Premier Reference Source

Driving Innovation and Productivity Through Sustainable Automation

Ardavan Amini, Stephen Bushell, and Arshad Mahmood

IGI Global
PUBLISHER of TIMELY KNOWLEDGE

Driving Innovation and Productivity Through Sustainable Automation

Ardavan Amini
EsseSystems, UK

Stephen Bushell
Bushell Investment Group, UK

Arshad Mahmood
Birmingham City University, UK

A volume in the Advances in Computational Intelligence and Robotics (ACIR) Book Series

Published in the United States of America by
IGI Global
Engineering 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: Amini, Ardavan, editor. | Bushell, Stephen, 1962- editor. | Mahmood, Arshad, 1966- editor.
Title: Driving innovation and productivity through sustainable automation / Ardavan Amini, Stephen Bushell, and Arshad Mahmood, editors.
Description: Hershey, PA : Business Science Reference, an imprint of IGI Global, [2021] | Includes bibliographical references and index. | Summary: “This book provides the scholars, researchers and industry practitioners with the knowledge and an understanding of current challenges and new capabilities and solutions being researched, developed and applied within the industry to drive sustainable automation for innovation and productivity”-- Provided by publisher.
Identifiers: LCCN 2020036224 (print) | LCCN 2020036225 (ebook) | ISBN 9781799858799 (hardcover) | ISBN 9781799868569 (softcover) | ISBN 9781799858805 (ebook)
Subjects: LCSH: Telematics. | Automation.
Classification: LCC TK5105.6 .D75 2021 (print) | LCC TK5105.6 (ebook) | DDC 629.8--dc23
LC record available at https://lccn.loc.gov/2020036224
LC ebook record available at https://lccn.loc.gov/2020036225

This book is published in the IGI Global book series Advances in Computational Intelligence and Robotics (ACIR) (ISSN: 2327-0411; eISSN: 2327-042X)

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

Advances in Computational Intelligence and Robotics (ACIR) Book Series

ISSN:2327-0411
EISSN:2327-042X

Editor-in-Chief: Ivan Giannoccaro, University of Salento, Italy

MISSION

While intelligence is traditionally a term applied to humans and human cognition, technology has progressed in such a way to allow for the development of intelligent systems able to simulate many human traits. With this new era of simulated and artificial intelligence, much research is needed in order to continue to advance the field and also to evaluate the ethical and societal concerns of the existence of artificial life and machine learning.

The **Advances in Computational Intelligence and Robotics (ACIR) Book Series** encourages scholarly discourse on all topics pertaining to evolutionary computing, artificial life, computational intelligence, machine learning, and robotics. ACIR presents the latest research being conducted on diverse topics in intelligence technologies with the goal of advancing knowledge and applications in this rapidly evolving field.

COVERAGE

- Adaptive and Complex Systems
- Pattern Recognition
- Synthetic Emotions
- Artificial Intelligence
- Machine Learning
- Cognitive Informatics
- Robotics
- Computational Logic
- Fuzzy Systems
- Algorithmic Learning

IGI Global is currently accepting manuscripts for publication within this series. To submit a proposal for a volume in this series, please contact our Acquisition Editors at Acquisitions@igi-global.com or visit: http://www.igi-global.com/publish/.

The Advances in Computational Intelligence and Robotics (ACIR) Book Series (ISSN 2327-0411) is published by IGI Global, 701 E. Chocolate Avenue, Hershey, PA 17033-1240, USA, www.igi-global.com. This series is composed of titles available for purchase individually; each title is edited to be contextually exclusive from any other title within the series. For pricing and ordering information please visit http://www.igi-global.com/book-series/advances-computational-intelligence-robotics/73674. Postmaster: Send all address changes to above address.

Titles in this Series

For a list of additional titles in this series, please visit:
http://www.igi-global.com/book-series/advances-computational-intelligence-robotics/73674

Examining Optoelectronics in Machine Vision and Applications in Industry 4.0
Oleg Sergiyenko (Autonomous University of Baja California, Mexico) Julio C. Rodriguez-Quiñonez (Autonomous University of Baja California, Mexico) and Wendy Flores-Fuentes (Autonomous University of Baja California, Mexico)
Engineering Science Reference • © 2021 • 346pp • H/C (ISBN: 9781799865223) • US $215.00

Emerging Capabilities and Applications of Artificial Higher Order Neural Networks
Ming Zhang (Christopher Newport University, USA)
Engineering Science Reference • © 2021 • 346pp • H/C (ISBN: 9781799835639) • US $225.00

Machine Learning Applications in Non-Conventional Machining Processes
Goutam Kumar Bose (Haldia Institute of Technology, India) and Pritam Pain (Haldia Institute of Technology, India)
Engineering Science Reference • © 2021 • 313pp • H/C (ISBN: 9781799836247) • US $195.00

Artificial Neural Network Applications in Business and Engineering
Quang Hung Do (University of Transport Technology, Vietnam)
Engineering Science Reference • © 2021 • 275pp • H/C (ISBN: 9781799832386) • US $245.00

Multimedia and Sensory Input for Augmented, