employed. The results of the t-test are shown in Table 4. As it is seen in Table 4, after examining Sig.2, Hypothesis 1, Hypothesis 2, Hypothesis 3, Hypothesis 4, Hypothesis 5, Hypothesis 6, Hypothesis 7, Hypothesis 8, Hypothesis 9 are not accepted. So there are not differences between electronics-automotive sector and other sectors in Industry 4.0 success factors.

Table 5 illustrates the correlations between Industry 4.0 success factors. As it is seen in Table 5, all of Industry 4.0 success factors have a correlation with each other by a significance level of 0.05.

Table 4. T-tests related relationship between firms' sectors and Industry 4.0 sucsess factors

Factors		F	Sig.	T	Sig.2
Strategic Vision	Equal variances assumed Equal variances not assumed	6.66	0.0154	-0.245 -0.288	0.808 0.776
Organizational Structure	Equal variances assumed Equal variances not assumed	0.37	0.546	-0.794 -0.799	0.434 0.432
Horizontal Integration in Value Chain	Equal variances assumed Equal variances not assumed	0.01	0.926	0.138 0.143	0.891 0.887
Vertical Integration	Equal variances assumed Equal variances not assumed	0.63	0.435	-1.046 -1.104	0.304 0.279
Information System and Technology Infrastructure	Equal variances assumed Equal variances not assumed	0.03	0.865	-0.537 -0.558	0.595 0.582
Smart Factories	Equal variances assumed Equal variances not assumed	1.21	0.281	0.046 0.051	0.964 0.960
Big Data Management	Equal variances assumed Equal variances not assumed	0.66	0.423	0.195 0.214	0.847 0.832
Qualified Workforce Structure	Equal variances assumed Equal variances not assumed	0.53	0.472	-0.171 -0.175	0.866 0.863
Security	Equal variances assumed Equal variances not assumed	0.15	0.699	-0,208 -0.215	0.837 0.832

Table 5. Pearson Correlations Between Industry 4.0 Success Factors

Factors	Strategic Vision	Organizational Structure	Horizontal Integration in Value Chain	Vertical Integration	Information System and Technology Infrastructure	Smart Factories	Big Data Management	Qualified Workforce Structure	Security
Strategic Vision									
Pearson Correlation	1	.753	.804	.772	.618	.651	.653	.561	.545
Sig. (2-tailed)		.000	.000	.000	.000	.000	.000	.001	.002
N	31	31	31	31	31	31	31	31	31
Organizational Structure									
Pearson Correlation	.753	1	.751	.641	.712	.636	.720	.509	.494
Sig. (2-tailed)	.000		.000	.000	.000	.000	.000	.003	.005
N	31	31	31	31	31	31	31	31	31
Horizontal Integration in Value Chain									
Pearson Correlation	.804	.751	1	.829	.646	.709	.686	.594	.492
Sig. (2-tailed)	.000	.000		.000	.000	.000	.000	.000	.005
N	31	31	31	31	31	31	31	31	31
Vertical Integration									
Pearson Correlation	.772	.641	.829	1	.502	.479	.469	.687	.594
Sig. (2-tailed)	.000	.000	.000		.004	.006	.008	.000	.000
N	31	31	31	31	31	31	31	31	31
Information System and Technology Infrastructure Value Chain									
Pearson Correlation	.618	.712	.646	.502	1	.731	.739	.638	.585
Sig. (2-tailed)	.000	.000	.000	.004		.000	.000	.000	.001
N	31	31	31	31	31	31	31	31	31
Smart Factories									
Pearson Correlation	.651	.636	.709	.479	.731	1	.809	.591	.471
Sig. (2-tailed)	.000	.000	.000	.006	.000		.000	.000	.007
N	31	31	31	31	31	31	31	31	31
Big Data Management Value Chain									
Pearson Correlation	.653	.720	.686	.469	.739	.809	1	.499	.412
Sig. (2-tailed)	.000	.000	.000	.008	.000	.000		.004	.021
N	31	31	31	31	31	31	31	31	31
Qualified Workforce Structure Value Chain									
Pearson Correlation	.561	.509	.594	.687	.638	.591	.499	1	.652
Sig. (2-tailed)	.001	.003	.000	.000	.000	.000	.004		.000
N	31	31	31	31	31	31	31	31	31
Security Value Chain									
Pearson Correlation	.545	.494	.492	.594	.585	.471	.412	.652	1
Sig. (2-tailed)	.002	.005	.005	.000	.001	.007	.021	.000	
N	31	31	31	31	31	31	31	31	31

CONCLUSION

Increasing global competition has enforced companies to focus more on quality, cost, and time to meet customer requirements more effectively. Hence, technology, information systems, smart factories, big data management, and qualified workforce play a more important role for improving these factors. The study presented here aimed to determine the critical success factors of the Industry 4.0. The research was conducted in 31 companies operating in Turkey. Big data management was found the most important success factor of Industry 4.0. The result of the research have pointed out that companies should consider their data management firstly for Industry 4.0 success. Smart factory is the second most important success factor of Industry 4.0. As a result, companies have to use computer aided design; enterprise resources planning, digital systems and machine data collection. On the other hand, the third most important success factor of Industry 4.0 is strategic vision. So, companies have to form their business strategy considering new business models. Another indication of this research is all of Industry 4.0 success factors have a correlation with each other. Furthermore, there are not differences between the electronics-automotive sector and other sectors in regard to Industry 4.0 success factors. Consequently, managers should pay attention to big data management and strategic vision. So, managers should manage their firms considering the essence of strategic management. If a firm employs strategic management, it is expected to be successful in Industry 4.0. Moreover, smart factories have occurred with digitalization, integration into new technologies, flexible manufacturing systems, and smart solutions. So, if managers should pay attention to these factors, Industry 4.0 projects implementation will be successful. Future studies will aim at diversifying Industry 4.0 success factors with several sectors and increasing the sample size. It should also be acknowledged that the present study is subject to some limitations.

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Chapter 15
Management of Big Data Projects:
PMI Approach for Success

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ABSTRACT

Big data is an emerging area of research that is of interest to various fields; however, studies in the literature and various sources claim that failure rates for big data projects are considerably high. There are different reasons for failure; varying from management processes to the use of wrong technologies. This study investigates how the project management framework proposed by Project Management Institute (PMI) can be effectively adapted to big data projects to reduce failure rates. The application of processes as mentioned in this study can help to eliminate the causes of failure in the early stages of the project; thus, increasing the successful completion rate of such projects.

INTRODUCTION

Big data became a hot topic, attracting the extensive attention of academia, industry, and government across the world. Due to the rapid development of the Internet, the Internet of Things and Cloud Computing, data generated and stored in almost every industry and business area grow significantly in recent years. (Jin, Wah, Cheng, & Wang, 2015). Specifically, big data concept is also fundamental and prevalent in the area of Industry 4.0. Data and analytics are core capabilities of Industry 4.0 and contributing digital technologies; namely cloud computing, mobile devices, IoT platforms, Location detection technologies, advanced human-machine interfaces, authentication and fraud detection, 3D printing, smart sensors, multilevel customer interaction and customer profiling, augmented reality and wearables (PWC, 2016).

DOI: 10.4018/978-1-5225-7865-9.ch015

Big Data analytics tools and techniques are rising in demand due to the use of Big Data in businesses. Organizations can find new opportunities and gain new insights to run their business efficiently. These tools help in providing meaningful information for making better business decisions (Verma, 2018). So, the number of projects which are in Big Data business increasing every year and these projects are becoming crucial for companies.

According to a Gartner report, it predicts $2.5 M per minute in IoT spending and 1 M new IoT devices will be sold every hour by 2021. It is a testament to the speed with which digital connectivity is changing the lives of people all over the world (Riddle, 2017). Because of Big Data is part of Industry 4.0, the need for processing of the data which will be generated from these devices and the number of big data projects will increase exponentially year by year.

Big data technologies provide project managers to find opportunities for making corporate decisions for creating successful projects. By analyzing the narrowed scope of data, the company can make better-informed decisions leading to higher success projects and profits. Also, data analysis leads to reducing project complexity. Having inadequate knowledge of information to make decisions is determinant to any business. Many managers must deal with uncertainty and complex problems, but if they can uncover digital material using the right tools to comprehend the project's problems, then they can reduce the intricacy of the project (McAllister, 2018).

Analysis methods that utilize big data groups in production increase the quality of production, save energy and facilitate equipment maintenance. From the perspective of Industry 4.0, collection and analysis of data from various systems such as enterprise and customer-based management systems as well as production systems, and real-time decision-making systems will become the standard in the future (TÜSİAD, 2016). Integrated systems will analyze data to predict errors, define parameters and adapt to changing conditions; thereby increasing productivity. That is why "Big Data Analytics" is one of the nine principles of Industry 4.0.

Handling big data requires additional constraints about volume, variety, velocity, and veracity. In this context;

- **Variety** refers to different types of data collected via smartphones or social media such as images, text, and audio.
- **Volume** refers to large amounts of any data from many different sources, including mobile digital data creation devices and digital devices.
- **Velocity** refers to the speed of data transfers. As mentioned in the *variety* concept, there are different forms of streamed data from multiple sources. So, new algorithms and methods are needed to process and analyze the online and streaming data adequately.
- **Veracity (Complexity)** is related to the correctness and accuracy of information. Behind any information management practice lie the core doctrines of data quality, data governance, and metadata management, along with considerations of privacy and legal concerns (Bello-Orgaz, Jung, & Camacho, 2016).

Considering the constraints above, management of big data application projects demand an understanding of additional requirements given with processing of big data, as well as working with multi-disciplinary teams. Development teams focus more on the technology and architecture for processing the data whereas business teams focus more on how to visualize meaningful business insights for the customer. Data scientists use techniques such as data mining, machine learning, and artificial intelligence to generate better insights and make decisions out of raw data. This work will discuss the required skill sets of a project manager to manage such a team in the following sections successfully.

This chapter considers all of those reasons above; it compiles and discusses the recommended project management approach of the Project Management Institute (PMI) for application to big data projects.

WHY DO BIG DATA PROJECTS FAIL?

In literature, various sources report that 65-100% of Big Data Analytics projects fail. Gartner, a research and advisory company, claims that 60% of big data projects would fail to move past preliminary stages in 2017 (Gartner Inc., 2015). In 2017, Nick Heudecker, who is an analyst at Gartner, said that they were overly optimistic about the forecast and the actual failure rate is closer to 85% (Heudecker, 2017). The primary cause for the failure is not the technology but integrating with existing business processes and applications, management resistance, internal politics, lack of skills, and security and governance policies.

The list of challenges in big data projects includes a combination of the following issues:

- Lack of appropriately scoped objectives
- Lack of required skills
- The size of big data
- The non-clearly defined structure of much of the big data
- The difficulty of enforcing data consistency
- Privacy
- Data management/integration
- Rights management
- ETL
- Data discovery (how to find high-quality data from the web?)
- Data veracity (how can we cope with uncertainty, imprecision, missing details?)
- Data verification
- Technical challenges for big data analytics when data is in motion rather than at rest (Zicari, et al., 2016)

Lack of appropriately scoped objectives is one of the most common problems encountered in Big Data projects. In this context, a big data project, as in any project, should also have a clearly defined business objective. The problem to be solved must be identified. New insights can be discovered through data analysis, but to uncover meaningful insights, the data should be collected and analyzed keeping the main problem in mind. As mentioned before, the whole system should be designed around the main problem and during the development phase should avoid using experimental development with new technologic features. Because those experimentations can result in project delays and getting the project away from the main problem.

Lack of required skills is also one of the most common problems for Big Data projects. It is essential to employ people with required skills during a big data project. As is known, big data is a rapidly evolving field of technology; an inexperienced project staff may be lost in this bottomless technology. This situation can cause severe time delays or project failures.

Management failures and lack of required skills can have disastrous consequences. In 2013, UK National Health Service abandoned NHS patient record system project. The project was initially expected to be completed with a £6.4 billion, had a cost of £10 billion when the government decided to shut it down (Syal, 2013). The project is described to be "the biggest IT failure ever seen" and the failure ultimately came down to human error. The system was left in the incapable hands of successive ministers, and civil servants who saw the costs continue to spiral as the new systems were badly managed, as well as data management issues and patient confidentiality problems.

In big data projects, the size of big data is very critical. Some specifications should be set according to the size of the data, and some of them should set at the beginning of the project. Planning of needs such as server capacity, database settings, selection of the algorithms is essential. On April 30, 2014, In the Los Angeles International Airport (LAX), all computers crashed, and this situation caused hundreds of delayed or canceled flights. The reason of the crash is the bug in the En Route Automation Modernization (ERAM) system which developed by Lockheed Martin Corp and worth 2.4 billion dollars. In that day, a U-2 spy plane was flying through to the airspace of LAX, ERAM notices the plane and trying to set altitude information in the airplane's flight plan. During this process, the system got many errors. An air traffic controller noticed the problem and entered the estimated altitude of the plane manually. After that, the system started to work on the calculating possibility of flight paths with other planes for avoiding crashes. As a result of this enormous calculation, the system fell short in memory and blocked every other flight process at the airport. The reason of ERAM's system failure was about limiting the size of data that planes send. Most planes have a simple flight plan, but that day, the U-2 spy plane had a complex one. As a result, faced with the unexpected size of data caused physical damage via delayed and canceled flights (Hamrouni, 2017).

Another major cause of a big data project to fail is poor data quality or having inaccurate, incomplete or outdated data to analyze. To be able to influence business actions, data analysis should lead to insights. Although there are some commonly accepted tools and techniques to increase the quality of data; the initial dataset should be consistent and have enough volume depending on the needs of the project.

In 2014, a credit card offer was sent to a journalist known as Lisa McIntire who lives in California. The offer was from Bank of America but posted by Golden Key International. Mail sent to Lisa's mother's address and addressed to "Lisa is a Slut McIntire". After her mother sent the picture of it, the journalist posted photos of the offer via social media. As a result, the dirty data problem caused failure and loss of prestige. Through this example, it is seen that data quality and veracity are significant factors for project success (Reddy, 2014).

Most of these reasons, which cause the failure of a project would disappear through the adaptation of project management processes as described by PMI. Next section focuses on the importance of big data project management and adaptation of project management processes to big data projects.

PMI APPROACH TO MANAGE BIG DATA PROJECTS

Big Data projects are specific IT projects. One should consider the following impacts of big data in the project management efforts, addressing the challenges summarized above, to successfully manage and finalize a project. The following table summarizes common phases of a big data project and the relation of each process to challenges and domains. Each process step has particular challenges in different domains, related to unique properties of big data.

ETL phase in Table 1 includes processes to prepare raw data for processing. Analytics phase is to extract information from the big data. Decision making phase is to evaluate the outcome of the analytics phase for insights. These phases are minimum for a big data project; other phases might be needed depending on the planned output of the project.

Project Management Body of Knowledge (PMBOK) Guide divides the project management process into five process groups and ten knowledge areas. Project management knowledge areas focus on areas of specialization for a project manager. PMBOK Guide is based on The Standard for Project Management and provides details about key concepts, trends, and considerations for project management processes and applies to projects from all industries and sectors (Project Management Institute, 2017a). This section investigates how one would answer the issues faced during the management of a big data project. The points to be noted are listed for each knowledge area, namely: Project Integration Management, Project Scope Management, Project Schedule Management, Project Cost Management, Project Quality Management, Project Resource Management, Project Communications Management, Project Risk Management, Project Procurement Management, and Project Stakeholder Management.

PMI's Pulse of the Profession Report (2017) suggests that organizations become more mature with their project management practices distinguish more successful project performance. Champions of the study have 80% or more of the projects completed on time and budget and meeting original business goals (Project Management Institute, 2017c).

1. Project Integration Management

Project Integration Management knowledge area includes the processes and activities to identify, define, combine, unify and coordinate various activities. This knowledge area contains Develop Project Charter, Develop Project Management Plan, Direct and Manage Project Work, Manage Project Knowledge, Monitor, and Control Project Work, Perform Integrated Change Control and Close Project or Phase

Table 1. Big Data Project phases, processes, challenges and domains

Phase	Process Step	Challenge	Domain			
			People	Process	Technology	GEIT
ETL	Capture and storage	Volume, Velocity, Variety	X	X	X	X
	Conversion and transformation	Variety, Velocity		X	X	X
	Cleansing and enrichment	Veracity, Volume	X	X	X	X
Analytics	Data profiling	Variety, Volume	X	X	X	
	Statistical modeling	Variety, Veracity	X	X	X	
	Algorithm / query development	Variety, Velocity, Veracity			X	X
Decision Making	Visualization	Variety, Veracity	X	X	X	
	Interpretation	Variety, Volume, Veracity	X			
	Automation	Volume, Variety, Velocity, Veracity		X	X	X

Source: (Voges, 2014)

processes (Project Management Institute, 2017a). Project Integration Management is the coordination of all elements within a project. From the perspective of a big data-oriented software development project, the following processes have a crucial impact on the outcome.

Develop project charter process binds the project to a business case. Some big data projects fail due to lack of a business problem as described above. Hence, clearly defining a business objective is a crucial part of a successful big data-oriented project.

Manage project knowledge process uses existing knowledge to contribute to organizational learning. Assets such as lessons learned from similar projects help to define clear objectives and apply relevant techniques in a big data project. Use of new technologies brings new knowledge to the organization, which makes transferring of knowledge a crucial point. Knowledge can be transferred in a written form as in documentation, knowledge base or best practices document, as well as internal training or coaching. PMI's 2015 report states that effective knowledge transfer increases the chance of project success by over 20% (Project Management Institute, 2015).

Close project or phase process finalizes a contract, a phase or a project. The team updates organizational process assets, and lessons learned register, thus enabling big data related know-how to propagate within the organization.

Integration of big data technology with existing tools and techniques within the company is also an issue of a big data related project that should be solved within Integration Management processes. Various big data integration tools facilitate the integration of big data processing solutions, applications, and databases. The complete ecosystem for the project must be planned.

2. Project Scope Management

Project Scope Management knowledge area processes are required to make sure the project includes all the necessary work to complete the objectives. This knowledge area contains Plan Scope Management, Collect Requirements, Define Scope, Create WBS, Validate Scope and Control Scope processes. (Project Management Institute, 2017a). One should consider the scalability and performance needs of a big data project, as well as other business and functional requirements. Also, additional steps for collecting and preparing big data should be included in the scope. Common steps for big data management are listed below:

- **Data Generation:** Identifying data sources and collecting data.
- **Data Acquisition:** Aggregate information in a digital form for further storage and analysis. This step includes pre-processing the data; such as conversion and cleansing operations.
- **Data Storage:** Organizing the collected information in a convenient format for analysis and value extraction.
- **Data Analysis:** Applying tools and techniques on data, to extract information enabling decision making (Hu, Wen, Chua, & Li, 2014).

Project scope management is crucial for all the project's lifecycle. According to PMI's 2017 Pulse of the Profession (Project Management Institute, 2017c), only 69% of projects meet their original goals and business intent. This statistic shows that enough importance is not given to scope management. In addition, various sources indicate that lots of projects could fail or over budget for this reason. Because of the reasons above and the complexity of big data projects, it is critical to qualify the scope carefully and thoroughly.

3. Project Schedule Management

Project Schedule Management knowledge area processes are required to make sure the project is completed within an estimated period. This knowledge area contains Plan Schedule Management, Define Activities, Sequence Activities, Estimate Activity Durations, Develop Schedule and Control Schedule processes (Project Management Institute, 2017a).

The team might not be able to use expert judgment to define required activities or estimate activity durations clearly if the current know-how level of the company is insufficient for the big data project during the planning phase. Therefore, Define Activities and Estimate Activity Durations processes should require the use of iterative techniques such as rolling wave planning or progressive elaboration. Both methods start with an overview and then give a higher level of detail as the project evolves.

In the literature, there are some proposed best practices for IT project estimation. These practices also apply to Big Data Projects. Some critical points for estimation are:

- Create a higher-level plan and estimate large tasks in a range
- Involve people doing the work in estimation processes
- Bring in experts and use Delphi Method
- Construct the estimates based on the application's architecture, modules and programming language (Trotsyuk, 2009)

Paying particular attention to automated testing, security and backup procedures eliminates some potential flaws from the beginning and reduces the risk of schedule overrun in a big data project. After choosing the time management method, a project manager should clarify the expectations of stakeholders. Setting priorities and adjusting the project schedule plan when necessary helps to keep the project on the plan. Periodical time tracking activities and review sessions ensure the project is progressing as planned (Tremel, 2016).

4. Project Cost Management

Project Cost Management knowledge area includes processes that are required to make sure the project is completed within the planned budget. This knowledge area contains Plan Cost Management, Estimate Costs, Determine Budget and Control Costs processes (Project Management Institute, 2017a).

Project scope, schedule, and costs are all related. A change in scope affects both project schedule and cost. The term "triple constraint" is widely used to refer to these three main restrictions of a project. Big Data projects often have hidden cost and complexity, which makes planning and controlling costs throughout the project harder.

In the estimation process, historical values for a similar project might not be present for a big data project. Using expert judgment also might not be an option is the team lacks the required know-how for a big data project. Reserves should be carefully planned with buy-in from the management. Thus, rolling wave and progressive elaboration techniques should be preferred for work with high uncertainty when possible.

As raw data is increasing in size, traditional data warehousing solutions become inadequate. Companies turn to cloud storage solutions, which increase the costs of additional integration requirement and usage license fees. As data privacy becomes an issue and several countries have strict regulations about data privacy; organizations also need to invest in data security. Proper licensing options should be considered according to the needs of the project. The project managers need to identify and review these costs to keep the project on budget.

Human resource costs have a big part in a big data project budget. Such projects mostly deploy staff with different expertise such as database analyst, data scientist, software architect, software engineer, system administrator, QA and test engineer, and project manager. A small delay in a milestone would lead to a big cost increase. Hence, scope and schedule management have a greater impact on project cost management for a big data project.

5. Project Quality Management

Project Quality Management knowledge area processes support continuous process improvement activities while ensuring the organization's quality policy applies to the project. This knowledge area contains Plan Quality Management, Manage Quality and Control Quality processes (Project Management Institute, 2017a).

Since big data projects mostly involve high uncertainty, producing frequent and small deliverables for inspection makes it easier to meet the business needs and stakeholder objectives.

Field expertise is required to identify special quality requirements of a big data project such as data usability and system resource allocation, which is also in the scope of Quality Management. Tao and Gao summarize the quality factors for a big data application project to be:

- System Performance
- System Data Security
- System Reliability
- System Robustness (Tao & Gao, 2016)

Domain-specific quality metrics should be defined, including both data validation and system performance to assure quality.

6. Project Resource Management

Project Resource Management knowledge area includes processes to ensure that the resources needed for the completion of the project are available when needed. This knowledge area contains Plan Resource Management, Estimate Activity Resources, Acquire Resources, Develop Team, Manage Team, and Control Resources processes (Project Management Institute, 2017a).

The project manager should plan license and server needs as well as team resources for a successful big data project when estimating activity resources. Team development should be planned including big data related education needs for project team members depending on the team expertise level. Note that, selected team members have a more significant impact on project plan than usual. Tom Deutsch, Program Director on IBM's Big Data team, claims to "select the people before the technology" (Deutsch, 2012). Managing the team also differs from the usual software development projects, as the team consists of people with different background and expertise from various areas. There should be resources with the right blend of talent and skill sets already available, or management should have a training plan, ensuring the readiness of resources with the right skill set for the project.

7. Project Communications Management

Project Communications Management knowledge area processes ensure effective information exchange throughout the project. This knowledge area contains Plan Communications Management, Manage Communication, and Monitor Communications processes (Project Management Institute, 2017a). Project communication should be carefully planned, considering the needs and expectations of stakeholders. Because big data is a new and complex field, project communication management is critical for big data projects. Also, internal policies causing resistance encountered during big data projects can be minimized by applying communications management processes.

PMI's *The Essential Role of Communications report* (2013) finds that effective communication is the most crucial success factor in a project. Due to ineffective communications, 56% of each dollar spent on projects is at risk. The same report recommends the following strategies to improve communication in a project:

- Close the communications gap around business benefits
- Tailor communications to different stakeholder groups
- Acknowledge the value of project management, including project management communications
- Use standardized project communications practices, and use them effectively (Project Management Institute, 2013)

As stated before, big data projects are developed by cross-functional, multi-disciplinary teams. Project managers with both technical and business understanding are required to successfully run projects including people from different fields.

8. Project Risk Management

Project Risk Management knowledge area processes aim to enhance the chance of project success and decrease the probability and impact of negative risks. This knowledge area contains Plan Risk Management, Identify Risks, Perform Qualitative Risk Analysis, Perform Quantitative Risk Analysis, Plan Risk Responses, Implement Risk Responses and Monitor Risks processes (Project Management Institute, 2017a).

The team should consider additional risks raised from big data infrastructure, security constraints and lack of know-how in the field. Mark Vael summarizes the process to address risk and improve the organization's ability to use big data so that it can meet its business objectives as:

- Provide insight by monitoring all data that runs in the company; analyze and then take action based on the results if the organization's big data security policies and procedures are still under construction.
- For data to be used productively, the organization needs to consider a corporate data lifecycle process, including big data systems.
- Organizations should seek advice and guidance of external data experts when needed.

- Organizations must get a proper insight into the performance of their data handling processes to minimize the risks.
- Make sure that the organization's employees, data, networks, partners, and customers are protected end-to-end.
- Ensure future-proof systems by not only using the right systems, but also the right tools and processes are implemented for big data today and can cope with the inevitable data growth in the future.
- Implement logical and physical access security controls to prevent unauthorized access to sensitive and valuable data. (Vael, 2013).

9. Project Procurement Management

Project Procurement Management knowledge area includes processes to purchase or acquire products, services or results needed from outside the project team. This knowledge area contains Plan Procurement Management, Conduct Procurements and Control Procurements processes (Project Management Institute, 2017a).

The project team needs to decide the infrastructure required for the solution addressing the business needs first. Although cloud solutions are popular and easy to access, regulations should force on-premise solutions. Hybrid solutions should also be considered. All three infrastructure solutions require different procurement process. The project team should consider the technologies to be used and address needed procurement steps in the planning phase.

Vendor management is a troublesome issue for big data projects, as it is for many IT projects. Vendors may not have required qualification or expertise. According to Ron Bodkin, many legacy consultants and system integrators have positioned themselves as experts, despite their lack of skills. In addition to that, many established product vendors are marketing their products as "big data" when they are in fact not (Bodkin, 2013). Vendor selection should be carefully planned and executed to minimize possible vendor related problems.

10. Project Stakeholder Management

Project Stakeholder Management knowledge area processes are required to identify and manage stakeholders affected by the project. This knowledge area contains Identify Stakeholders, Plan Stakeholder Engagement, Manage Stakeholder Engagement, and Monitor Stakeholder Engagement processes (Project Management Institute, 2017a).

A primary reason for big data projects to fail is lack of support from the management. Managers of big data projects should focus on gaining support from all project stakeholders, based on their needs and expectations from the project. Inaccurate stakeholder analysis or failing to understand the needs of the most critical stakeholders based on a power/interest grid are other main reasons why a big data project may fail. The project manager also needs to understand the different needs of stakeholders from various fields. Both the data required by the data scientist and a business requirement set up by the client are all significant and require special attention.

To sum up, the effective use of project management processes as described in PMBOK (Project Management Institute, 2017a) increases the overall project success rate. Application of proven project management practices leads to less waste and greater success according to PMI's Pulse of the Profession 2018 report. The report also states that success is no driven by a single factor (Project Management Institute, 2018). Project managers need to apply suggested processes through initiation to closure phase for a successful outcome.

FUTURE RESEARCH DIRECTIONS

Organizations are going through changes in the era of digitalization and Industry 4.0. Companies seeking competition should adapt to the changing world, taking actions to meet changing customer and market demands. As the world trend is changing, project managers should embrace change. Companies worldwide are going through a set of changes; which is called "digital transformation". Digital transformation involves using digital technologies to redesign a process, aiming to transform that service into a significantly better experience. More and more real-time data will be available as a result of such transformations. Research areas such as big data, cloud computing, Internet of Things, machine learning and artificial intelligence will come into prominence.

Initial research in digital transformation project management field concludes that management of projects requires new ways of managerial thinking (Hassani, El Bouzekri El Idrissi, & Abouabdellah, 2017). Mark A. Langley; President and CEO of PMI states that digital transformation projects have unique challenges and proper project management is required to ensure that the organizations take critical steps to achieve desired results with digital transformation (Langley, 2018).

Project managers are expected to embrace the digital transformation of their company and lead the change. The role of a project manager in digital transformation and the obstacles a company faces during the transformation phase is an emerging research area, which requires further investigation.

Another emerging research and application area are the use of agile practices in project management. Although the Agile Manifesto for software development (Beck, ve diğerleri, 2001) expressing definitive values and principles of agile was published decades ago, effective use of agile and delivery of immediate value to customers become a hot topic in recent years. PMI extended the PMBOK Guide with Agile Practices Guide in 6th edition, only last year. PMI claims that organizations need to shift their focus from internal to outward customer experience, to stay competitive and relevant (Project Management Institute, 2017b). Therefore, further investigation on the use of agile practices for big data projects is a field which requires further research.

CONCLUSION

With the increasing of big data usage, organizations will have more opportunities to manage their businesses better, and the importance of big data projects will increase. Especially in the Industry 4.0 era, a number of IoT devices and big data projects are expected to be mounted. In addition, big data tools will positively affect project management periods like reducing complexity, and they will help in creating successful projects.

In the big data concept, data is large, complex and grows exponentially in a short time. Because of these facts and reasons which will be mentioned in the sections above, managing big data projects are challenging. In this context, various sources report that 65-100% of Big Data Analytics projects fail every year.

There are many reasons for Big Data projects to fail; such as lack of binding the project to a well-defined business objective, management problems or stakeholder engagement. This study investigated how the PMI approach can be effectively adapted to big data projects. With the application of processes in the knowledge areas of Project Integration Management, Project Scope Management, Project Schedule Management, Project Cost Management, Project Quality Management, Project Resource Management, Project Communications Management, Project Risk Management, Project Procurement Management and Project Stakeholder Management, it is proven that possible causes of failure would be eliminated in the early stages of the project, increasing the success rate.

ACKNOWLEDGMENT

This research is supported by Cerebro Software Services, Inc.

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KEY TERMS AND DEFINITIONS

Big Data: Big data is data that contains huge, variable and growing data.

Big Data Analytics: Big data analytics is the process of analyzing big, complex and variable data.

Big Data Analytics Projects: Projects that related to big data analytics.

Big Data Projects: Projects that focus on big data.

Data Analytics: Data analytics is a process that examines, clears, converts and models data to explore useful information, draws conclusions and supports decision making.

ETL: Short for "Extract, Transform, Load", ETL is a process in database usage to prepare data for analysis.

GEIT: Short for "governance of enterprise IT", GEIT is a framework which ensures that the IT resources of an organization are used in an effective way to fulfill stakeholder needs.

Progressive Elaboration: A project management technique, which involves continuously improving and detailing the plan as more detailed and specific information becomes available.

Project Management: Project Management is the planning, reporting, and control of project activities to reach the project goals.

Project Management Body of Knowledge (PMBOK): PMBOK is a book which published by PMI that contains world's well-known project management standards.

Project Management Institute (PMI): PMI is a not-for-profit association that accept professional membership for project and program managers.

Rolling Wave Planning: A project management technique that plans the project in waves, as the project proceeds and details become clearer.

Chapter 16

Scrutinizing the Barriers That Impede Industry 4.0 Projects: A Country-Wide Analysis for Turkey

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ABSTRACT

The concept of Industry 4.0 has recently attracted attention from academics, research institutions, and companies. In order for projects to achieve success in Industry 4.0, project specifications must be known and they must be conducted with utmost care. While Industry 4.0 projects ensure lots of advantages, they encounter many risks such as data integration, process flexibility, and security problems. Identification of barriers to Industry 4.0 is important for the success of the projects. The aim of the chapter is to determine the Industry 4.0 barriers in implementation process in Turkey's conditions investigate the interrelations among them and develop a model that can measure the interacting effects of the barriers on the other barriers in the Industry 4.0 implementation process. To reach that aim, interpretive structural modeling (ISM) and decision-making trail and evaluation laboratory (DEMATEL) are used. According to results, one of the most important findings is the lack of digital vision which found as the only affecting barrier and it affects all the other barriers.

DOI: 10.4018/978-1-5225-7865-9.ch016

INTRODUCTION

There are many different definitions of project in literature. According to Project Management Institute Global Standard (2008), a project is defined as *"a temporary endeavor undertaken to create a unique product, service or result"*. Tuman (1983) states that *"A project is an organization of people dedicated to a specific purpose or objective. Projects generally involve large, expensive, unique, or high risk undertaking which have to be completed by a certain date, for a certain amount of money, with some expected level of performance"*. In its broadest definition, a project is defined as *"a specific, finite activity that produces an observable and measurable result under certain preset requirements"* (mymanagementguide.com, 2018). Project management is the discipline of planning, organizing, procuring and managing resources to reach and complete the goals and objectives of a specific project (Gencer and Kayacan, 2017).

The relevant literature review reveals that the characteristics of project management are discussed by many academicians. Project management characteristics are essential for project manager to successfully complete a project. Main characteristics of project management could be highlighted as follows *"temporariness"* (Kırmızı, 2012; Roudias, 2015; Epstein, 2015; mymanagementguide.com, 2018), *"progress elaboration"* (Kırmızı, 2012; mymanagementguide.com, 2018), *"minor changes"* (Kırmızı, 2012; Roudias, 2015), *"uniqueness"* (Roudias, 2015; Epstein, 2015), *"single definable purpose"* (Kırmızı, 2012; Epstein, 2015), *"familiarity"* (Epstein, 2015), *"uncertainty"* in some parts of the project, *"cross functionality"* (engages people from different seniority and departments) (Rouidas, 2015), *"appropriate resources"* and *"available budget"* (Kırmızı, 2012). Additionally, Tukel and Rom (1998) have conducted a nationwide survey to identify and categorize the characteristics projects in diverse industries. They conclude that projects in diverse industries have different characteristics, and though many common project characteristics exist, there are remarkable differences in projects across industries.

Project management is used by organizations as a tool to increase productivity (Frame, 1995; Mir and Pinnington, 2013), and the ultimate objectives of industry 4.0 projects, in parallel with project management, are to reduce costs, to increase the efficiency of the field or to reduce the used area, to reduce energy use, to work at high speed and reliability, and to produce more efficient and better quality (Yılmaz, 2016). According to Al-Nasseri and Aulin (2016), along with the stated advantages of project management, there are some obstacles encountered in the process of developing, implementing and controlling the stages of the project. The barriers of development and implementation stages of project management are *"lack of effective leadership"* (Voth, 2009; Müller and Turner, 2010), *"insufficient support from project stakeholders in the development of plans and schedules"* (Iyer and Jha, 2006; Davis, 2014), *"poor decision-making regarding activity critically"* (Hameri and Heikkila, 2002; Gonzalez et al., 2014), *"lack of education and training in planning and scheduling"* (Nepal et al., 2006; Hameed, 2005; Yang et al., 2011), *"incompatibility of planning methods with the naturepf the project schedule"* (Jurf and Beheiry, 2012; Burke, 2003), *" the absence of schedule contingency"* (Hoel, 1999; Mulholland and Christian, 1999), and "*the absence of resource-constrained scheduling for dealing with uncertainty problems"* (Elmaghrab et al., 2003; Abeyasinghe et al., 2001). Barriers of developing and controlling stage of project management are *"lack of effective leadership"* (Voth, 2009; Müller and Turner, 2010), *"lack of education and training in planning and scheduling"* (Nepal et al., 2006; Hameed, 2005; Yang et al., 2011) and *"the absence of new technology and software for planning and scheduling"* (Noronha and Sarma, 1991; Taroun, 2014; Makhtari et al., 2011). Barrier of controlling stage of project management is *"trivial control and reporting system between management levels"* (Voth, 2009; de Snoo et al, 2011). These barriers are also influential in the implementation of industry 4.0 projects, and are therefore similar to the barriers of industry 4.0 projects.

Industry 4.0, emerged in Germany, is widely known in Europe and its importance has rapidly been recognized by the global scale (Morrar et al., 2017). The Industry 4.0 projects which offer better quality, faster, cheaper and more efficient production and aim flexibility, speed, sustainable competitive advantage and personalized solutions (Evans, 2017; Bernardini, 2015), should be examined in the scope of project management. According to Kelly (2017), Industry 4.0 project teams should implement big data and analytics, should use Industrial Internet of Things (IoT) experience through personal work, open source projects or side projects, should use mobile devices as the primary interface for some of the major systems and use automation and cloud software systems to make the teams and organizations think more strategically. As project managers increasingly need to use digital products to organize company structures (IAPM, 2017), industry 4.0 activities and project management concepts have become related to each other. The concept of industry 4.0, where digitalization is at its core, integrates production systems with state-of-the-art information and communication technology (Tusiad, 2016). And this digitalization won't only affect the physical world, it also will change the way of working radically (GPM, 2017). More simplified data management; less costly and more personalized solutions, greater automation of more intensive labor processes and the introduction of greater opportunities for taking measures that simplify all these processes are among the main advantages of digitalization (IAPM, 2017). So, in this new digitized world, the importance of projects will grow as every single case of industry 4.0 implementation consists of systematic and planned combination of multiple technologies (GMP, 2017).

On the one hand, Industry 4.0 projects ensure lots of advantages, on the other hand, however, they face many risks (PwC, 2016). According to Khan and Turowski (2016), the risks available for Industry 4.0 are data integration, process flexibility, and security problems. Industry 4.0 risks are divided into physical risks and information technology (IT) related risks (PwC, 2016). Physical risks contain investment, capital and employee risks. For the projects to be successful, the people in the project should feel safe and motivated. For successful projects, a step-by-step approach should be adopted to identify, improve and solve existing problems. It is very important to understand the hierarchical and contextual relationship between potential barriers in order to remove these difficulties altogether (Khan and Turowski, 2016). On the other hand, IT risks related with cyber-securtiy and customer privacy may influence the industrial manufacturing process (Tupa et al., 2017). These risks of Industry 4.0 can cause major failures if not considered a threat (Engelbertink and Woudstra, 2017).

In order for these risks to be removed and perceived as threats, the barriers in front of Industry 4.0 projects need to be known and removed. For this reason, the question of research is "What are industry 4.0 barriers and how do they impede Industry 4.0 projects?" The aim of the study is to determine the industry 4.0 barriers in implementation process in Turkey's conditions. The study aim to find the relationships between the obstacles identified as a result of the literature review and to develop a model that can affect the barriers of obstacles on the industry implementation process. The study consists of four chapters. First of all, a literature search was made about industry 4.0 barriers, and secondly the research methodology was determined. As a result of the interviews with 14 experts, the findings were demographically given. ISM method was applied to determine whether pre-determined barriers influence one another and investigate effect ratings and establish a model for the causal relationship between them and using the DEMATEL method, the intensity and level of interaction between the barriers and the intensity of the interactions they produce are quantitatively determined.

LITERATURE REVIEW

The identification of the factors affecting the success of enterprises in the transition to Industry 4.0 and their understanding of the effects of these factors is an important issue in terms of the effectiveness of the transition to Industry 4.0. According Koçak and Diyadin (2018), the critical success factors of Industry 4.0 are strategic vision, organizational structure, horizontal integration in value chain, vertical integration, information system and technological infrastructure, smart factories, large data management, qualified work force structure and security. These critical success factors are crucial to the management of a successful Industry 4.0 project and to remove the obstacles identified in the literature.

When the literature on this new concept is examined, it has been found that the literature focuses more on conceptual content, purposes and possible outcomes, and it is seen that there is a gap in the literature about barriers. This limited number of studies has mostly been carried out by group consulting companies in such countries as Germany and Denmark (BCG, 2016; McKinsey, 2016). A thorough analysis of these studies reveals that industry-wide studies have been conducted on manufacturers (McKinsey, 2016; BCG, 2016) and some major industrial sectors like technology suppliers (Pwc, 2016; McKinsey, 2015). Country-wide studies are also available in the literature (European Parliament, 2016; WEF, 2016; Tusiad, 2016). In addition, industry 4.0 barriers have been discussed in studies carried out by companies such as the PWC, the CNI and the World Economic Forum with more than one country and with a large number of participants (PWC, 2014; CNI, 2016; WEF, 2016).

Industry 4.0 projects ensure lots of advantages but also they encounter many risks such as data integration, process flexibility, security problems. These risks of Industry 4.0 can cause major failures if not considered a threat. Identification of barriers to industry 4.0 is an important issue for the success of the projects. The main reasons for uncertainty are the uncertain cost advantages of high investment levels and industry 4.0 application areas. Labor force does not have sufficient skills to deal with industry 4.0, and shortcomings in standardization create uncertainty in institutions (Kamble et al., 2018). The challenges related to competitiveness and future viability, organization and production compliance prevent industrial manufacturers from applying Industry 4.0 independently from the size of the company (Müller and Voigt, 2018). According to Sund (2017), complexities of combining new and legacy systems, security policy flexibility and regulatory hurdles are main barriers to implement Industry 4.0. There are five common mistakes in the implementation of Industry 4.0 that prevent this opportunity from being fully exploited lack of strategic direction, incorrect technological assessment, lack of forecasting and measurement of impacts, failure to aim for short term results and failure to plan for operation and deployment of solutions (Gaitan and Martinez, 2018).

Lack of necessary talent, lack of clear business case, high entry costs, lack of legal framework, unclear economic benefit, concerns about cyber-security and concerns about intellectual property are demonstrated as the main industry 4.0 barriers in all these studies (see Table 1). Exceeding all identified barriers will help in the successful implementation of Industry 4.0 (Kamble et al., 2018).

According to Standish Group Massachusetts studies, 80% of all IT projects have failed, 50% of them overspent and missed their deadlines and 30% of these projects have concluded with no results (Gentner, 2016). Considering that the concept of the industry 4.0 includes the concept of IT, it is thought that it is necessary to analyze what causes these projects failure. The determination of industry 4.0 barriers and the interaction between these barriers is vital to reduce ambiguities in order to avoid or minimize these failures in projects under Industry 4.0. According to Davies (2015), if it can overcome these barriers,

Table 1. Barriers of Industry 4.0 Projects

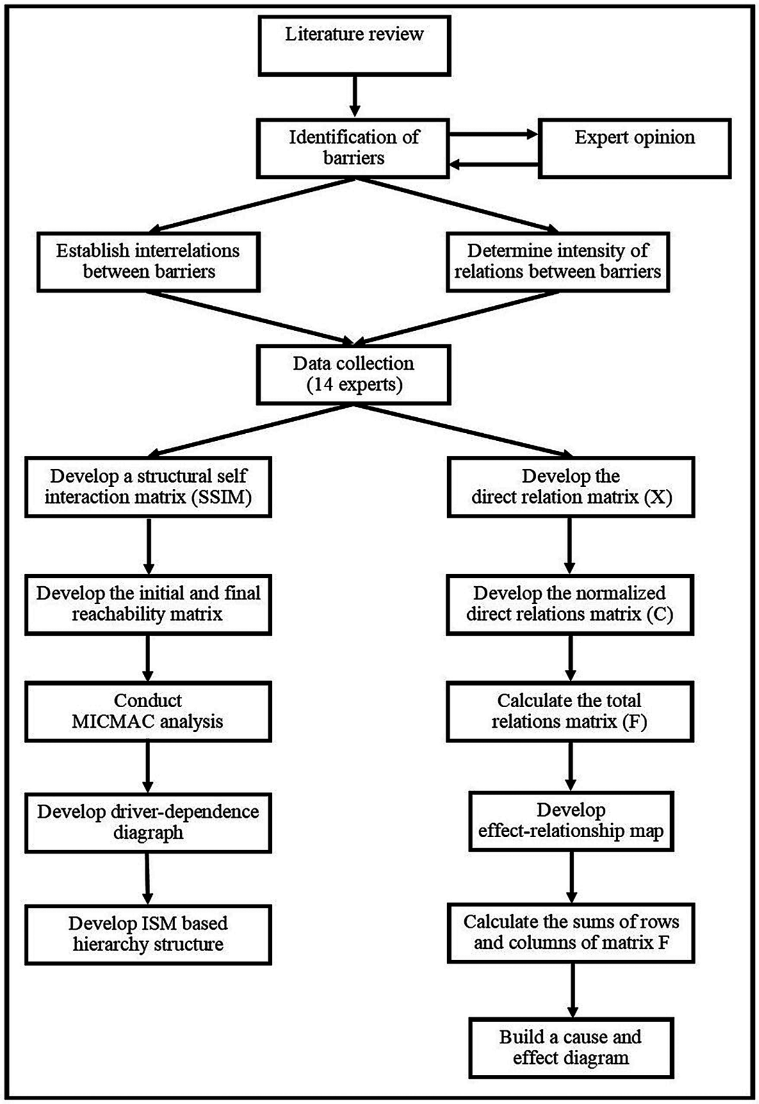
Barriers of Industry 4.0 Projects	Relevant Studies
Lack of Necessary Talent	McKinsey, 2016; PwC, 2014,2016; BCG, 2016; European Parliament, 2016; World Economic Forum, 2016; Tusiad, 2016, 2017; Brunelli et al., 2017; Slusarczyk, 2018
Concerns about Cyber-Security	McKinsey, 2015, 2016; PwC, 2014, 2016; European Parliament, 2016; CNI; 2016; Schröder, 2017; Tusiad, 2017; Slusarczyk, 2018; Kamble et al., 2018
Concerns about Intellectual Property	McKinsey, 2016; PwC, 2016; European Parliament, 2016; Schröder, 2017
Lack of Digital Vision	PwC, 2016; BCG, 2016; Schröder, 2017; Slusarczyk, 2018
Lack of Knowledge about Applications and Industry 4.0 Technologies	McKinsey, 2016; BCG, 2016; European Parliament, 2016; Tusiad, 2017; Kamble et al., 2018
High Entry Costs	PwC, 2016; BCG, 2016; European Parliament, 2016; Tusiad, 2016-2017; CNI, 2016, Schröder, 2017; Kamble et al., 2018
Unclear Economic Benefits	PwC, 2014,2016; European Parliament, 2016; CNI, 2016; Schröder, 2017; Tusiad, 2017; Slusarczyk, 2018.
Insufficient Technological Infrastructure of A Country	PwC, 2014, 2016; European Parliament, 2016; CNI, 2016; Tusiad, 2016, 2017; Slusarczyk, 2018
Lack of Organizational Structure and Culture	McKinsey, 2016; PwC, 2016; CNI, 2016; Tusiad, 2016; European Parliament, 2016; Slusarczyk, 2018; Kamble et al., 2018
Lack of Legal Framework	McKinsey, 2015; PwC, 2014, 2016; European Parliament, 2016; Schröder, 2017; Kamble et al., 2018

industry 4.0 can raise and focus more on digitization than on industrialization and help increase total value added

RESEARCH METHODOLOGY

The aim of this study is to determine the industry 4.0 barriers in implementation process in Turkey's conditions investigate the interrelations among them and develop a model that can measure the interacting effects of the barriers on one another barriers in the industry 4.0 implementation process. Some researchers (Wu et al., 2010; Xiao Yan, 2011; Hou and Zhou, 2011; Lin et al., 2012; Mehregan et al., 2014; Song et al., 2015; Cui et al., 2016; Bag, 2017; Kai et al., 2017 and Wang et al., 2018) use ISM in conjunction with DEMATEL because the former does not provide the intensity and severity of interactions between factors. Hence, in this study, it is aimed to identify the most influential barriers by utilizing multi criterion decision making tools of interpretive structural modeling (ISM) and decision-making trail and evaluation laboratory (DEMATEL). To reach this specific aim, first, a detailed literature review related with industry 4.0 barriers has been conducted in the relevant literature to identify the potential barriers. After identification of potential barriers, interrelations between these barriers have been established by using ISM and the intensity of these relationships has been determined by using DEMATEL. Both methods support collecting data through questionnaires. So questionnaire is used as data collection form in the study. Surveys are carried out through 14 participants who are specialists and academicians working in different sectors and businesses at different scales and the data collection process is completed via internet. Detailed flow schema of the study is given below Figure 1.

Figure 1. Flow Schema of the Study



Data analysis is intended to be carried out by using ISM technique to determine whether pre-determined barriers influence one another and investigate effect ratings and establish a model for the causal relationship between them. Then, using the DEMATEL method, the intensity and level of interaction between the barriers and the intensity of the interactions they produce are quantitatively determined. The relationship between the variables is summarized through combining the results.

FINDINGS

Demographical Results

To obtain ISM and DEMATEL results, the questionnaire forms have been answered by the chosen 14 Industry 4.0 specialists. Professions, businesses, working fields and experience of these specialists are given in Table 2, Table 3, Table 4 and Table 5.

21% of specialists are academicians according to Table 2. Supply chain managers, entrepreneurs and Industry 4.0 projects managers' constitute 14% of the total sample.

Table 3 reveals that the specialists have pointed out a lot of work areas, mainly science, technology, innovation and research which constitutes 18.75% of total working fields. In the field of Management

Table 2. Professions of the Specialists

Profession	Frequency	Percent
Academicians	3	21.43
Supply Chain Managers	2	14.29
Entrepreneurs	2	14.29
Industry 4.0 Project Managers	2	14.29
General Managers (Engineers)	1	7.14
Industry and Technology Experts	1	7.14
Coordinators	1	7.14
Foreign Trade Specialists	1	7.14
Executives	1	7.14
Total	**14**	**100**

Table 3. Working Fields of the Specialists

Working Field	Frequency	Percent
Science, Technology, Innovation and Research	3	18.75
Management and Organization	2	12.5
Supply Chain	2	12.5
Production Planning and Management	2	12.5
Industry 4.0	2	12.5
Digital transformation projects in industry	1	6.25
IT conversion projects	1	6.25
Software Development	1	6.25
Textile	1	6.25
computational medical	1	6.25
Total	**16**	**100**

and Organization, Supply Chain, Production Planning and Management and Industry 4.0 two specialists have been interviewed.

Table 4 indicates that 43% of the specialists have been involved in Industry 4.0 for 4 to 10 years, another 43% have been working in this field for 11 to 20 years.

ISM Results

ISM method is used to develop a model that shows the relationship between barriers that mentioned in the literature and to find out the interrelations among these barriers.

Structural self-interaction matrix in Table 5 revealed that there are 16 barriers that effect one another, 6 barriers are affected by other barriers and 23 barriers are unrelated.

There appears no relationship between the *"lack of necessary talent"* and *"Lack of legal framework"*. Additionally, *"Lack of necessary talent"* seems to be interrelated with four barriers, such as; *"Lack of digital vision", "Lack of knowledge about applications and Industry 4.0 technologies", "High entry costs"* and *"Insufficient technological infrastructure of a country"*. The *"Lack of necessary talent"*

Table 4. Experience of the Specialists

Working Years of Specialists	Frequency	Percent
4 to 10 years	6	42.86
11 to 20 years	6	42.86
More than 20 years	1	7.14
No info	1	7.14
Total	**14**	**100**

Table 5. Structural Self Interaction Matrix (SSIM)

	Barriers	2	3	4	5	6	7	8	9	10
1	Lack of necessary talent	V	V	X	X	X	A	X	V	O
2	Concerns about cyber-security		O	X	X	O	O	A	O	X
3	Concerns about intellectual property			O	O	O	O	O	O	X
4	Lack of digital vision				X	V	O	X	O	O
5	*Lack of knowledge about applications and Industry 4.0 technologies*					*O*	*X*	*X*	*O*	*X*
6	High entry costs						X	X	O	O
7	Unclear economic benefits							X	O	O
8	Insufficient technological infrastructure of a country								O	O
9	Lack of organizational structure and culture									O
10	Lack of legal framework									

Where, for any two barriers i and j;
V=Barrier i will help achieve j
A= Barrier j will be achieved by i
X= Barriers i and j will help achieve each other
O= Barriers i and j are unrelated

barrier affects three barriers, which are; *"Concerns about cyber-security", "Concerns about intellectual property"* and *"Lack of organizational structure and culture"* and affected by *"Unclear economic benefits"* barrier.

The *"Concerns about cyber-security"* is affected by "Insufficient technological infrastructure of a country". It also affects and is affected by *"Lack of digital vision", "Lack of knowledge about applications and Industry 4.0 technologies"* and *"Lack of legal framework"*. Yet, the *"Concerns about cyber-security"* barrier not related with four barriers, which are; *"Concerns about intellectual property", "High entry costs", "Unclear economic benefits"* and *"Lack of organizational structure and culture"*.

The *"Concerns about intellectual property"* barrier interrelated with *"Lack of legal framework"* while it is not related with any other barrier.

The *"Lack of digital vision"* affects *"High entry costs"* barrier. It also affects and is affected by *"Lack of knowledge about applications and Industry 4.0 technologies"* and *"Insufficient technological infrastructure of a country"*. There is no relationship between the *"Lack of digital vision"* and three barriers, such as; *"Unclear economic benefits", "Lack of organizational structure and culture"* and *"Lack of legal framework"*.

The *"Lack of knowledge about applications and Industry 4.0 technologies"* affects and is affected by three barriers, which are; *"Unclear economic benefits", "Insufficient technological infrastructure of a country"* and *"Lack of legal framework"*. Whereas it is not related with *"High entry costs"* and *"Lack of organizational structure and culture"*.

"High entry costs" barrier affects and is affected by *"Unclear economic benefits"* and *"Insufficient technological infrastructure of a country"* while not related with *"Lack of organizational structure and culture"* and *"Lack of legal framework"*.

The *"Unclear economic benefits"* is interrelated with *"Insufficient technological infrastructure of a country"* whereas there is no relationship between the barriers of *"Lack of organizational structure and culture"* and *"Lack of legal framework"*.

There is no relationship between *"Insufficient technological infrastructure of a country"* and *"Lack of organizational structure and culture"* and *"Lack of legal framework"*. There is no relationship between *"Lack of organizational structure and culture"* and *"Lack of legal framework"*.

The next step in the ISM method is to improve the initial accessibility matrix over the SSIM matrix data (Attri, et al., 2013). The initial reachability matrix obtained by substituting the values X, A, V, O over 1 and 0, and the final reachability matrix which is obtained from the initial reachability matrix and gives the driving and dependence power of each barrier is given in Table 6.

The driving power of each barrier gives the total number of barriers (including itself) which it may help realize as the dependence gives the total number of barriers (including itself), which may help realizing it (Saatçioğlu and Özmen, 2010). The driving and dependent power values obtained in this step will be later used in the analysis of the MICMAC (impact matrix multiplication applied to classification) in the classification of barriers into the four groups of autonomous, dependent, linkage and independent (driver) barriers.

MICMAC Analysis

When applying MICMAC analysis, reachability and antecedent series are detected for each barrier using the values in the initial reachability matrix. Then the barriers numbered 2, 3, 5, 6, 7, 9, and 10 positioned at the 1st level as reachability and intersection sets of them are the same. The numbers of the positioned

Table 6. Initial and Final Reachability Matrix

	Barriers	Barriers										Driving Power
		1	2	3	4	5	6	7	8	9	10	
1	Lack of necessary talent	1	1	1	1	1	1	1	1	1	0	**9**
2	Concerns about cyber-security	0	1	0	1	1	0	0	0	0	1	**4**
3	Concerns about intellectual property	0	0	1	0	0	0	0	0	0	1	**2**
4	Lack of digital vision	1	1	0	1	1	1	0	1	0	0	**6**
5	Lack of knowledge about applications and Industry 4.0 technologies	1	1	0	1	1	0	1	1	0	1	**7**
6	High entry costs	1	0	0	0	0	1	1	1	0	0	**4**
7	Unclear economic benefits	0	0	0	0	1	1	1	1	0	0	**4**
8	Insufficient technological infrastructure of a country	1	1	0	1	1	1	1	1	0	0	**7**
9	Lack of organizational structure and culture	0	0	0	0	0	0	0	0	1	0	**1**
10	Lack of legal framework	0	1	1	0	1	0	0	0	0	1	**4**
Dependence Power		**5**	**6**	**3**	**5**	**7**	**5**	**5**	**6**	**2**	**4**	

barriers are removed from the intersection and reachability series. Therefore, they are positioned at the top of the ISM model. In the second tour, barriers numbered 1, 4 and 8 positioned at the 2nd level and analysis is terminated. Levels, reachability sets, antecedent sets and intersection sets of all barriers are given in Table 7.

According to MICMAC analysis results (Figure 2), five barriers, which are; *"Concerns about intellectual property", "High entry costs", "Unclear economic benefits", "Lack of organizational structure and culture"* and *"Lack of legal framework"* are found as autonomous barriers. Autonomous barriers represent the barriers with poor driving and dependence power so they don't have much influence on the other barriers in the system. These barriers are disconnected from the system in some degree, they have a few strong or weak connections with other barriers in the system (Saatçioğlu and Özmen, 2010).

Table 7. Level Identification

Barrier	Reachibility Set	Antecedent Set	Intersection Set	Level
1	1,2,3,4,5,6,7,8,9	1,4,5,6,8,	1,4,5,6,8,	2
2	2,4,5,10	1,2,4,5,8,10	2,4,5,10	1
3	3, 10	1,3,10	3, 10	1
4	1,2,4,5,6,8	1,2,4,5,8	1,2,4,5,8	2
5	1,2,4,5,7,8,10	1,2,4,5,7,8,10	1,2,4,5,7,8,10	1
6	1,6,7,8,	1,4,6,7,8	1,6,7,8,	1
7	5,6,7,8,	1,5,6,7,8	5,6,7,8,	1
8	1,2,4,5,6,7,8,	1,4,5,6,7,8	1,4,5,6,7,8	2
9	9	1,9	9	1
10	2,3,5,10	2,3,5,10	2,3,5,10	1

In the second group, there is only one barrier which is *"Concerns about cyber-security"*. This dependent barrier represents the barrier with poor driving but strong dependence powers. Concerns about cyber-security barrier is at the top (1st) level in ISM hierarchy and shows high dependence on the other barriers.

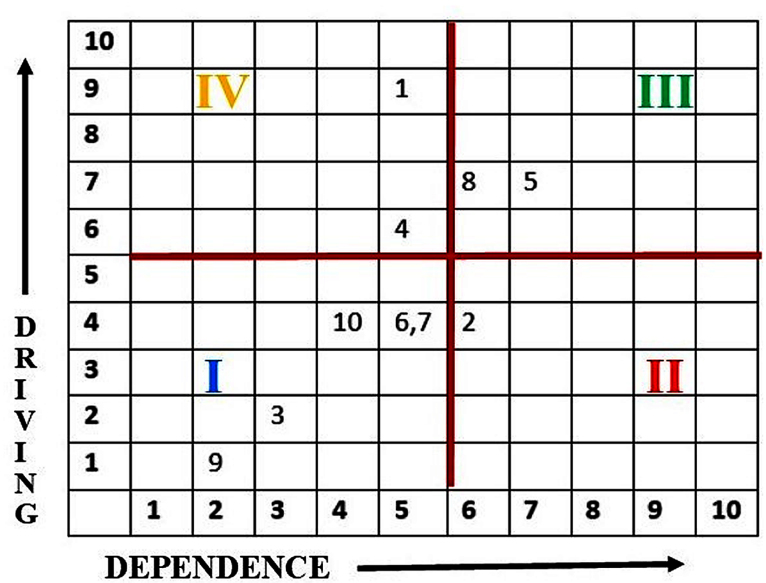
In the third, Linkage group represents the barriers with medium driving and dependence power and there are two barriers in this group, which are; *"Lack of knowledge about applications and Industry 4.0 technologies"* and *"Insufficient technological infrastructure of a country"*. According to Saatçioğlu and Özmen (2010), these third group barriers are unstable and any action on these barriers will have an effect on others immediately, so a little change and improvement about technological awareness and technological infrastructure in Industry 4.0 concept affects the system in a considerable manner.

Two barriers are demonstrated in the fourth group. These independent group barriers represent the barriers that have greater driving but poor dependence power. *"Lack of necessary talent"* and *"Lack of digital vision"* barriers belong to this independent group. As barriers in this group have greater driving powers, these barriers need to be considered as priority and they are positioned at the bottom (2nd) level of ISM hierarchy. The development of strategies to overcome these barriers has been shown to contribute to the evolution of the industry 4.0 concept.

ISM Modelling

According to level identification results shown in Table 8, ISM-based hierarchy structure between the ten barriers are created and given in Figure 3. In the second and bottom level, there are *"Lack of necessary talent"* (barrier 1), *"Lack of digital vision"* (barrier 4) and *"Insufficient organizational structure of a country"* (barrier 8), and there are two-sided relations between all these barriers. These three barriers are highly dependent on the barriers that are positioned at the first level of the hierarchy. Also they affect all the other barriers in the system.

Figure 2. MICMAC Analysis (Driver - Dependence Diagram)



First level of the hierarchy has seven Industry 4.0 barriers. Assessing *"Concerns about cyber-security"* (barrier 2), *"Concerns about intellectual property"* (barrier 3), *"Lack of knowledge about applications and Industry 4.0 technologies"* (barrier 5), *"High entry costs*" (barrier 6), *"Unclear economic benefits"* (barrier 7), *"Lack of organizational structure and culture"* (barrier 9) and *"Lack of legal framework"* (barrier 10) will help to improve effectiveness and performance of all industry 4.0 system. All one-sided and two-sided relations between these barriers are given and detailed in Figure 3, ISM-based hierarchy structure.

DEMATEL Results

To create visible structural models of cause and effect relationships of the given barriers DEMATEL method is used in the study. As a first step of this method, the direct relation matrix (X) is given in Table 8, created by taking the arithmetic mean of the points, collected from the experts, on the binary comparison scale. The maximum value of each row and each column of this (X) matrix is determined as the "s value" (Karaoğlan and Şahin, 2016). Thus, total values of each row and column are calculated and "S value" is determined as 36.78.

The normalized direct relationship matrix (C) obtained by dividing each element of the direct relation matrix by 36.78 which is known as s value, is shown in Table 9.

After creating C Matrix, to obtain Total Relation Matrix (F), $F = C\left(I - C\right)^{-1}$ equality is applied. The obtained Total Relation Matrix is given in Table 10.

In order to construct the effect relationship map, the threshold value of 0.1843 which is the average of the values of the Total Relation Matrix, is taken as the threshold value. While the relationships below this value are ignored, the effects of the relationships that are above this threshold value are divided in three groups. Medium, strong and very strong degrees of relationships are shown in Figure 4.

In order to create DEMATEL causality diagram, total of row and column values of Total Relation Matrix are calculated to obtain D and R values. These D, R, D+R and D-R values are given in Table

Figure 3. ISM- based hierarchy structure

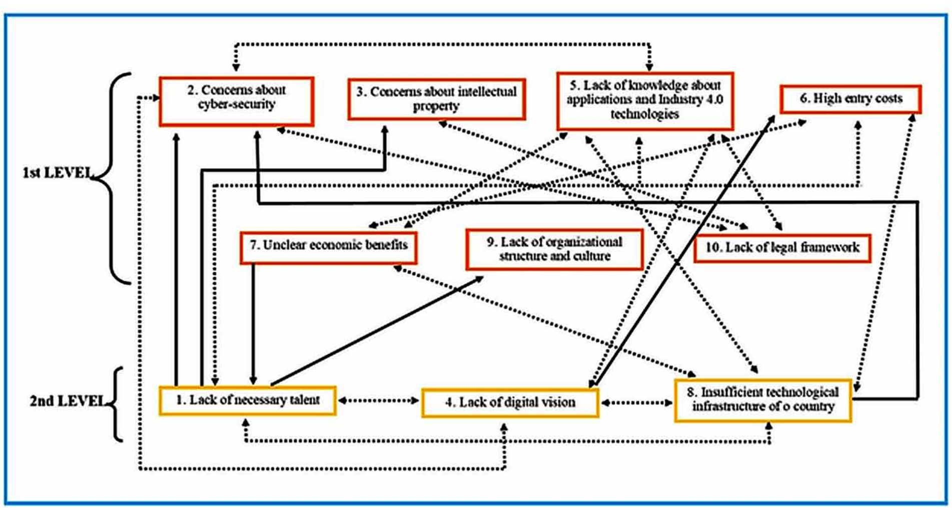


Table 8. Direct Relation Matrix (X)

	1	2	3	4	5	6	7	8	9	10	Total
1	**0**	3.33	3.75	4.33	4.4	2.66	3	4	3.83	2	31.3
2	4	**0**	4.5	0	0	3	0	0	5	0	16.5
3	1	0	**0**	4	0	3	1	0	0	0	9
4	5	3.5	3	**0**	4	3.6	3.5	3.66	0	3.66	29.92
5	5	3	5	5	**0**	3	3.8	4	0	3	31.8
6	4	5	4	4	0	**0**	0	3	0	0	20
7	4.2	4	3.33	4	3.5	3.5	**0**	3	0	3	28.53
8	4.33	4	2.5	4	4	3.5	3	**0**	0	3	28.33
9	5	4	0	4	2.66	3	3	2	**0**	0	23.66
10	4.25	3.5	4.33	0	0	3.33	3	3.5	0	**0**	21.91
Total	**36.78**	30.33	30.41	29.33	18.56	28.59	20.3	23.16	8.83	14.66	

Table 9. Normalized Direct Relation Matrix (C)

	1	2	3	4	5	6	7	8	9	10
1	0.00	0.09	0.10	0.12	0.12	0.07	0.08	0.11	0.10	0.05
2	0.11	0.00	0.12	0.00	0.00	0.08	0.00	0.00	0.14	0.00
3	0.03	0.00	0.00	0.11	0.00	0.08	0.03	0.00	0.00	0.00
4	0.14	0.10	0.08	0.00	0.11	0.10	0.10	0.10	0.00	0.10
5	0.14	0.08	0.14	0.14	0.00	0.08	0.10	0.11	0.00	0.08
6	0.11	0.14	0.11	0.11	0.00	0.00	0.00	0.08	0.00	0.00
7	0.11	0.11	0.09	0.11	0.10	0.10	0.00	0.08	0.00	0.08
8	0.12	0.11	0.07	0.11	0.11	0.10	0.08	0.00	0.00	0.08
9	0.14	0.11	0.00	0.11	0.07	0.08	0.08	0.05	0.00	0.00
10	0.12	0.10	0.12	0.00	0.00	0.09	0.08	0.10	0.00	0.00

11. The *"Lack of digital vision"* barrier with positive D-R value is found as the only affecting barrier, as a cause barrier it affects the entire system. All the other barriers with negative D-R value are found as affected barriers.

The relationship and structure between the barriers is clearly visualized in Figure 5. According to the DEMATEL Causality Diagram exceeding the lack of vision, which is the only barrier in the affecting group, will require a more difficult process than the affected group barriers.

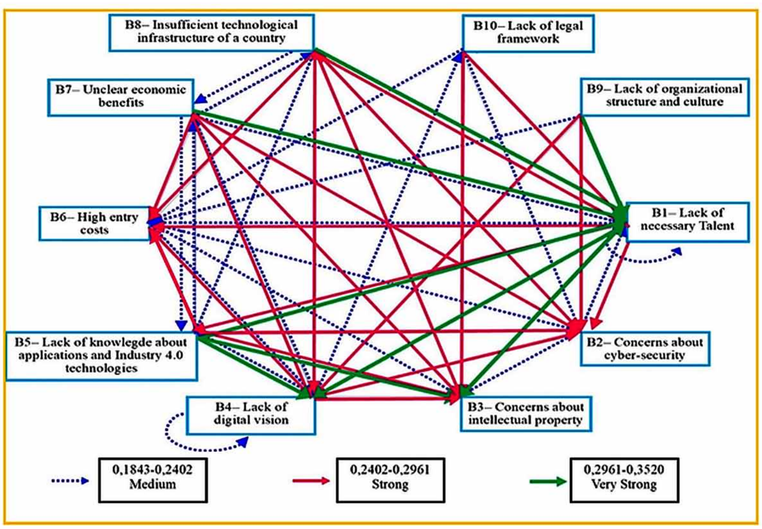
CONCLUSION

As it is stated in the literature of this study, project management is a tool for organizations to increase their productivity and increasing the productivity is also the main aim of the Industry 4.0 concept (Frame,

Table 10. Total Relation Matrix (F)

	1	2	3	4	5	6	7	8	9	10
1	**0.2355**	**0.2791**	**0.3005**	**0.3074**	**0.2408**	**0.2581**	**0.2100**	**0.2531**	0.1666	0.1552
2	**0.2087**	0.0935	**0.2053**	0.1066	0.0626	0.1666	0.0621	0.0716	0.1704	0.0380
3	0.0988	0.0644	0.0653	0.1628	0.0428	0.1346	0.0656	0.0523	0.0190	0.0347
4	**0.3439**	**0.2750**	**0.2838**	**0.1885**	**0.2223**	**0.2716**	**0.2132**	**0.2417**	0.0732	**0.1922**
5	**0.3520**	**0.2689**	**0.3373**	**0.3214**	0.1317	**0.2671**	**0.2271**	**0.2550**	0.0732	0.1828
6	**0.2369**	**0.2386**	**0.2287**	**0.2175**	0.0812	0.1161	0.0775	0.1625	0.0571	0.0607
7	**0.3127**	**0.2750**	**0.2795**	**0.2755**	**0.2022**	**0.2592**	0.1173	**0.2156**	0.0699	0.1696
8	**0.3191**	**0.2779**	**0.2625**	**0.2771**	**0.2163**	**0.2606**	**0.1949**	0.1432	0.0710	0.1717
9	**0.3157**	**0.2632**	0.1742	**0.2612**	0.1804	**0.2284**	0.1830	0.1799	0.0687	0.0875
10	**0.2516**	**0.2144**	**0.2482**	0.1334	0.0832	**0.2085**	0.1546	0.1833	0.0553	0.0613

Figure 4. Effect-Relationship Map

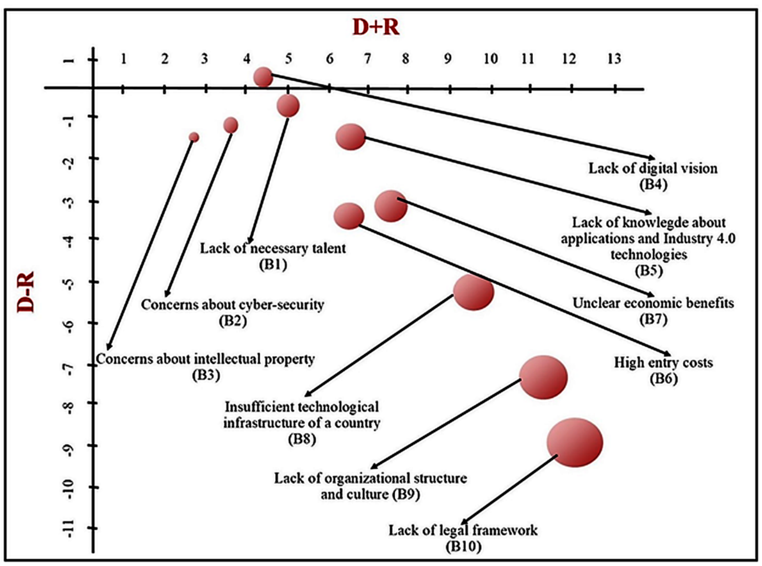


1995; Mir and Pinnington, 2013; Yılmaz, 2016). However, as it is the relatively new concept, there are some difficulties, risks and barriers in the implementation process of these industry 4.0 projects. To achieve success, it is very important to understand the hierarchical and contextual relationship between potential barriers in the Industry 4.0 projects implementation process. Hence, the aim of this study is to specify the industry 4.0 barriers in implementation process in Turkey's conditions, investigate the inter-relations among them and develop a model that can measure the interacting effects of the barriers on the other barriers in the industry 4.0 implementation process. To reach is specific aim, first relevant literature has been reviewed to identify the most important barriers in the Industry 4.0 projects implementation process and ten most quoted barriers have been detected. Then, multi-criterion decision making tools of interpretive structural modeling (ISM) and decision-making trail and evaluation laboratory (DEMATEL) have been used. One of the most important findings of the study is the lack of digital vision. Vision is

Table 11. Affecting and Affected Values (D+R, D-R)

	BARRIER	D	R	D+R	D-R	
1	Lack of necessary talent	2.41	2.67	5.08	-0.27	AFFECTED
2	Concerns about cyber-security	1.19	2.44	3.62	-1.25	AFFECTED
3	Concerns about intellectual property	0.74	2.23	2.97	-1.49	AFFECTED
4	**Lack of digital vision**	2.31	2.13	4.44	0.17	**AFFECTING**
5	Lack of knowledge about applications and Industry 4.0 technologies	2.42	4.19	6.61	-1.78	AFFECTED
6	High entry costs	1.48	5.03	6.50	-3.55	AFFECTED
7	Unclear economic benefits	2.18	5.53	7.71	-3.35	AFFECTED
8	Insufficient technological infrastructure of a country	2.19	7.52	9.72	-5.33	AFFECTED
9	Lack of organizational structure and culture	1.94	9.62	11.56	-7.68	AFFECTED
10	Lack of legal framework	1.59	10.78	12.38	-9.19	AFFECTED

Figure 5. DEMATEL Causality Diagram



the first step of every successful project but according to this specific study's results the lack of digital vision found as the only affecting barrier and it affects all the other barriers in Turkey.

According to ISM results, barriers like; uncertainty of economic benefits, concerns about intellectual property, high entry costs, lack of organizational structure and culture and lack of legal framework have been found as autonomous barriers and in some degree they are disconnected from the system. On the other hand, technological barriers as; insufficient technological infrastructure of a country and lack of knowledge about applications and Industry 4.0 technologies have been found as linkage barriers. So, a little change and improvement about technological awareness and technological infrastructure in Industry 4.0 concept affects the system in a considerable manner. Also lack of necessary talent and lack of digital vision barriers have been found as independent barriers. As a result, the development of strategies to overcome these two very important and prior barriers has been shown to contribute to the evolution of the industry 4.0 concept. Industry 4.0 projects show similarities with IT (Information Technology) projects indeed. Hence, top management should focus IT solutions while they encountering with problems in Industry 4.0 implementation process.

According to the DEMATEL results, it is seen that the most important outcome of the study is the lack of digital vision. It is the only barrier in the affecting group and it will require a more difficult process than the affected group barriers. It shows that, in Industry 4.0 concept, the barriers are hardly recognized in Turkey. Although the vision is the first step of every project, the lack of digital vision of the industry is clearly seen in the study. Thus, to increase the industry 4.0 awareness and education activity in Turkey is recommended. Further, to accelerate the improvement activities about technological infrastructure used in the industry 4.0 in Turkey will contribute to the improvement process indeed.

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Chapter 17
Measuring Software Development Project Performance:
A Case Study on Agıle KPI's for Software Start-Ups

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ABSTRACT

Adopting agile methodologies to software development processes helps software companies to sustain their growth through efficiency for long term. In the digital transformation era, Industry 4.0 as part of High-Tech Strategy 2020 for Germany involves agile principles and brings the latest technological trends in production process. The purpose of this chapter is to design a proper agile project management performance measurement model for start-up software companies. First, all key performance indicators related to agile development in the literature have been listed. Then KPIs that are provided from literature review with content analysis have been reviewed and categorized by expert opinions that were collected through in-depth interviews. Seven strategic KPIs and their data collection systems are defined and designed. Lastly, process and data collection improvements are recommended in order to sustain agile development measurement model.

DOI: 10.4018/978-1-5225-7865-9.ch017

INTRODUCTION

Managing projects with high obscurity level is one of the most strenuous tasks in software project management. Since it has been clearly understood that traditional methodology undercuts the efficiency of software projects, a more iterative and flexible project management methodologies started to proliferate in the industry. The implementation of agile methods to IT project management approach produced compelling results of the outputs of the companies. In recent decades, adopting agile methodologies to software development process helps software companies to sustain their growth through efficiency for the long term. On the other hand, in digital transformation era, Industry 4.0 which involves agile principles brought the agility topic into the research agenda again by raising the need for case studies on applying agile principles in SMEs. As agile approach is interdisciplinary and brings flexibility to organizations, it becomes an aid tool to be utilized for converging processes for higher performance in transformation periods.

In the digital transformation era, software development projects face the challenge of rapidly changing user requirements, increasing technology push, time pressure on product delivery and frequent releases. Hence, effective performance measurement in agile software development has become a significantly rising topic where researchers and practitioners intensely explore feasible and adaptable approaches.

However, flexible and chaotic nature of agile methods refrains companies from measuring the performance as successful as they used to do. Consequently, taking actions becomes harder without clear performance monitoring. Especially during digital transformation projects, agility and lean approaches in project management are expected to be utilized for rapid convergence to new technologies, and hence will require high-level monitoring and performance measurement methodologies of projects.

The purpose of this study is to design a proper Agile Project Management performance measurement model for start-up companies in software business by defining strategic KPIs, measuring defined KPIs and evaluating the results.

As a case study, a midsized software company which evolved in ITU innovation and entrepreneurship ecosystem and operates like a startup in ITU Teknokent, a technology development zone in Turkey, is going through a transformation stage from being a start-up to an important corporation in the international market. Having a structured, well designed agile project management performance measurement model is one of the most pivotal steps for this kind of company. On one hand, it is necessary for staying competitive in the global market on the other hand; technology development zone administration requires performance measurement data to evaluate the companies' performances periodically. Research Model is presented in Appendix A.

In summary, the introduced Agile Project Management Performance Measurement Model aims to support start-up software companies' efforts of growing in the global market with a well-structured and sustainable infrastructure. In addition to that, this chapter aims to help to create an Agile Project Management Performance Measurement Framework for the midsized software companies that operate in developing countries with scarce resources.

BACKGROUND

Theoretical background is presented in the following sections. Background section has two parts: (i) Project Management Methodologies in Software Development and (ii) Performance Measurement in

Software Development Projects. In these sections, sub-topics are presented in a deductive manner, from general terms to specific terms about agile KPI's for performance measurement in software development projects. After giving brief information on the Project Management Methodologies in Software Development, we focus on the Agile Project Management Methodology and, for being the most popular and most widely researched Agile methodology, we provide insights about SCRUM method.

In the second section, we provide basic concepts and definitions about Performance Measurement in software projects, and then we present the characteristics of Key Performance Indicators that are the major tools for tangible performance measurement. Referring to Agile Measurement Principles, we combine Agility and KPI concepts in the subsection of "Agile KPI's.

Project Management Methodologies in Software Development

As Schwalbe (2011) stated, topics and focus area of project management sharply changed in previous decades. Before the 1980s, project management primarily focused on providing schedule and resource data to top management in the military, computer, and construction industries but today project management involves various industries (Schwalbe, 2011). Improvements in Information and Communication technologies like computer hardware, software, networking and emergence of interdisciplinary, global teams radically changed the project environment.

As the number and complexity of projects continue to increase, critical issues about project management also evolved. As Schwalbe (2011) underlined, the success rate of information technology projects has more than doubled since 1995, but still only about a third are successful in meeting scope, time, and cost goals. Flexible and disciplined project management approaches became critical for business success.

In previous decades, various software development approaches have been introduced (Abrahamsson et al., 2002). These software development methodologies which can be classified as heavyweight (suitable for projects where requirements are more constant and complex) and lightweight (suitable for projects where specs are likely to change rapidly, hence require incremental approach and iterations for flexibility) (Despa, 2014). Some of these major methodologies are defined below:

- First described by Royce (1970), Waterfall methodology in software development is the most commonly used, linear sequential SW development project management process which emphasized meticulous planning and comprehensive documentation (Despa, 2014).
- Prototyping methodology entails building a demo version of the software product with critical functionality where initial specifications are defined only to provide sufficient information to build a prototype (Despa, 2014). Prototyping evolved from increasing product specification definition needs and it uses the prototype to refine specifications by taking it as a baseline for communication between the project team and project owner (Cooling and Hughes, 1989).
- Iterative and incremental software development methodology relies on building the software application one step at the time in the form of an expanding model (Larman and Basili, 2003). The process is repeated until the model becomes a fully functional application that meets all requirements (Despa, 2014).
- Rapid application development is a development lifecycle designed to take advantage of powerful software development (Martin, 1991). By imposing less emphasis and encouraging faster development, and higher quality results than the traditional methodologies are achieved.

- Extreme programming uses smaller more manageable chunks than conventional software development process (Despa, 2014) and reduces the cost of changing software by performing limited planning, analysis and design activities in software development process (Beck, 1999; Despa, 2014). The introduction of the extreme programming method is taken as the starting point for agile software development approaches (Abrahamsson et al., 2002).
- Agile development methodologies and especially Scrum methods enable incrementally building software in complex environments (Rising and Janoff, 2000). Software requirements are formulated and prioritized by the product owner (Despa, 2014). The "Agile Movement" in the software industry started with the publication of Agile Software Development Manifesto by a group of software experts in 2001 (Beck et al. 2001; Cockburn 2002). Agile methods recognize people as the primary drivers of project success, coupled with an intense focus on effectiveness and maneuverability (Highsmith and Cockburn, 2001).
- Other methods such Crystal Methods (Cockburn 2000), Feature-Driven Development (Palmer and Felsing 2002), and Adaptive Software Development (Highsmith 2000) then belonged to Agile methods family (Abrahammson et al., 2002).

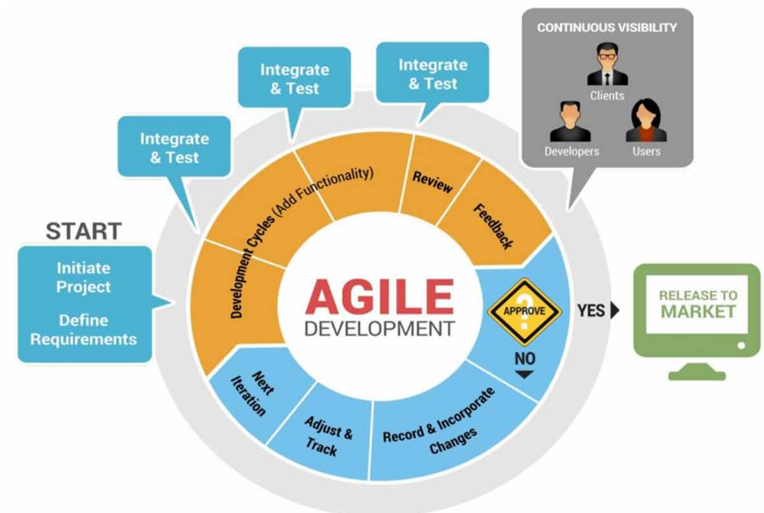
Among these, Agile Development Methodologies became increasingly popular by their advantages for minimizing the risks associated with the planning process and development of software solutions (Georgiev and Stefanova, 2014). In fact, these developments in software development methodologies reshaped the project management practices in software projects, and they even had been infectious to other project management practices.

On the other hand, as Spundak (2014) discussed, there is a need for hybrid approaches which intend to combine traditional waterfall, prototyping, agile methods of project management. For this, the practitioners should define the needed detail level for the definition and control mechanism of the project and then adapt the appropriate methodology in the required project management framework. Similar to "Agile with Discipline" methodology of IBM which incorporates components of agile development into a more structured approach to project management through providing sufficient documentation and timelines with flexibility, hybrid approaches can leverage the advantages of Agile with the strengths of traditional practices (Adelakun et al., 2017).

Agile Project Management in Software Development

Today's dynamic business environment is forces organizations to constantly change their software requirements to adjust to new environments. As well as welcoming changing requirements, fast delivery of software products are expected. In this aspect, traditional plan-driven developments fail to meet up these requirements. Agile software development brings its own set of novel challenges that must be addressed to satisfy the customer through early and continuous delivery of the valuable software (Beck et al., 2001; The Twelve Principles of Agile Software, 2001). Agile development model (Figure 1) includes the initiation of the project and definition of initial requirements, then continues with development cycles that includes integration and test phases in between. After the completion of the review-feedback-approval phases, frequent releases takes place. In the lack of approval, after the change and adjustment phases, next iteration starts (Agile Manifesto, 2002). Including a set of software development methods based on iterative and incremental development process, agile system development methods emerged as a

Figure 1. Agile Development Model
(Agile Manifesto, 2002)



response to the inability of traditional plan-driven approaches to handle rapidly changing environments (Highsmith, 2002).

Agility is the ability to sense and respond to business prospects in order to stay inventive and aggressive in an unstable and rapidly shifting business environment (Highsmith, 2002). As can be seen from Table 1, The uniqueness of this approach is about the agility of the development process, development teams, and their environment. Agile teams consist of multi-skilled individuals. The development teams also have on-site customers with substantial domain knowledge to help them better understand the requirements (Abrahamson, Solo, Ronkainen, & Warsta, 2002). Multiple short development cycles also enable teams to accommodate request for change and provide the opportunity to discover emerging requirements.

Working definitions of agile methodologies can be summarized as a group of software development processes that must be iterative (take several cycles to complete), incremental (not deliver the entire product at once), self-organizing (teams determine the best way to handle work), and emergent (processes, principles and work structures are recognized during the project rather than predetermined). In 2001, seventeen well-respected experts of agile methodology formed an Agile Alliance to better promote

Table 1. Agile Approach summary

Agile Approach
Iterative; The evolutionarydelivery model
Adaptive
Emergent, rapid change, unknown -Discovered during the project
Self-organizing teams
Client onsite and considered as a team member

their views and wrote the Agile Software Development Manifesto. The basic ideas of the philosophy are introduced through four basic values (Agile Manifesto, 2002);

- Individuals and interactions over processes and tools
- Working software over comprehensive documentation
- Customer collaboration over contract negotiation
- Responding to change over following a plan

Apart from the Agile Manifesto, there is also a set of principles which determine that what is to be agile (The Twelve Principles of Agile Software, 2001);

- Highest priority is to satisfy the customer through early and continuous delivery of valuable software.
- Welcome changing requirements, even late in development. Agile processes harness change for the customer's competitive advantage.
- Deliver working software frequently, from a couple of weeks to a couple of months, with a preference to the shorter timescale.
- Business people and developers must work together daily throughout the project.
- Projects are built around motivated individuals, give them the environment and support they need, and trust them to get the job done.
- The most efficient and effective method of conveying information to and within a development team is the face-to-face conversation.
- Working software is the primary measure of progress.
- Agile processes promote sustainable development. The sponsors, developers, and users should be able to maintain a constant pace indefinitely.
- Continuous attention to technical excellence and good design enhances agility.
- Simplicity--the art of maximizing the amount of work not done--is essential.
- The best architectures, requirements, and designs emerge from self-organizing teams.
- At regular intervals, the team reflects on how to become more effective, then adjusts its behavior.

In the latest report of Collab.Net (2018) on the State of Agile in organizations, the reasons with increasing trend for adopting agile methods in companies are listed as accelerating software delivery, enhancing delivery predictability, improving IT/Business alignment and reducing project cost. According to the same report, the use of Kanban, product road mapping and portfolio planning had been among the rising agile techniques.

A Favorable Agile Software Development Methodology: SCRUM

Among different types of methodologies and Frameworks in AGILE like Dynamic systems development method (DSDM) or Rapid Application Development (RAD), SCRUM is a process which project team focus on delivering the highest business value in shortest time and the development team works as a unit to reach a common goal as opposed to a "traditional, sequential approach" (Jeldi and Chavali, 2013). It primarily deals with problems at the team level and aims to improve teamwork effectiveness by guiding teams to be self-directing.

Despite the Scrum Alliance (2015) states that Scrum is an agile framework for completing complex projects, Scrum is originally designed for small organizations and teams, hence for multiple site and multiple team projects may face some challenges in implementing Scrum.

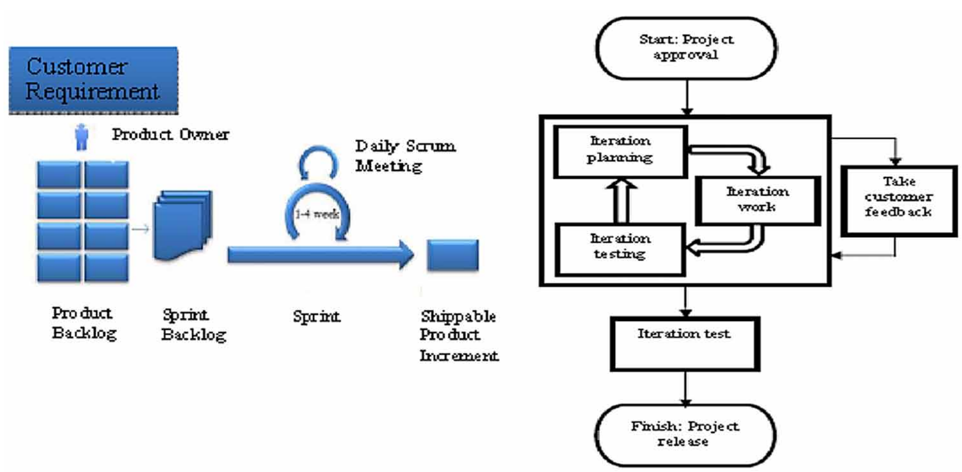
The Scrum approach has been developed for managing the system development process. It is an empirical approach applying the ideas of industrial process control theory to systems development resulting in reintroduction of the ideas of flexibility, adaptability and productivity (Schwaber and Beedle 2002). The rules of Scrum bind together the events, roles, and artifacts, governing the relationships and interaction between them (Schwaber and Sutherland, 2013). Hence Scrum is more likely to be a project management framework.

"Scrum Flow Framework" (shown in Figure 2) has the following components (Paul and Singh, 2012; Jeldi and Chavali, 2013; Scrum Alliance, 2015; Open View, 2016):

- A product owner creates a prioritized wish list called a product backlog.
- During sprint (short period of time, usually between 1 to 4 weeks, to complete a whole iterative project cycle) planning, the team pulls a small chunk from the top of that wish list, a sprint backlog, and decides how to implement those pieces.
- The team has a certain amount of time — a sprint (usually two to four weeks) — to complete its work, but it meets each day to assess its progress (daily Scrum).
- Along the way, the Scrum Master keeps the team focused on its goal.
- At the end of the sprint, the work should be potentially shippable: ready to hand to a customer, put on a store shelf, or show to a stakeholder.
- The sprint ends with a sprint review and retrospective.
- As the next sprint begins, the team chooses another chunk of the product backlog, begins working again.

Scrum roles are categorized as "Scrum Team", "Scrum Master" and "Scrum Product Owner" (The Scrum Institute, 2018; Schwaber and Sutherland, 2013).

Figure 2. Scrum Flow Framework
(Paul and Singh, 2012)



- The Scrum Master is responsible for ensuring Scrum is understood and enacted; act as a servant-leader for the Scrum Team. Scrum Master ensures that the Scrum Team adheres to Scrum theory, practice, rules.
- The Development Team consists of professionals who do the work of delivering a potentially releasable Increment of "Done" product at the end of each Sprint. Only members of the Development Team create the Increment. Development Teams are structured and empowered by the organization to organize and manage their own work, so that the synergy optimizes the Team's overall efficiency and effectiveness.
- The Product Owner is responsible for maximizing the value of the product and the work of the Development Team. How this is done may vary widely across organizations, Scrum Teams, and individuals. The Product Owner is the sole person responsible for managing the Product Backlog.

Performance Measurement in Software Development Projects

Performance measurement can be defined as a process that includes data collection, data analysis and declaration of the results of the performance of a specific individual, group, organization, system or component. Performance measurement systems come across with different challenges. Eccles (1991) mentions 5 activities for reinforcing the strategies of the company by using performance measurement in his article called "The Performance Measurement Manifesto":

- Developing an information architecture
- Putting the technology in place to support this architecture
- Aligning bonuses and other incentives with the new system
- Drawing on outside resources
- Designing an internal process to ensure the other four activities occur

Within this broad perspective, measuring performance in software development projects includes production performance (delivery to customer) and process performance (efficiency of Process) (Liang et al., 2007). Project performance in projects today deal not only with hard aspects such as financial, schedule, and quality (Pollack, 2007) but also with soft dimensions such as communication, team engagement, cohesion (Ravindranath, 2016, Kerzner, 2013).

One of the most important sources on "Project success factors" is the framework of characteristics, definitions and measurement techniques that were introduced by Pinto and Slevin (1986, 1988) in three dimensions of technical validity, organizational validity, and organizational effectiveness with those of time, cost, performance and client satisfaction on projects. Some highlighted success factors from this framework are project mission, top management support, project schedule/plan, client consultation, personnel, technology to support the project, client acceptance, and also some factors that inspired agile project management such as monitoring and feedback, channels of communication, and troubleshooting expertise.

Key Performance Indicators: Major Tools to Make Performance Measurement Tangible

Key Performance Indicators (KPIs) are one of the most widely used performance measurement techniques. However, the definition of KPI can be controversial due to the purpose of its use. According to Bauer (Figure 3), *KPIs are quantifiable metrics which reflect the performance of an organization in achieving its goals and objectives.* Therefore, KPIs should be in accordance with the organization's vision, strategy and objectives. Some approaches have been developed for a long time ago in order to ensure the conformance of metrics with the organization. One of the most respected frameworks in that context is GQM (Goal, Question, and Metric) that links metrics to specific strategic objectives in order to justify the metrics.

As Crispin & Gregory (2011) states that metrics should be considered as a factor for motivating rather than degrading team's morale. In addition to that, the right set of metrics helps organizations to monitor its performance and provide the conformity level of keeping track of goals. Selection of what to measure is a pivotal step in creating a measurement model. The KPI set should be designed by considering the main purpose of measurement. The organization should be concerned that the designed measurement system does not lead to the dysfunction of the organization. In some cases, teams try only to improve the outcome of an indicator and fail to prioritize the organizations' original goal.

Agile Measurement Principles

Measuring levels should be carefully considered during the design of the measurement model. While measuring the lower levels can cause an increase in dysfunction, limiting the measurement level may hinder the potential of the model.

Figure 3. Strategic Alignment Pyramid
(Bauer,2004: KPIs - Metrics That Drive Performance Management,

Poppendieck (2011) and Austin (1996) introduce the concept called "Measure Up" which refers not to measure levels which are lower than the team level. Another related concept was introduced by Guckenheimer which is called "Value Up" that supports to focus on the customer value. Traditional effort-based measurement models become obsolete since agile development requires a flexible and customer value oriented organizational structure. Hartmann suggests a set of more specific criteria in order to define a successful agile metric (Hartmann, 1993);

- Supports and encourages lean and agile principles
- Measures outcome, not output
- Follows trends, not numbers
- Answer a particular question for a real person
- Belongs to a small set of KPIs
- Is easy to collect
- Reveals, rather than conceals, its context and significant variables
- Provides information to discussions about performance
- Provides feedback on a frequent and regular basis
- Reassures ||good-enough|| quality

Agile KPI's

Key performance indicator (KPI) in software development aims to measure some features of the current software activities and the processes. Measurement results are important for the organization to make better products and to improve current ongoing processes. The feedbacks that get after correct measurements help to predict the future quality of products. First of all, measurable metrics need to be identified, defined and included in performance measurement systems. Agile software project performance is mostly dependent on monitoring and control mechanisms (Cheng et al., 2009). Agile metrics create a common ground between the expectations from the project and software development processes, and as well they act as communication tools which enable the progress monitoring by different stakeholders (Broadus, 2013). According to agile principles like iterative development, accepted change, and adjustable requirements, the agile metrics are analyzed more frequently and require some set of tailor-made metrics rather than metrics used in traditional project monitoring (Broadus Iii, 2013; Hariharan and Arpasuteera, 2017).

Agile metrics generally focus on value-added to the customers by using customer deliverables against time, cost and quality. Cheng et al. (2009) categorized some agile metrics in team, task and quality dimensions by combining both hard and soft aspects. On the other hand, Broadus Iii (2013) classified Agile KPI's or metrics by velocity, Burn up, Burn down, Running Tested Features, Defect Density. These metrics are perceived as hard dimension because of quantitative attributes (Pollack, 2007). However, there is a need for hybrid metrics like customer satisfaction KPI, which can combine time, cost, quality and effective communication (Kerzner, 2013). When using the right set of Agile KPI's one can gain insight into how Agile working contributes to team performance and organizational performance as a whole. As well, Agile KPI measurement performance is valuable to have quantitative arguments following from these KPI's (Levels, 2016).

A Primary Concern When Setting Key Performance Indicators: Dysfunction in Measurement Systems

As explained above, the purpose of the measurement systems is to get some feedback in order to improve a process, product or project. The dysfunction of the measurement system happens when the performance index improves but there is no improvement of the process, product or project. Performance measurement initiatives may also inadvertently induce a range of unintended and dysfunctional side-effects (Aryankhesal et al., 2013). In agile project management, traditional performance metrics measures may not work within agile teams causing dysfunction (Galen, 2012). Metrics dysfunction is a metric whose collection influences the very behavior being measured—leading to metrics dysfunction (like the number of bugs corrected which depends to the number of bugs that can be manipulated by the developer) (Austin, 1996).

In this context, Austin (1996) categorized the metrics by their intention as motivating and informative measurement: While informational metrics are used only to get some insights from the development team, motivational metrics have a purpose to create positive organizational change among those being measured. As Austin (1996) stated, motivational metrics have a higher risk to create dysfunction since measuring every relevant aspect of the work in the software development process is a challenging issue. Target setting for performance measurements also bears the same risk as motivational measurement (Poppendieck and Poppendieck, 2011). In order to avoid the misuses of measuring systems, informational purposes should be used with hard-to-deceive metrics while a high level of trust is achieved within the organization. As Poppendieck and Poppendiek (2011) explained, target setting for the organizations, teams or people has the same risk of dysfunction.

THE CASE STUDY FROM A SOFTWARE STARTUP COMPANY: ANALYSIS OF THE "AS-IS" STATE (CURRENT PRACTICE) OF AGILE PROJECT MANAGEMENT AND PERFORMANCE MEASUREMENT

In this Case Study Section, which is the contributive application of this chapter, there are two subsections which reflect two phases (analysis and design) of a typical system development process (i) Analysis of the As-Is State of the Agile Project Management and Performance Measurement of the studied company and, (ii) Proposed Design for To-Be State Agile KPI Set for the studied Company. In accordance with the structuring in the Background section, Case Study sections also have sub-topics for Project Management Practices and Project Performance Measurement Practices for both phases of As-Is and To-Be. Research Model which clarifies the flow of the research is presented in Appendix A.

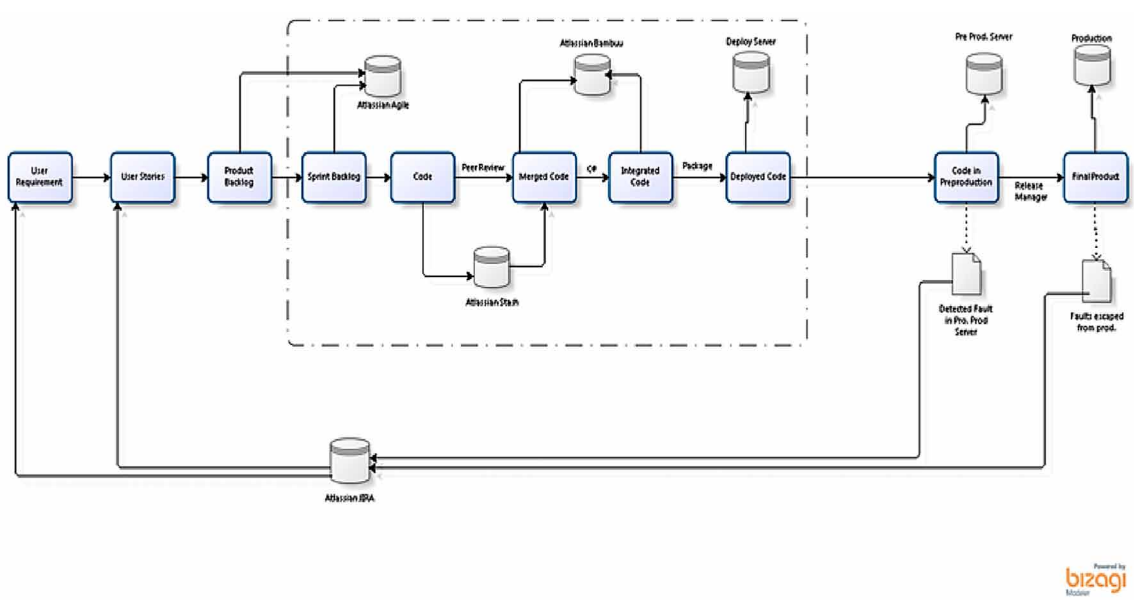
Current Agile Project Management Practices in Software Development

Studied Software Start-Up Company has been using scrum methodology in technical teams. Although the Scrum Guide states that product owner should participate to all planning meetings, some of the projects are carried out without the customer participation since some of the clients are not competent in agile methodology. In that case, project manager and analyst of the project plays the product owner role during the scrum meetings. On the other hand, every team member in is trained about scrum methods. Therefore, there is no vital impediment that undermines agile processes in internal projects. In addition, agile processes are supported company-wide. Sales and Human Resources departments are trying to adopt the latest agile software development processes within their routine tasks.

Sprints are planned to be 2 weeks and start with sprint planning meetings. At the beginning of every project, longer and more detailed release planning meetings are carried out. After the user requirements transformed into user stories by the analyst of the project, members of the scrum team list the product backlog items in the initial release planning meeting. The backlog items at that level are described as “epic” which refers to its complexity and the necessary amount of resources to complete that task. During the sprint planning meetings, product backlog items are defined and divided into more basic and simple tasks. Every task which is defined during this meeting can be completed by one individual team member. At the end of the sprint planning meeting, sprint backlog items, tasks that are planned to complete during 2-week sprint, are listed into the online scrum planning tool.

- **Development Process During Sprint:** After the sprint tasks are listed on to the scrum planning tool, every team member (developer) chooses the task that he/she starts to carry out. That process transforms the user stories into the code parts. Developers write the codes in Visual Studio and upload these files to the version control system. Codes are merged into the main branch after a peer developer controls and accepts the merge request. After all the sprint backlog items are completed, merged codes are transferred to Build / CI Server. Codes are merged with the main branch of the codes which are developed earlier. Those codes are transferred into Deploy Server and Test Server to be tested in company environment by the tester. At the end of the process, codes are deployed into the Production Server of the customer by the release manager (Figure 4).

Figure 4. Start-Up’s Software Development Process



- **Retrospective Meeting at the End of Sprint:** The team organizes another meeting at the end of the sprint in order to evaluate the efficiency and effectiveness of the sprint. 3 basic questions given below are answered and argued during the retrospective meetings. After the end of the sprint, sprint planning meeting are held to keep the incremental project development process:
  - What did we do well, that if we don't discuss we might forget?
  - What did we learn?
  - What should we do differently next time?
  - What still puzzles us?

Current Agile Project Performance Measurement Practices and KPI's

Software Start-Up Company decided to develop an in-house measurement system for its technical teams 2 years ago. The model has been developed with limited resources in a limited time. Although the system satisfied the requirements at that time, it was not improved in order to keep in pace with the changes and developments of the technical teams. Consequently, measurement system started to become obsolete with every change in the organization.

For instance, a part of the measurement system was designed to monitor whether all teams use an online scrum tool. The purpose of this KPI is to make every technical team to use online scrum planning tools, however, it became unnecessary after every team got used to online scrum tool. KPIs that are measured by Quality and Internal Audit Department are shown in Table 2. The current measurement practices of Software Start-Up Company are carried out by the Quality and Internal Audit Department. 5 KPIs are measured from 3 different data collection points. While data from version control system is collected automatically, other 2 data collection points do not have any automation. The data collection and analysis are carried out quarterly. The analysis of the quarterly KPI results is reported to the top management with a graphical summary. In addition to that, a different version of the report is prepared if the top management wants to share some of the results with the technical teams and project managers. The measurements are carried out both company and team levels.

PROPOSED DESIGN FOR AGILE KEY PERFORMANCE INDICATOR SET FOR THE ANALYSED SOFTWARE START UP COMPANY (TO-BE STATE)

Definition of Total Agile KPI's Set: Understanding the "Theoretical Base" Through Literature Research

Before defining the metrics for a specific organization, designer of an agile project performance measurement system should focus on which metrics of hard and soft aspects are measured, keeping the actual aim at the end of this measurement process. Chosen metrics should fit the project type, organization strategy, resources and constraints of the organization and the project team to avoid negative consequences and dysfunctional impacts on the project measurement process.

For responding to these needs, we aimed to propose a list of "widely accepted and practiced" and adaptable KPI's for the studied software start-up company. For this aim we conducted a content analysis on literature and published theoretical/practical background (23 different major articles and books on "Agile Software Development Performance measurement") to gather information on currently known

Table 2. Current Measurements of Software Start-up

KPI	Explanation	Data Collection System
Version Tag Usage Rate	Number of Taged Modules / Number of Total Modules	Automated Data Collection From Version Control System
Branching Struture Quality	Number of Modules with 2 Branches/ Number of Total Modules	Automated Data Collection From Version Control System
Peer Review Rate	Number of Modules with merge request/ Number of Total Modules	Automated Data Collection From Version Control System
Documentation	Number of Prepared Documents/ Number of Required Documents	Manual Data Collection From Wiki Based Collaboration Tool
Scrum Tool Usage Rate	Number of Teams currently use a scrum tool / Total Number of Teams	Manual Data Collection From Scrum Tools

agile KPI's and measures. In the end of content analysis, a total of 99 KPI's are found and listed. The referred sources are listed below by their categories of topic:

- *Agile SW Development Method:* Abrahamsson et al.,2002; Duvall et al.,2007; Scrum Alliance, 2015.
- *Performance Measurement in Software Development*: Basili, 1994; Eccles, 1991; Gopal, 2002; Gustaffsonn, 2011; Hartmann and Dymond, 2006; Hughes, 2000; Upadhaya et al., 2014; Blackburn, 2015; Montequin et al, 2013; Elahe et al., 2014, Cheng et al., 2009, Broadus Lii, 2013, Andersson, 2010, Poppendieck and Poppendieck, 2008., Andersson, 2010
- *Software Metrics*: Fenton and Pfleeger, 1997; Grady, 1992; Kitchenham, 1996; Mannila, 2013; Umarji and Seaman, 2008; Rawat et al., 2012; U.S. Department of Defense, 2018; Cleff A., 2010
- *Testing Performance*: Crispin & Gregory, 2010; Shahid et al., 2011.
- Andersson, D. J. 2010. Kanban, successful evolutionary change for your technology business. 1st printing. Sequim, WA: Blue Hole Press.

Referring to classification of Mannila (2013), the collected measurements and usage categories are summarized in summary table as type, level, period, scope and Frequency. Definition of measurement categories are shown in Table 3:

In the second round of Content Analysis, frequencies of 99 KPI's that are listed in Appendix B are counted. Adapted from the approach of Mannila (2013) among these KPIs the ones which appeared in more than 3 different sources in literature were identified and listed in Table 4.

DEFINITION OF ENHANCED KPI SET

The KPIs that appeared in more than 3 different sources in literature were identified by content analysis. After the literature research, several interviews have been made with 3 experts (software engineers with 10 years of experience) on Agile Performance Measurement Methods. Experts rated the priority of each KPI that were derived from literature. These KPIs have been discussed and categorized as "must have" and "nice to have" KPI set in accordance with their frequency of being mentioned in previous literature and with the ratings of the experts. KPI's which had been both highly (>5) mentioned in literature

Table 3. Measurement Definition Table

Category	Explanation	Metrics
Scope:	Defines the measurement scope like what is measured.	story point, user story, feature
Period:	Defines the time period of the measurement	week, sprint, month, quarter, 6 months, year
Level:	Defines the organization level in which the measurement is followed	team, value stream, site, product, release
Type:	Defines the type of measurement (number, ratio, etc.).	number, ratio (%), trend, cumulative, correlation
Frequency:	Defines the commonality and reference/usage intensity target of the measure	how many times a measurement was introduced or promoted in the source data

and rated high (3) by the experts, but those not being used currently by the studied software start-up company are selected as “Must have” KPIs (Table 5). As well, KPIs which have been both highly (>5) mentioned in literature and rated medium (3) by the experts, but those not being used currently by the studied software start-up company are selected as “Nice to have” KPIs (Table 6).

Must Have KPIs

The KPIs in “Must Have” category are needed to be on the measurement model even though the company does not have the measurement capability. Therefore, “Must Have” KPI set has been studied in order to verify the measurement capability of the company (Table 5). Also, each “Must Have” KPI is analyzed if the company can measure it within its current data collection system and its current agile processed in Table 6. Secondly, KPIs which cannot be measured because of the current agile processes is explained. In addition to the explanation, necessary process improvements have been recommended to the company as well.

The detailed explanations of KPI’s that are recommended for being used in Agile Software Project Management framework of the studied company is given in Table 6 with their KPI Explanation, “Category”, “Type”, “Level”, “Period” and “Scope”. Definitions of each KPI and related “Process Improvement Recommendations” are also presented in the following sections.

The process improvement recommendations are also shown in Figure 5 more accurately.

- **Green Build Ratio: Continuous Integration-** Continuous Integration is a software development practice where members of a team integrate their work frequently; where each integration is verified by an automated build by including some test like regression test cycle and smoke test cycle to detect integration errors as quickly as possible. Many teams find that this approach leads to significantly reduced integration problems and allows a team to develop cohesive software more rapidly (Fawler, 2006).

Table 4. KPI List and Expert ratings

Key Performance Indicator	Frequency in Literature (Mannila, 2013)	Expert Rating (1:Low 2:Medium 3:High)	Current use in Company
Feature Development			
Number of features available for releasing	13	3	Yes
Number of features available in planned release date	7	3	Yes
Feature cycle time (days) correlation to the work amount	5	3	Yes
Quality of Team Planning			
Content stability (added/removed items)	*6*	*2*	No
Used hours per planned items in priority order	6	1	No
Quality of User Stories			
User story average cycle time - from started to done	6	1	No
User Story Deployment			
Accepted user stories (potentially shippable content)	13	1	No
Team Velocity			
Team velocity versus capacity	*6*	*2*	No
Team commitment keeping ratio (on time delivery)	5	2	No
Green Build Ratio (MUST HAVE)			
Product CI and automated test case success	**8**	**3**	Yes
Test Case Amounts			
Manual and automated acceptance tests/total test cases, report showing the ratio of automated tests	12	3	Yes
Unit test coverage for the developed code (%), number of passing tests – way towards (A)TDD	**9**	**3**	No
Fault Source			
Faults found by customer, escaping from production	**8**	**3**	No
Number of Faults			
New/closed/open faults by priority level (critical, major, minor)	13	3	Yes
Customer Care Cases			
New customer cases (faults).	4	1	
Open customer cases (faults)	4	1	
Multitasking in time usage			
Sprint work flow diagram for user stories under the work, cumulative view to ”not started”, ”ongoing” and ”done” tasks in a sprint. Indicates if a team has silos and impediments	**6**	**3**	No
Sprint workflow diagram for features under the work, cumulative view to multitasking in the team. Number of items in the process and if the team works together on the same tasks	6	3	No
Sprint burn-down/-up			
Sprint burn-down chart for tracking of team level work progress, work remaining	*10*	*2*	No
Release burn-down/-up			
Release burn-down chart for tracking work progress in a release (story points - sprints), if the project or release is “on schedule”	7	3	Yes
Feature effort estimation accuracy, original versus team vs. real work	5	2	No

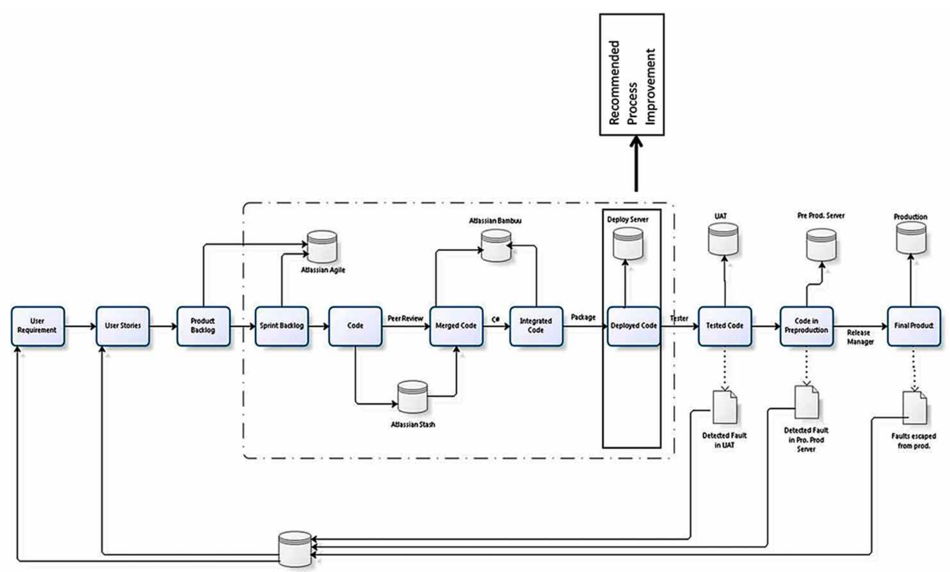
Table 5. Must Have KPIs

No.	Key Performance Indicator	Measurement Capability of Company
1.	**Green Build Ratio:** Product CI and automated test case success (regression steps)	Process Improvement is Needed
2.	**Test Case Amounts**: Unit test coverage for the developed code (%)	Capable
3.	**Fault Source**: Faults found by customer, escaping from production	Data Collection Improvement Needed
4.	**Multitasking in time usage**: Sprint workflow diagram for user stories under the work, cumulative view to ”not started”, ”ongoing” and ”done” tasks in a sprint. Indicates if a team has silos and impediments	Capable

Table 6. Explanations and Classification of Must Have KPIs

KPI Explanation	Category	Type	Level	Period	Scope
1. Product CI and automated test case success (upgrade, smoke, regression steps)	Green Build Ratio	Ratio	Team	Sprint	Feature
2. Unit test coverage for the developed code (%)	Test Case Amounts	Ratio	Team	Sprint	Feature
3. Faults found by customer, escaping from production	Fault Source	Number & Trend	Product	Quarter	Feature
4. Sprint work flow diagram for user stories under the work, cumulative view to ”not started”, ”ongoing” and ”done” tasks in a sprint. Indicates if a team has silos and impediments	Multitasking in time usage	Ratio	Team	Sprint	User Story

Figure 5. Recommended Process Improvement



As summarized by Collab.NET (2012) the flow of continuous integration's iterative cycle at a high level is: "**monitor, check out, build, test and release; with a feedback mechanism**": "*The flow of continuous integration requires that the team monitors the code base for any changes. Once a change occurs it needs to be checked out, built, and tested for quality. If successful and no defects are detected, it is released to a central storage repository or release area. If something does go wrong during the build process or a defect is detected, the team needs to know immediately that something went wrong so that this can be resolved quickly. Therefore, there needs to be a built-in feedback mechanism"* (collab. NET, 2012). Continuous Integration brings multiple benefits to the organization (Duvall et al., 2007):

- Increase visibility which enables greater communication
- Spend less time debugging and more time adding features
- Stop waiting to find out if your code's going to work
- Reduce integration problems allowing you to deliver software more rapidly

Process Improvement Recommendation: The studied software company must also improve their Green Build Ratio measurement and monitoring practices in accordance with the above given iterative cycle.

- **Unit Test Coverage:** Unit testing is a software testing method by which individual units of source code are tested to determine whether they are fit for use hence it forms the basis for component testing (Laudon and Laudon, 2011). The goal of unit testing is to isolate each part of the program and show that the individual parts are correct. Test coverage (also referred to by some as code coverage) is one of many metrics that are commonly used to give a statistical representation of the state of the code written for a certain piece of software (Shahid et al., 2010).

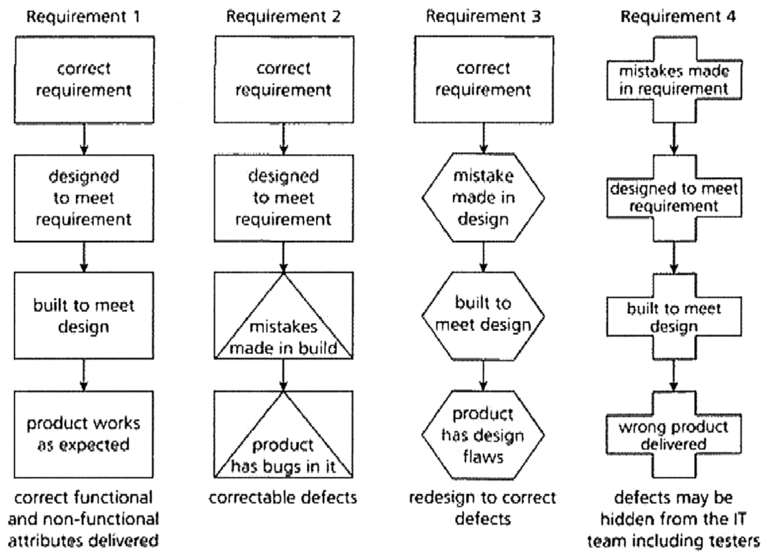
Process Improvement Recommendation: In order to measure automated test case success, Software Company needs to improve its testing processes since there is no data point in the current process. After the code is deployed, an additional testing process can be carried out on User Acceptance Testing server. Although UAT done also by the customer, adding an extra internal testing process will help company to increase its automated test case success with the data verification.

Faults Found by Customer

For this KPI measurement there are two types of questions; (I) "How many new customer defect reports have been received during the month?" and (II) "How many customer defect reports are open at the end of the month at the time the calculation is done?". The number of reported customer defect reports gives an indication whether internal testing is effective, and the overall testing process is done well. From Figure 6, we can see different types of defects and error that are categorized in 4 requirements. The defects in **Requirement 4** were introduced during the definition of the requirements; the product has been designed and built to meet that flawed requirements definition. If the product is tested for meeting requirements, it will pass its tests but may be rejected by the customer. Defects

Process Improvement: To establish a software measurement environment, the software organization must define a data collection process and recording media.

Figure 6. Fault Category Chart



- **Sprint Work Flow Diagram: S**print work flow diagrams (Figure 7) shows the pace of work, how much work is done, the status of ongoing, and backlog steps Furthermore, to gain insight into a portfolio of features, scenarios, or user experiences, product owners and program managers can map user stories to features. By sprint work flow diagrams team members can see clearly what is going on in the current work; the plans of next step can be mapped according to these diagrams; process can be graphed as cumulatively. As Petersen and Wohlin (2010) explained, in cumulative work flow diagrams "*The x-axis shows the time-line and the y-axis shows the cumulative number of requirements having completed different phases of development. The area between those two lines is the number of incoming requirements to be detailed.*"

The workflow (Figure 8) shows the progression and regression of work that team members will perform. From this flow diagram team can analyze the status of sprint when new items are added and removed; and also observe the commitment of a team member when the new features those are added/ removed to the process. The results of this activity can be an asset to measure the quality of agile process.

Process Improvement Recommendation: The studied company should apply sprint cumulative work flow diagrams and establish a process for added and removed items in the backlog to increase the effectiveness in their project monitoring activities.

Nice to Have KPIs

KPIs in "Nice to Have" category provide valuable information to agile project performance measurement models. However, according to those KPIs are not pivotal for the model to provide a clear agile measurement results. Consequently, only the KPIs that the company is capable of measuring in Table 7 will be added to the measurement model.

Figure 7. An Example of Cumulative Work Flow Diagram
(Petersen and Wohlin, 2010)

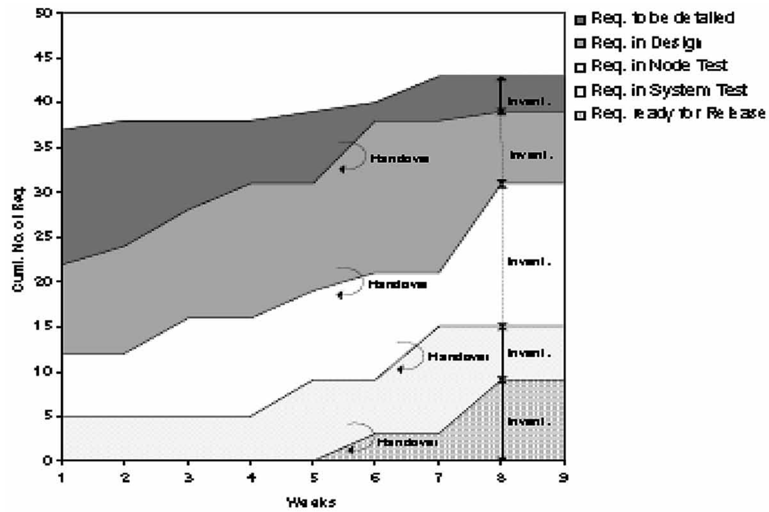


Figure 8. Process of Added/Removed Items

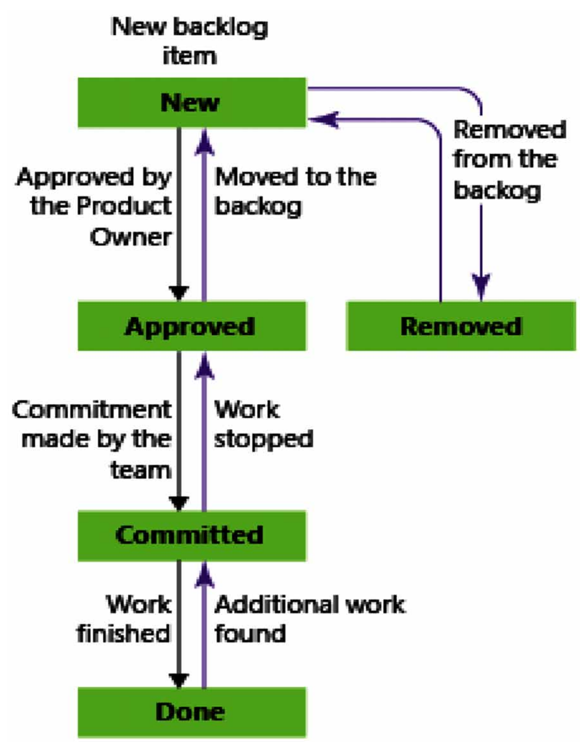


Table 7. Nice to Have KPIs

No.	Key Performance Indicator	Measurement Capability of Company
1.	Feature Development	
	Number of features available for releasing	Data Collection Improvement is Needed
	Quality of Team Planning	
2.	Content stability (added/removed items)	Capable
3.	Used hours per planned items in priority order	Data Collection Improvement is Needed
	Quality of User Stories	
4.	User story average cycle time - from started to done	Data Collection Improvement is Needed
	User Story Deployment	
5.	Accepted user stories (potentially shippable content)	Process Improvement is Needed
	Team Velocity	
6.	Team velocity versus capacity	Capable
7.	Team commitment keeping ratio (on time delivery)	Data Collection Improvement is Needed
	Multitasking in time usage	
8.	Sprint work flow diagram for features under the work, cumulative view to multitasking in the team. Nr of items in process, if the team works together on the same tasks	Data Collection Improvement is Needed
	Sprint burn-down/-up	
9.	Sprint burn-down chart for tracking of team level work progress, work remaining	Capable
	Release burn-down/-up	
10.	Release burn-down chart for tracking work progress in a release (story points - sprints), if the project or release is “on schedule”	Data Collection Improvement is Needed
11.	Feature effort estimation accuracy, original versus team versus real work	Data Collection Improvement is Needed

The detailed explanations of “Nice to Have KPI’s that are recommended for being used in Agile Software Project Management framework of the studied company is given in Table 8 with their KPI Explanation, “Category”, “Type”, “Level”, “Period” and “Scope”. Definitions of each KPI and related “Process Improvement Recommendations” are also presented in the following sections.

- **Content Stability:** According to Schwaber and Sutherland (2013), definitions of Product Backlog and Sprint Backlog are as follows:
- The Product Backlog is an ordered list of everything that might be needed in the product and is the single source of requirements for any changes to be made to the product. All items in the Product Backlog are prioritized and sorted by business value. The top priority items that are selected for development during Sprint Planning drive the next development activities.
- *The Sprint Backlog is the set of Product Backlog items selected for the Sprint plus a plan for delivering the product Increment and realizing the Sprint Goal. The Sprint Backlog is a forecast by the team in sprint planning meeting and is about what functionality will be in the next increment and the work needed to deliver that functionality. In the Sprint Backlog, the Team plans the necessary*

Table 8. Content Stability Summary

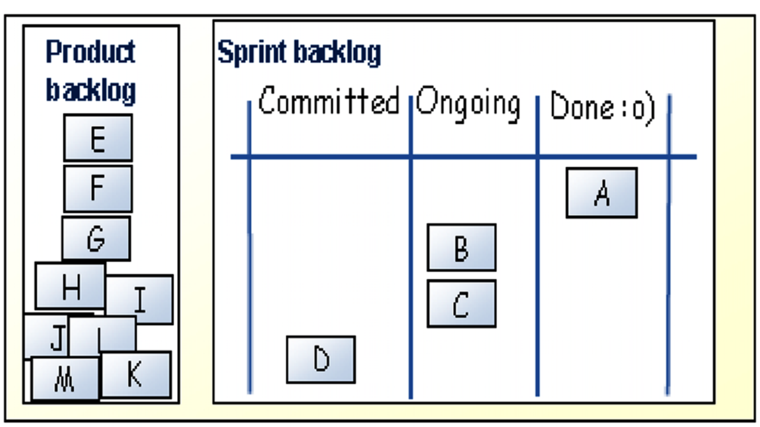
KPI Explanation	Category	Type	Level	Period	Scope
B1.Content stability (added/removed items)	Quality of Team Planning	Ratio	Team	Sprint	User Story
B2.Team velocity versus capacity	Team Velocity	Ratio & Trend	Team	Sprint	User Story
B3.Sprint burn-down chart for tracking of team level work progress, work remaining	Sprint burn-down/-up	Number	Team	Sprint	User Story

tasks to implement the items selected from the Product Backlog in Sprint Planning. Estimations are set and Sprint Backlog is updated by the development team during the Sprint. As the work is done, the Development Team may find that more, less or different tasks are needed. To minimize delays and encourage flow, the team should strive to have no more than one item blocked at a time. "

As shown in the Figure 9, a well-organized team plan is needed for content stability. Otherwise, tasks which are not started yet will be much more and the same situation will be in process and done parts. Thus, adding and removing items in our sprint planning will affect schedule performance. By this KPI quality of team planning can be measured by completion time for releasing of the product.

- **Team Velocity vs. Capacity:** The team's velocity is defined as the number of story points delivered per iteration (sprint). Less capacity means fewer products delivered (Manilla, 2013; Gustaffson, 2011; Leffingwell, 2008). The team should have a realistic workload. Hence, team must perform both velocity planning and capacity planning which are related to each other. An efficient team velocity and capacity planning schedule is a valuable asset for performance evaluation by determining an input for this KPI. An effective Team Velocity vs. Capacity planning schedule can be designed as follows:
- Each team member registers the number of hours they have worked per user story on a daily basis.

Figure 9. Scrum Board Flow Diagram
(Kniberg, 2009)



- At the end of the sprint, we should calculate the total amount of worked hours.
- Number of delivered story points Per worked hours gives the sprint's velocity: man-hours per story point.
- Before the next sprint planning session, the availability of the individual team members during that sprint should be determined and summarized in available man-hours. Then, the available man-hours are divided by the velocity (expressed in man-hours per story point) to know the amount of story points to be delivered by the next sprint.

As a KPI metric, we can define the performance measurement of team velocity-capacity by using the formula which is "*CBV = SP* (Number of story points) */DC* (Delivered capacity: DC).

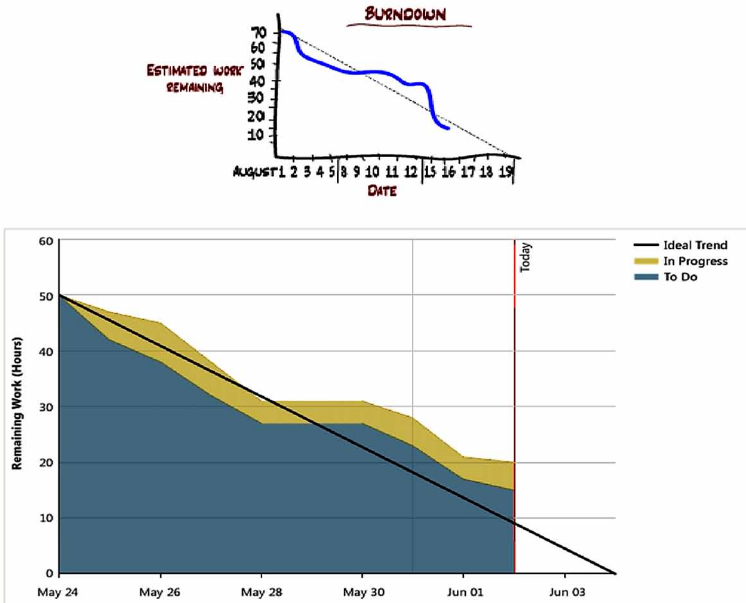
- **Sprint Burn-Down Chart:** This chart shows the remaining work in a sprint backlog and the duration of task completion by the team, and it predicts when team will achieve the goals of the sprint. Raw data is provided from the sprint backlog. The horizontal axis shows days in a sprint, and the vertical axis measures the amount of remaining work to complete the tasks in the sprint (Figure 10). By this graph, team working performance can be used as a useful KPI to evaluate and analyze organizational performance. As Kniberg (2009) defines:"*A sprint burndown chart shows, on a daily basis, how much work remains in the current iteration. The unit of the Y-axis is the same as the unit used on the sprint tasks. Typically hours or days (if the team breaks backlog items into tasks) or story points (if the team doesn't). In Scrum, sprint burndown charts are one of the primary tools for tracking the progress of an iteration. Release burndown charts which follow the same format at a release level can also be used– showing how many story points are left in the product backlog after each sprint.*

CONCLUSION

As software projects become more complex day by day, static project management methodologies cannot respond to its demanding challenges. Object-oriented methodologies are introduced to the software industry in order to satisfy the demands of obscure projects. Agile development, one of the most popular object-oriented PM solution in the software industry, can be currently considered as the best option for complex projects in software industry. Although companies started to define generally accepted agile frameworks, there is not any generally accepted agile measurement model. Therefore, monitoring and measuring agile processes is one of the biggest challenges for the companies that started to implement agile development processes. The aim of the project is to design a performance measurement model for Software Start-Up Company's software projects which are managed by agile methods.

Firstly, current literature about the topic has been researched and 99 different key performance indicators have been listed (in Appendix B). Then, KPIs that is observed in more than 3 sources has been listed to further inspection. After that, expert interviews have been made in order to put KPIs into "must have" and "nice to have" category. On the other hand, the company has been studied in order to implement the measurement model. In that context, current measurement practices and current agile development processes have been investigated.

Figure 10. An Example of Sprint Burn down Chart
(Kniberg, 2009)



The next step was the evaluation of Software Start-Up Company's measurement capability of recently selected KPIs. In this step, a data collection system improvement and a process improvement have been recommended to the company. KPIs in nice to have category are evaluated if the company have the capability to measure them. Only the KPIs that can be measured by the current process and data collection system are included to measurement model. Lastly, data collection system is designed by matching data sources to key performance indicators.

The model is designed specifically for Software Start-Up Company, however it can be generalized in industry level under some constraints. Those constraints are;

- **Company Structure:** The numbers of projects a developer works on at the same time make the measurement of KPIs difficult.
- **Agility Level:** Different level in agile process implementation requires different key performance indicators. Therefore, the measurement model cannot be completely utilized by the companies that just started to implement agile methodologies to their processes.
- **Agile Development Management Tools:** Agile Development requires a high level of coordination between the process management tools. Therefore, the companies that do not have an integrated set of modules, measuring those KPIs would be very difficult.

In literature, there is limited resources on a validated list of Agile Performance Indicators and there is still room for research in proposing recommended models on filtering the current KPI sets that can reflect the needs and conditions of the practicing organizations. We aimed to contribute to closing the gap between the practical needs of practitioners and the theoretical background. These KPI Sets and the selection model which we used (detailed scanning of secondary data sources and literature for creating

KPI set; filtering KPIs by their frequency in sources; creating practical classifications of KPI sets, collecting expert opinions for classifying KPIs by being "must have" and "nice to have").

The recent model can be improved by benchmarking. During the design of the model, benchmarking with similar companies has not been used. However, it can improve the quality of the measurement model for further studies. In addition to that, an AHP model could be integrated to expert review phase of the study.

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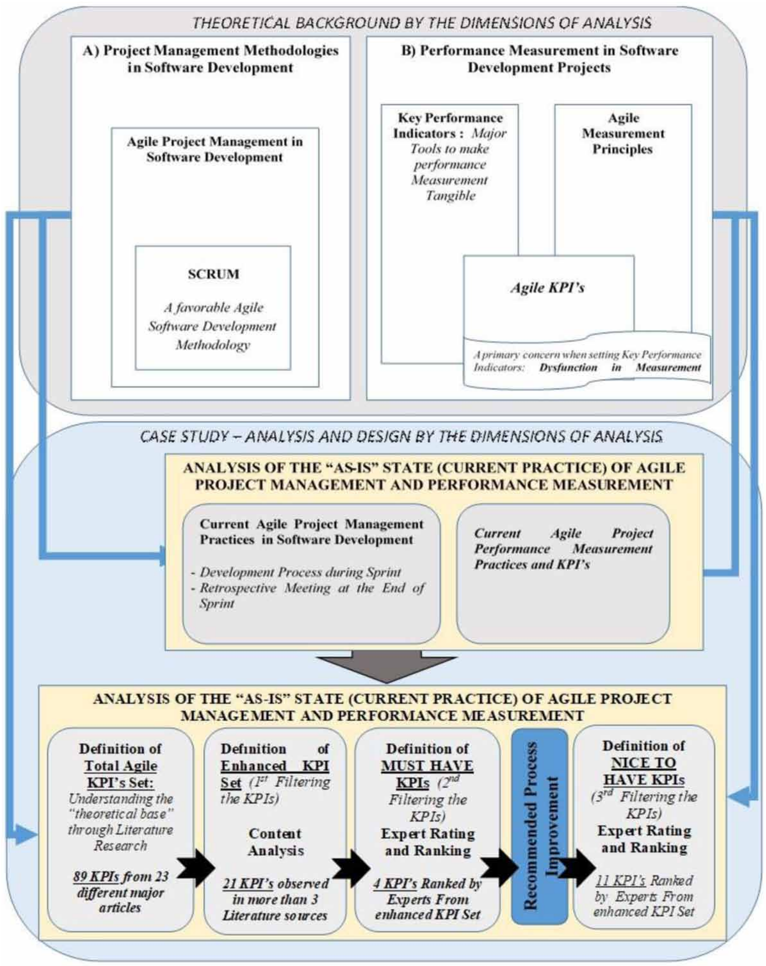
APPENDIX A

Research Model

Figure 11.



APPENDIX B

Key Performance Indicators (99 KPIs) Derived From Literature

Figure 12a.

Nr.	KPI
1	Cumulative Flow Diagrams
2	Control Charts
3	Percent Complete and Accurate
4	Flow Efficiency
5	Time Blocked per Work Item
6	Blocker Clustering
7	Escaped Defects
8	Escaped Defect Resolution Time
9	Release Success Rate
10	Release Time
11	Time Since Last Release
12	Cost Per Release
13	Release Net Promoter Score
14	Release Adoption / Install Rate
15	Customer / Business Value Delivered
16	Risk Burndown
17	Push / Pull
18	Product Forecast
19	Product Net Promoter Score
20	User Analytics
21	Test Coverage
22	Build Time
23	Defect Density
24	Code Churn
25	Code Ownership
26	Code Complexity
27	Coding Standards Adherence
28	Crash Rate
29	Team Happiness / Morale
30	Learning Log
31	Team Tenure
32	Phone-a-Friend Stats
33	Whole Team Contribution
34	Transparency (access to data, access to customers, sharing of learning, successes and
35	Product delivery/lead time precision
36	Number of innovations/ideas in different phases - Idea, Prototype,
37	Pilot, Production
38	Cost/off-shoring savings (euros)
39	Service level/incident resolution – as per service level agreements.
40	Planning/detailed planning horizon – time in future when less than
41	80% of people are covered by detailed committed plan.
42	Planning/backlog horizon (months)
43	Quality - defect count per iteration
44	Quality/technical Debt
45	Quality/faults-slip-through
46	Predictability/velocity - delivery capacity, velocity for productivity
47	Predictability/running automated tests – counts test points
48	Value/customer satisfaction survey
49	Value/business value delivered
50	Lean/lead time – from concept-to-cash
51	Lean/work in progress
52	Lean/queues – the cost of delay of the items in the queues
53	Mini-waterfall level inside a team and sprint
54	Feature component cycle time "from concept to cash" (days).
55	TDD usage per sprint per team/value stream (hours).
56	User story check list (definition of done) compliance level/ratio (%)
57	Pair programming usage per sprint per team/value stream (hours).
58	Team test automation versus manual testing/total testing per sprint
59	Planned testing hours versus implementation hours ratio

Figure 12b.

60	Number of passing test cases (unit, functional, user story, GUI, load),
61	Number of implemented methods per a sprint, trend.
62	Test coverage on code/methods per a sprint, trend.
63	Number of defects reported by priority per week.
64	Defect in- and outflow (amount) per week/sprint/month
65	Team work progress during a sprint by using burn-down chart and estimated versus actu
66	Reported defects over a time, per week/sprint/month.
67	Amount of sprint deliverable re-factored and coded to standards
68	Amount of sprint deliverable unit tested, coverage results per each sprint
69	Sprint deliverable have passing, automated, acceptance tests.
70	Coverage report showing the ratio of automated tests.
71	Project work flow diagram for tasks under the work at the moment,
72	Sprint work flow diagram for tasks under the work at the moment,
73	Average lead time from starting a feature until it is finished
74	Work in process (WIP) diagram, shows the work in process.
75	Lead time
76	Due date performance - item/feature delivered in time.
77	Throughput – number of items delivered in a given time period
78	Issues and blocked work items – a cumulative flow diagram
79	Flow efficiency – the lead time against used time
80	Initial quality – number of escaped defects as a percentage of total WIP
81	Bugs/feature each day in a sprint).
82	Automated acceptance test coverage in %
83	Continuous build success rate in %
84	Developers integrate code multiple times per day, average
85	Re-factoring work ratio in a sprint
86	Code review implementation ratio
87	Level of pair programming, hours used per sprint
88	Team velocity versus capacity in a sprint
89	Value feature points delivered per sprint
90	Release date percentage, promised/actual content
91	Number of defects and normalized defects in a sprint
92	Support calls and normalized support calls in a sprint
93	Limit work to capacity: feature development time in sprints when team velocity
94	Cycle time of deployed features, number of features per time division
95	Request age (age of active customer requests)
96	Customer request arrival rate per week
97	Cycle time from concept to cash.
98	Financial return.
99	Customer satisfaction

Chapter 18
Feasibility Analysis of Industry 4.0 Projects and an Application in Automotive Maintenance Systems

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ABSTRACT

In this chapter, general feasibility analysis steps are redefined for the Industry 4.0 projects. In addition to the traditional feasibility analysis steps, for Industry 4.0 projects, scenario analysis and decision trees are implemented to feasibility analysis that enables us to identify the outcomes of several scenarios for the risky parameters. At the end of the chapter, proposed feasibility analysis procedure is applied to an Industry 4.0 project. Utilization of internet of the things on an automotive maintenance service system is selected as the case study. In this project, the proposed system for the automotive maintenance service sector is a web-based application, which warns driver and maintenance service provider at the same time before the failure happens and by this way enables drivers to have the maintenance before the failure occurs. The versions of the proposed system are analyzed, and the best version is selected at the end of the analysis.

DOI: 10.4018/978-1-5225-7865-9.ch018

INTRODUCTION

The last version of industrial revolutions, Industry 4.0 is a concept, which was introduced at Hannover Exhibition in Germany. In general, this version which can be defined as the automated version of the third industrial revolution, covers the innovation of new generation robots in manufacturing by understanding the systems in production with artificial intelligence and learning algorithms creating a global communication network and using the obtained data as information with concepts such as big data.

Industry 4.0 brings solutions to companies especially in the field of competition with differentiation strategy. Consumers expect new technological developments as soon as possible with lower cost. The finished products can be produced much faster with flexible production systems and can be penetrated to market in the same way. Thus, the Industry 4.0 meets customers' expectations. Therefore, Industry 4.0 projects have become more popular for the companies to survive in competitive environments.

Most of the Industry 4.0 projects require sizeable initial investment amounts due to the need of advanced technologies. The pioneer of the Industry 4.0 concept the German government has invested € 200 million in the first stage for the project, which includes indigenizing innovations such as reducing carbon emissions, building eco-friendly and smart cities, using alternative fuels, switching to smart networks. This amount is only a starting value for the production and use of new technologies.

The developments that will be used more frequently with Industry 4.0 or will be first appeared can be count as cyber physical systems, horizontal and vertical integration, internet of things, machine learning, big data and data analytics, cloud computing, virtual reality, 3D printers and cyber security.

The implementation of these new technologies needs huge investment budgets, which makes feasibility analysis of an Industry 4.0 project very crucial for the managers to gather the best and worst scenarios of the investment decisions.

The main objective of the feasibility analysis is determining the viability of the project in the planning phase of project management. Feasibility analysis of Industry 4.0 projects become different due to the lack of information about the undeveloped technologies and their unpredictable success levels. Therefore, in the planning phase of project management, different scenarios should be analyzed and feasibility analysis outcomes should have different back up plans in case of unsuccessful technologies.

Mostly companies, which need an improvement on their systems by application of Industry 4.0 tools, has different alternative Industry 4.0 projects that utilize different tools and have different outcomes. To analyze an improvement on the system, all possible versions of Industry 4.0 projects should be analyzed at once to find out the best project. Decision trees are useful when different scenarios are examined. Therefore, to find out the best investment project feasibility analysis and decision trees are used together in this chapter.

The purpose of this chapter is to propose a framework for the feasibility analysis of Industry 4.0 projects, which utilizes scenario analysis for the determination of best Industry 4.0 tools and decision trees to handle risks on the assumptions of the parameters of investment projects.

The chapter organized as follows: At first general background and information on traditional feasibility analysis, decision trees and capital budgeting techniques are given. Then a framework for feasibility analysis of Industry 4.0 investments is proposed and explained in detail. At the end, the chapter concludes with an application of the proposed method on an investment project in automotive maintenances sector.

BACKGROUND

Nowadays, Industry 4.0 and its applications are very popular both in academic and industrial researches. Mrugalska and Wyrwicka (2017) state the concept of Industry 4.0 as "the integration of networked sensors and software used to predict, control and plan complex physical machines and devices for better commercial and social outcomes" or "a new value chain organization throughout the life cycle of products and management level ". Can and Kıymaz (2016) points out that all units, which are directly or indirectly related with Industry 4.0 plan, collaborate with each other, and that digital data, software and information technology are integrated with each other. Batista et al. (2017) explain that Industry 4.0 is a further developmental stage in the organization and management of the entire value chain process in sensor and actuator sub-structures in manufacturing. According to Qin et al. (2016) Industry 4.0 is a complex network between various companies, factories, suppliers, logistics, resources, customers, etc. Schumacher et al. (2016) reported that in the Industry 4.0, internet and support technologies such as embedded systems are the backbone of integrating physical objects, human players, intelligent machines, production lines and processes across organizational boundaries.

According to Rennung et al. (2016), the concept of Industry 4.0, which includes brief descriptions in the literature above, is seen as an important strategy to survive in a competitive environment in the future. Industrial companies currently focus on Industry 4.0 in order to overcome difficulties such as increasing individualization of products, increasing resource efficiency and shortening the time of entry into the market. According to Thames and Schaefer (2016), Industry 4.0 will provide manufacturing ecosystems that are driven by intelligent systems with autonomic features such as self-configuration, self-monitoring and self-improvement. This includes the design and implementation of competitive products and services, as well as flexible logistics and production systems. As a result, operational efficiency at an unprecedented level will be achieved and efficiency will be accelerated. This will lead to new types of advanced production and industrial processes towards man-machine collaboration and symbiotic product realization.

Mrugalska and Wyrwicka (2017) pointed out the productivity potentials of Industry 4.0 as follows:

- Increasing competition and flexibility (quality, time, risk, robustness, price and environment friendliness) arising from the dynamic structure of business processes,
- Remove faults in the demand chain from the center,
- Optimize decision-making through real-time end-to-end visibility,
- Providing increased resource productivity (providing the highest output from a given source volume) and efficiency (using the lowest possible amount of resources to achieve a given output)
- Creating Value Opportunities (innovative services, new forms of employment, the development of SMEs and new enterprises)
- Reduce energy and personal costs.

Like all investment projects, Industry 4.0 projects should be analyzed well before the implementation by a feasibility analysis. Developing a new business is a complex and difficult process. Every detail about business must be inspected, well defined, and refined. In addition, there must be alternative plans for every situation. Otherwise, even though the business is developed and started, it would not be a clear projection for business. There are lots of articles which uses feasibility analysis for Industry 4.0 projects to determine whether they are investable or not. Kohn et al. (2018) assessed the feasibility of using a combination of thin elastomer tubes and SMA wires to develop an active catheter. Silva et al. (2018) proposed a customer feedback platform for vehicle manufacturing in Industry 4.0 context, and performed feasibility analysis for the proposed system. Noonpakdee (2018) presented a system analysis and design of manufacturing information system employing radio frequency identification technology (RFID) for real time information tracking for plastic product manufacture and evaluated its economic feasibility. Brad et al. (2018) proposed a model to assess economic feasibility of a future factories over its lifecycle. Marquez-Grana et al. (2017) performed a feasibility study for a novel head support for stereotactic radiosurgery.

Feasibility and feasibility analysis in technical terms have many descriptions. One of them describes feasibility analysis as determination and computation of consistency between the definition of a problem and recommended solution (Graaskamp, 1973). Another one specifies feasibility analysis as a basis that states the future of a business under different presuppositions (Matson, 2000).

In general, feasibility analysis could be determined as a projection of an investment project during a determined study period that starts with the creation of the investment idea and ends with the disposal of the investment project to determine its viability. The first stage of preparing feasibility analysis consists of identification of the strategic aims, priorities, and alternated plans. This identification about strategic concerns bases the development of the analysis. According to the strategic concerns, areas of interest about market trends must be identified with aggregation of demographic data, economic and political factors and trends (Graaskamp, 1973).

Three main branches of a feasibility study are market analysis, technical analysis and financial analysis. Market analysis provides important information about market. It measures the competitiveness of project or product with related researches and information like customer analysis, market share, and potential of the market, possible reaction or impact of the market.

Preparing the production plan and method, determining the raw and/or bulk materials and the technology that will used in production, and designing of the facilities are all related with technical analysis. Researching and indicating the appropriate technical components is one of the most crucial stages of the analysis.

The aim of financial analysis is identifying the economic situation of the investment area, availability of the location, and economic capacity of project. All of the monetary variances like cost and revenue analysis, nominal value of the project, and returning of investment analysis are considered for finding any funds and determining future monetary targets on financial analysis. In consideration of all functions and description of feasibility analysis, evaluation of a project or a plan in compliance with operational, economic, legal, technological, and scheduled capabilities or requirements can be the one of the most extensive definitions of feasibility analysis.

To sum up, feasibility analysis is completed with evaluation of the specified targets, limitations, context, and models together. The whole analysis is transformed to a report that is used for observing the outputs of the proposed project.

The predictions about benefits and costs are one of the most essential substances of feasibility analysis. In general, there are periodic financial information like sales revenue, new investments, turnover rates, improvements etc. This information might use to define the benefits and costs. Capital budgeting techniques are used to determine an equivalent measure for the cash flows of a project by taking into account time value of money concept. Discounting cash flow methods, especially net present value method is widely used to findout the profitability of an investment project. When CF_t denotes cash flows occurred at the end of period t , i denotes the interest rate for given period and n denotes the study period, Eq. 1 can calculate net present value (NPV) of the cash flows:

$$NPV = \sum_{t=0}^{n} \frac{CF_t}{\left(1+i\right)^t} \tag{1}$$

For a given interest rate, positive NPV s show that the investment project is profitable so it is an attractive investment opportunity for the investors. If there are more than one investment project, the best project is the one, which has the highest NPV .

To be on the safe side, due to the ambiguous nature of future estimates, it is suggested to utilize from another method that takes into account different possible outcomes for the cash flow estimations. Decision trees are useful to analyze different scenarios when the probabilities of the scenarios can be determined. In a decision tree, each node represents a feature, each branch represents a decision with a given probability and each leaf represents the outcome of related branch. All possible routes of a decision tree start from the beginning point and ends with a particular leaf is a decision scenario that has the same outcome of the respected leaf with the probability of reaching that leaf from the beginning point. Using decision trees on capital budgeting enables the analyst find out the expected outcomes of each decision scenario and an overall expected net present value for the investment project.

A FRAMEWORK FOR THE FEASIBILITY ANALYSIS OF INDUSTRY 4.0 PROJECTS

As it is mentioned in the introduction part, the unknown parameters of the proposed technologies are the most important problem of feasibility phase of project management in Industry 4.0 projects. To avoid this problem in this chapter scenario based feasibility analysis is developed. There are 6 main steps of the proposed methodology which are shown in Figure 1.

Step 1: Identification of the process in which the Industry 4.0 tools are applied

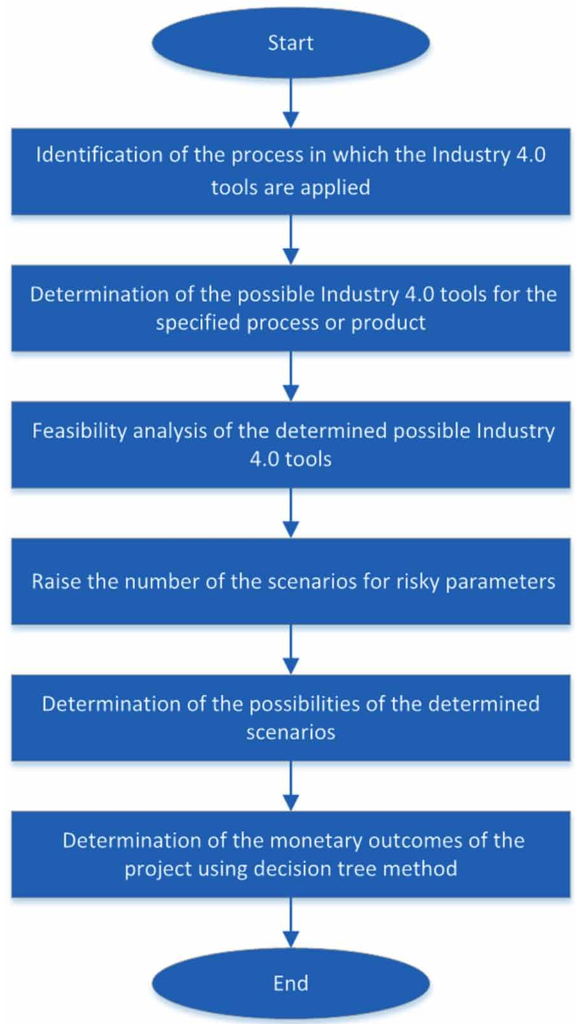
The first step of the proposed method is identification of the study area for the feasibility analysis. The subsystem, which has to be improved in the first instance, could be a process or a product. In this step, a detailed process analysis is suggested to find the subsystems that need an improvement.

Step 2: Determination of the possible Industry 4.0 tools for the specified process or product

After identification of the main study area, the possible Industry 4.0 tools that will improve the system should be determined in detail. It is suggested to define the risks of the determined tools in this step to aware of dealing with inapplicable ones.

Step 3: Feasibility analysis of the determined possible Industry 4.0 tools

Figure 1. Flow chart of the proposed methodology



In this step, traditional feasibility analysis steps are applied for the determined Industry 4.0 investments.

- **Market Analysis:** In market feasibility study, the value of the project in market is determined. It is suggested to utilize from surveys and expert opinions in this step. Market analysis consists of identification of the competitors, potential customers, demand forecasting and project sales revenues.
- **Technical Analysis:** In technical feasibility study, available technology for the proposed investment project is determined. Production technology, machinery and equipments, product components are detailed in this step.
- **Financial Analysis:** In financial feasibility study, the economically viability of the project is analyzed. It consists of estimation of all cash inflows and outflows of the project, evaluation of the economic equivalences of the estimated cash flows and determination of the profitibality of the project. In addition, budget sources, which are required for the initial investment of the project, should be determined in this step.

Step 4: Raise the number of the scenarios for risky parameters

At the end of traditional feasibility analysis, both monetary and nonmonetary results of the proposed investment project are shown in a report. In this step, risks of the investment project should be determined in detail. For example, if the feasibility report expects an increase on the demand of the product by the investment, there should be different scenarios such as one including an increase on the demand and one including a decrease on the demand or stable demand. There will be several scenarios for the investment projects outcomes at the end of this step of the analysis.

Step 5: Determination of the possibilities of the determined scenarios

For the determined scenarios, the managers and experts determine the probabilities of the scenarios. It is recommended to use group decision-making tools such as focus groups or nominal technique in this step.

Step 6: Determination of the monetary outcomes of the scenarios

In this step, economic evaluation of the scenarios for the investment project is performed using capital budgeting techniques. It is suggested to use a decision tree that is useful for the experts to see the profits of scenarios as a sheme. It enables managers to select the best scenario considering different factors such as the project that has the best net present value or the project that has the best probability to have at least a particular net present value.

Application on Industrial Transformation in Automotive Maintenance Systems

For the application of the proposed framework, automotive maintenance sector is chosen. In the literature, it is seen that utilizing Industry 4.0 tools for automative maintenance systems could be very useful. Zhao et al. (2012) stated that, industrial products and everyday objects would take on smart characteristics and capabilities with the benefit of integrated information processing. They may also take on electronic identities that can be queried remotely, or be equipped with sensors for detecting physical changes around them, even particles as small as dust might be tagged and networked. Naryal and Kasliwal (2014) described the implementation of a prototype system used for successful real time data acquisition, fault diagnosis and display with child safety and vehicle monitoring features for Hybrid vehicles. Byttner (2011) developed an approach that builds up knowledge over time by exploratory search among the signals available on the internal field bus system and comparing the observed signal relationships among a group of equipment that perform similar tasks.

The main purpose of the application is to improve the automotive maintenance processes by the implementation of the Industry 4.0 tools. The steps of the proposed framework are applied as follows:

Step 1: Identification of the process in which the Industry 4.0 tools are applied

In an automotive maintenance company, there are two main types of processes such as periodical maintenances and repairs. Repairs consist of the operations that are done for the cars, which had an accident. Therefore, the number of the repairs in a month is unpredictable. In addition, the operations and repair parts vary in each case. Periodic maintenance consists of general check-up, oil change, cleaning and overhaul of the braking system, air filter replacement, checking battery and the cooling system and others. Due to the unpredictable manner of the repairs, in this chapter, implementation of Industry 4.0 tools is evaluated for the improvement of the periodic maintenance scheduling. Basic functions of the proposed system are detailed as follows:

- The proposed system can be used in vehicle tracking. By this way, users may feel more confident in case of any lost or stolen vehicles. In the same way, with the collected data from the equipment being monitored, proposed system is ensured that the maintenance is done correctly and adequately before the deterioration, so it can be taken as a predictive maintenance.
- The proposed system includes continuous monitoring of the machinery or equipment and the analysis of the processing conditions and their progress over time. The status of the motors is determined either periodically or by continuous measurement. According to the results of the measurements and controls, failure time can be predicted. Accordingly, the necessary parts are taken to the maintenance schedule at appropriate times. In addition, by analyzing the collected data, the sources and developments of the defects are learned. This ensures that the equipment is used at maximum efficiency and that unexpected breakdowns are avoided. It also avoids excessive electricity consumption due to inefficient motor performance and reduces the cost of energy requirement.
- In addition to the predictive maintenance, it could be possible to detect the momentary changes in the vehicle at the time of an accident and perform the action according to the situation. For example, Instantaneous detection of sudden brakes or airbag deployments can be used to determine if there is an accident. In this case, it is possible to find out the current status of the related units by calling the vehicle owner, and if the vehicle owner does not answer, the ambulance and necessary units can be sent to the location information obtained from the vehicle. In this way, a major step can be taken to reduce any loss in the event of an accident.
- In addition, with a distance or speed limitation module, which can also be set by the vehicle owner, the owner may be alerted by the mobile application or message in case the user moves away from the zone or exceeds a certain speed limit.
- If the application is considered from the security point of view, if the vehicle changes position while there is no key on the vehicle, this information can be transmitted to the user via the relevant units or mobile application. The vehicle owner will be able to act very quickly if the vehicle is being towed or operated by the momentary position information to be received with the aid of the GPS Module on the device.
- In the proposed system, vehicle owners manage the door or luggage locks as they wish when they want to access the vehicle remotely with a module imlementation. In this case, the desired access can be provided even if the owner is not near the vehicle.

All these functions will be followed by a mobile application.

Step 2: Determination of the possible Industry 4.0 tools for the specified process or product

The main problem in the scheduling of the periodic maintenances is the deviations in the expected demand. Mostly periodical maintenances are scheduled for the usage of the car in terms of miles. Some of the customers reach the determined level of the usage earlier than expected and needs the maintenance one or two months before the scheduled date. Therefore, by using internet of things concept of Industry 4.0, it is aimed to predict the date for the periodical maintenance for each of the customer by taking into account their current usage behaviors. For example, the next periodical maintenance for a customer will be at the 1000 miles' usage of the car. If the customer drives his/her car more than his/her usual driving habits the system will warn the service and customer to update the scheduled date for the maintenance.

To improve the system, also the modifications listed below will be analyzed in the feasibility analysis:

Module 1. Implementation of an intelligent system which shows the depreciation of the spare parts: With this improvement the needed spare parts can be forecasted before and they could be ordered on time.

Module 2. An intelligent warning system for the accidents: This module monitors the unexpected stops of the car, which could be an indicator of an accident. The system calls the user when an unexpected stop occurs and if the customer does not answer the phone the system informs the police and ambulance for the accident and gives the GPS coordinates.

Module 3. Remote control system for the vehicle: This module lets the owner limits the speed of the car, stops the car in a few minutes after warning the driver and alerts the owner when the car is out of the predetermined area. This module could be useful for the parents who want to control their children. The module is also useful when a car is stolen. It will enable the owner to lock the car, which makes impossible to drive the car even with the keys.

Module 4. Movement warning system: This module warns the owner when the car changed location without the keys activated. If a tow truck moves the car, the owner is warned and can interfere on time.

Step 3: Feasibility analysis of the determined possible Industry 4.0 tools

In this step, the proposed modules for the automotive maintenance system are examined as different investment alternatives. The steps of the feasibility analysis are detailed below:

- **Market Analysis:** To find the willingness of the customer for the proposed system a questionnaire is conducted. First of all, the modules that are presented in the previous step are compared by the customers. In addition, the budget which customers are willing to pay for the determined modules are investigated. Nearly 400 car owners complete the questionnaire. The average budget that they are willing to pay for the proposed system is about 10$ per month independent from the modules included. 30% of the participants are willing to have the periodic maintenance system (PMS) without the proposed modules. The percentage of willingness increases wih the implementation of the proposed modules. The results are shown in Table 1 for several module combinations:
- **Technical Analysis:** In this step, a prototip device for the proposed system is developed and shown in the Figure 2. The system needs a SIM card and a GSM module to locate the SIM card to the vehicle for the internet connection, a GPS module to gather the location information, an On-board Diagnosis (OBD), OBD cable and ELM327 connector to track the current situation of the car and data transfer and a tiny and affordable computer RP to control the electronic system parts and interactive applications.

Financial Analysis: In this step, costs of the proposed system are analyzed in detail. Revenues and costs of the alternative are analyzed considering the impact of time value of money.

Table 1. Module Combinations and their demand projections

Module Combination	Percentage of the willingness
PMS without any module	30%
PMS with Module 1	33%
PMS with Module 2	49%
PMS with Module 3	36%
PMS with Module 4	39%
PMS with Module 1 and Module 2	51%
PMS with Module 1 and Module 3	39%
PMS with Module 1 and Module 4	41%
PMS with Module 2 and Module 3	54%
PMS with Module 2 and Module 4	58%
PMS with Module 3 and Module 4	49%
PMS with Module 1, Module 2 and Module 3	64%
PMS with Module 1, Module 2 and Module 4	63%
PMS with Module 1, Module 3 and Module 4	54%
PMS with Module 2, Module 3 and Module 4	72%
PMS with Module 1, Module 2, Module 3 and Module 4	74%

Figure 2. Prototype of the proposed device

The managers forecasted the demand for the first year as 3,000 units. Therefore, the unit costs for the equipments are calculated for 30,000 units of demand, and shown in Table 2.

As shown in Table 2, Module 1 needs several sensors to monitor the spare parts of the vehicle. Module 2 and 4 uses GPS module and SIM card, therefore, there will not be additional costs for the implementation. To implement Module 3 a basic remote control system will be used. Total unit cost of PMS is 95.6$ per year. The alternatives including Module 1 have total unit cost of 116.6$ per year, the alternatives including Module 3 have total unit cost of 98.6$ per year and the alternatives including both Module 1 and 3 have total unit cost of 120.6$ per year.

The software development costs for different modules are determined in Table 3. To be able to develop softwares for the modules, PMS should be developed first.

The price for the proposed system is determined by managers as 10$ per month for all of the versions considering the questionnaire results. For the first year, it is expected to have a demand of 3,000 units for the periodic maintenance system. Demand of the module alternatives are calculated based on the willingness of the customers, which are shown in Table 1. In addition, each year demand is assumed to be increased by 20% for the following years.

Initial investment cost consists of the fixed cost of mould and software developing costs. Total revenues and total costs are calculated for each year for a study period of 5 years and the results are shown in Table 4 for the alternative combinations of the modules.

Table 2. Costs of the Technical Equipment

Equipment	Cost
RP mini computer	40 $/unit
OBD	6 $/unit
SIM Card	2.5 $/month
SIM Card Module	3.5 $/unit
GPS Module	8 $/unit
Connector	8 $/unit
Mould for the protective box	1,500$
Plastic protective box	0.1 $/unit
Sensors for Module 1	21 $/unit
Technical Equipment for Module 3	4 $/unit

Table 3. Costs of the Sofware Developments

Software	Initial Cost	Upgrade/update costs
PMS	25,000 $	5,000$/year
Module 1	20,000 $	5,000$/year
Module 2	10,000 $	3,000$/year
Module 3	15,000 $	1,000$/year
Module 4	10,000 $	1,000$/year

Table 4. Cash Flows of the Investment (x1,000)

Module Combination	Demand for the 1st year	Cash Flows of Year 0	Cash Flows of Year 1		Cash Flows of Year 2		Cash Flows of Year 3		Cash Flows of Year 4		Cash Flows of Year 5	
		Initial Inv. cost	TR	TC	TR	TC	TR	TC	TR	TC	TR	TC
PMS	3	26.5	360	292	432	349	518	418	622	501	746	600
PMS + Module 1	3.3	46.5	396	395	475	472	570	564	684	675	821	808
PMS + Module 2	4.9	36.5	588	476	706	570	847	683	1,016	817	1,219	979
PMS + Module 3	3.6	41.5	432	365	518	436	622	522	746	626	895	750
PMS + Module 4	3.9	36.5	468	379	562	453	674	543	809	650	971	779
PMS + Module 1 + Module 2	5.1	56.5	612	608	734	727	881	869	1,057	1,041	1,268	1,246
PMS + Module 1 + Module 3	3.9	61.5	468	481	562	575	674	688	809	824	971	986
PMS + Module 1 + Module 4	4.1	56.5	492	489	590	585	708	699	850	837	1,020	1,002
PMS + Module 2 + Module 3	5.4	51.5	648	547	778	654	934	783	1,121	938	1,345	1,124
PMS + Module 2 + Module 4	5.8	46.5	696	563	835	674	1,002	807	1,202	967	1,442	1,159
PMS + Module 3 + Module 4	4.9	51.5	588	495	706	593	847	710	1,016	850	1,219	1,019
PMS + Module 1 + Module 2 + Module 3	6.4	71.5	768	786	922	940	1,106	1,125	1,327	1,348	1,592	1,614
PMS + Module 1 + Module 2 + Module 4	6.3	66.5	756	749	907	895	1,088	1,072	1,306	1,283	1,567	1,537
PMS + Module 1 + Module 3 + Module 4	5.4	71.5	648	663	778	793	934	950	1,121	1,137	1,345	1,362
PMS + Module 2 + Module 3 + Module 4	7.2	61.5	864	727	1,037	871	1,244	1,043	1,493	1,249	1,792	1,497
PMS + Module 1 + Module 2 + Module 3 + Module 4	7.4	80.5	888	907	1,066	1,086	1,279	1,300	1,535	1,557	1,842	1,866

Managers decided to have at least 20% minimum attractive rate of return (MARR) from the investment project. With 20% MARR net present values of the alternatives are calculated and shown in Table 5.

At the end of financial analysis, eight of 16 possible module combinations are eliminated due to their negative net present values.

Step 4: Raise the number of the scenarios for risky parameters

The main risky assumptions on the evaluation of the alternatives are demand expectations and demand increase ratios, therefore, in this step; some of the alternatives are analyzed for different expected demands. Experts and managers decided to examine two module combinations that have net present values more than 500,000$ in the financial analysis.

To raise the scenarios for each selected alternative two demands are determined for each year. Hence, there are 32 scenarios for each alternative.

Step 5: Determination of the probabilities of the determined scenarios

A group of experts and top managers determine the probabilities of the expected demands for the alternatives by negotiation. For the pessimistic scenario of the first year, demands are taken as the maximum of the demands of alternatives that has one less module than the examined alternative; therefore, it is taken as 4,900 units for Module 2 and 5,800 for Module 2, 3 and 4 with a probability of 0.3. For the optimistic scenarios of the first years, it is assummed to have the expected demand with a probability of 0.7. For the upcoming years, pessimistic scenario of an optimistic scenario has a probability of 0.3 for an

Table 5. Net Present Values of Module Combinations

Module Combination	Net Present Value ($)
PMS without any module	262,703
PMS with Module 1	-30,546
PMS with Module 2	438,604
PMS with Module 3	245,291
PMS with Module 4	343,010
PMS with Module 1 and Module 2	-24,804
PMS with Module 1 and Module 3	-102,725
PMS with Module 1 and Module 4	-31,816
PMS with Module 2 and Module 3	383,229
PMS with Module 2 and Module 4	516,047
PMS with Module 3 and Module 4	344,184
PMS with Module 1, Module 2 and Module 3	-128,964
PMS with Module 1, Module 2 and Module 4	-19,926
PMS with Module 1, Module 3 and Module 4	-118,224
PMS with Module 2, Module 3 and Module 4	520,488
PMS with Module 1, Module 2, Module 3 and Module 4	-142,630

increase of 10% and optimistic scenario of an optimistic scenario has a probability of 0.7 for an increase of 20% on demand. Pessimistic scenario of a pessimistic scenario has a probability of 0.6 for an increase of 5%, and optimistic scenario of a pessimistic scenario has a probability of 0.4 for an increase of 10%.

Step 6: Determination of the monetary outcomes of the scenarios

The net cash flow estimations of the selected alternatives are shown in Figure 3 and 4 with their probabilities. The net present values of all branches are calculated and shown next to each branch.

SOLUTIONS AND RECOMMENDATIONS

Expected net present values are calculated as 434,939$ for Module 2 and 4 option, and 427,966$ for Module 2, 3 and 4 option at the end of decision tree analysis. It is seen that the sequence of the projects is changed with the effect of expected probabilities of the demand increasing ratios for different scenarios. Managers also want to consider the probability of having at least 450,000$ as a selection criterion. The system with Module 2 and 4 has a probability of having at least 450,000$ as net present value is 0.53 whereas it is 0.48 for the system with Module 2, 3 and 4. Therefore, at the end of the feasibility analysis the system with Module 2 and 4 is selected for the investment.

The results of the proposed framework show that although it is not as profitable as the selected module combination, additional Module 3 implementation is also an attractive investment opportunity. Therefore, it is suggested to offer customers Module 3 implementation as an additional tool with an additional price. This could increase both the market share of the company and customer satisfaction.

As a recommendation to the managers, it is suggested to improve proposed system considering the users' additional expectations. After implementation, another survey could be used to determine customer satisfaction levels and expectations. With the help of this data, new additional modules can be offered to the customers with additional prices.

FUTURE RESEARCH DIRECTIONS

Data collection is one of the most significant achievements of Industry 4.0 applications. The data collected from the applied systems could be used to improve the system considering the needs of the users. As an example, the automative maintenance system collects driving behaviours of the customers. This data could be used in design of automatives to make it more comfortable and safety for the users.

All investments of Industry 4.0 tools should be updated with developing technologies in the direction of possible software, systems or devices. Therefore, to improve the system, feasibility analysis should be repeated for new applicable modules periodically starting from the second step of the proposed method. It is suggested to use data mining tools in determination of the customer behaviours and needs.

Figure 3. Decision Tree of the Alternative with Module 2 and Module 4

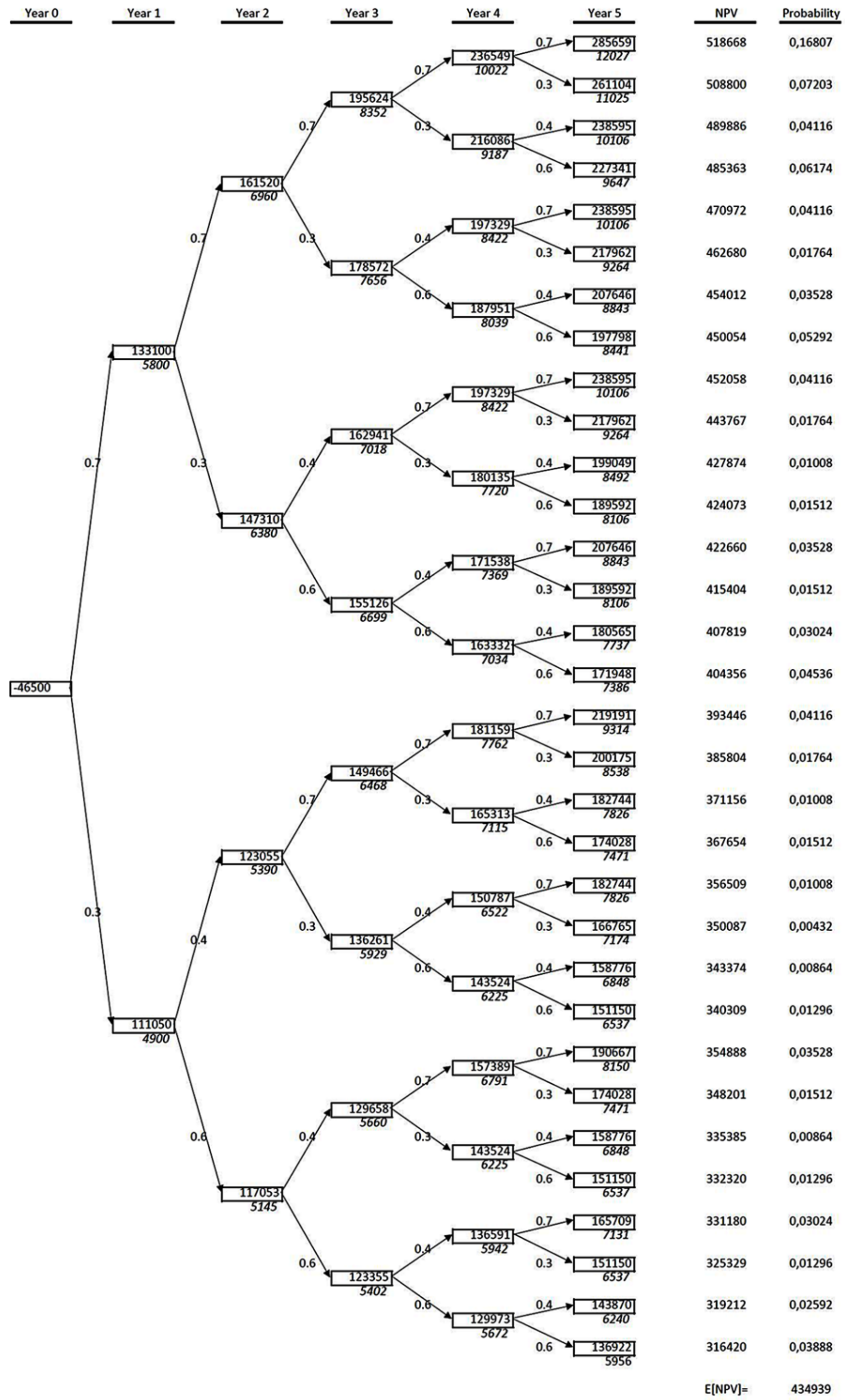
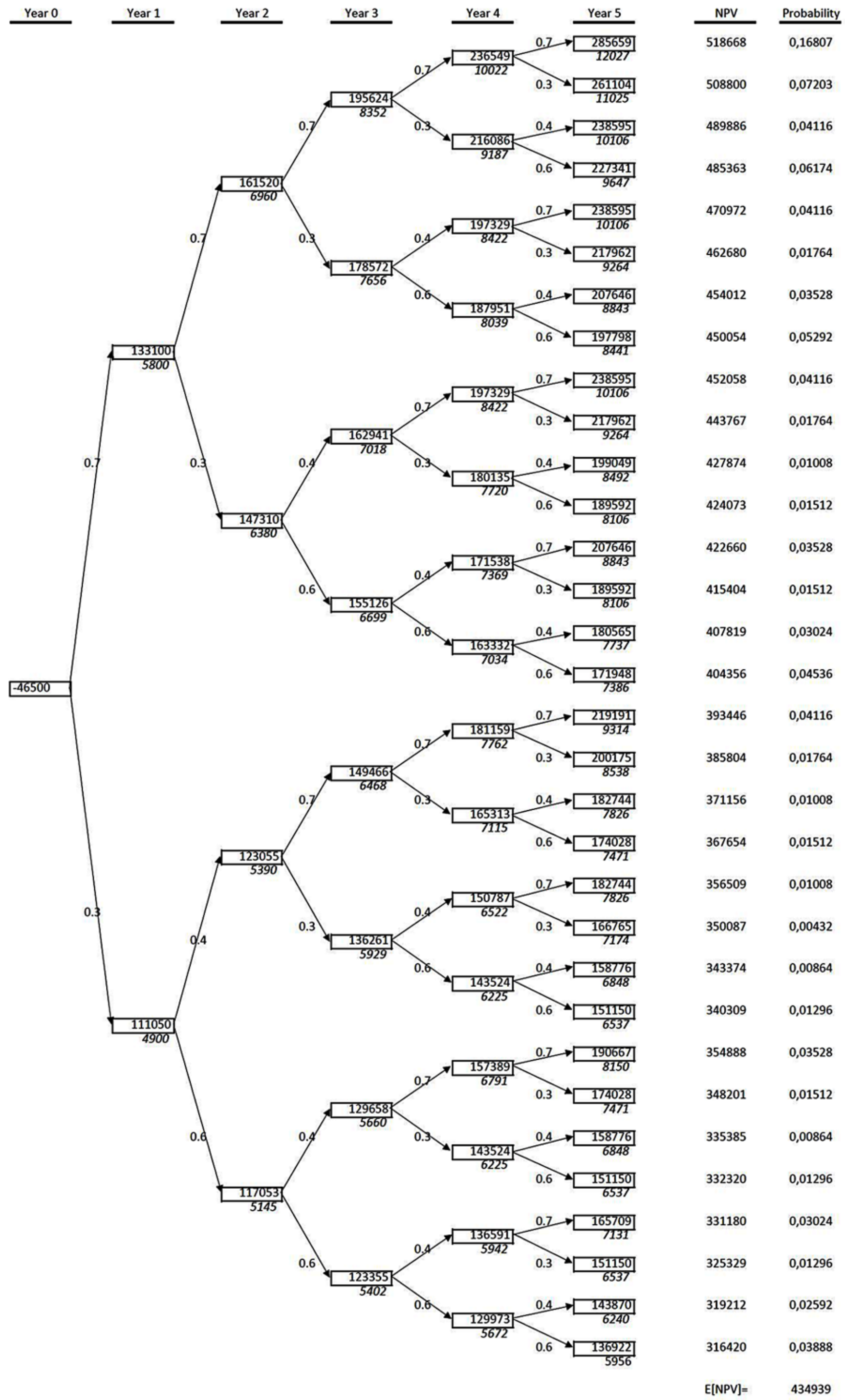


Figure 4. Decision Tree of the Alternative with Module 2, Module 3 and Module 4



CONCLUSION

Feasibility analysis is one of the core steps of project management. It determines the viability of the project idea considering market needs, technical requirements and capital budgeting. In this chapter, a detailed feasibility analysis is performed for transition to Industry 4.0 in automative maintenance service sector. In addition to traditional feasibility analysis, different Industry 4.0 tools are examined with scenario analysis. By this way, the most appropriate Industry 4.0 tools for the process are identified. Due to the unpredictable factors that affect future estimations, the alternatives that have better outcomes are analyzed for different value of the risky parameters. In this step, decision tree analysis is used to visualize the outcomes of each scenario. At the end of the framework, managers could decide the best investment project alternative considering the best net present value, expected net present value or the best probability that gives at least a particular net present value depending on their preferences.

As a conclusion, the proposed feasibility analysis framework enables decision makers to deal with the undeveloped technologies, which are essential for Industry 4.0 investment projects. With the utilization of scenario analysis, the proposed approach enables to anticipate alternative futures.

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Carl Marnewick traded his professional career as a senior Information Technology (IT) project manager for that of an academic career. The career change provided him the opportunity to emerge himself in the question why IT/IS-related projects are not always successful and do not provide the intended benefits that were originally anticipated. This is currently a problem internationally as valuable resources are wasted on projects and programmes that do not add value to the strategic objectives of the organisation. It is an international problem where there is a gap between theory and practice and is in the ideal position to address this problem. The focus of his research is the overarching topic and special interest of the strategic alignment of projects to the vision of the organisations. This alignment is from the initiation of a project to the realisation of benefits. He developed a framework (Vision-to-Project i.e. V2P) that ensures that projects within an organisation are linked to the vision. Within this framework, a natural outflow of research is the realisation of benefits to the organisation through the implementation of IT/IS systems. Benefits realisation is part of a complex system and my research to date has identified the following impediments in the realisation of benefits: (i) IT project success rates as well as IT project management maturity levels did not improve over the last decade and these results are in line with similar international research; (ii) IT project managers are not necessarily following best practices and industry standards; (iii) governance and auditing structures are not in place and (iv) IT project managers' training and required skills are not aligned. If these four aspects are addressed through research and practice, then benefits realisation can occur. His research has given him national and international presence.

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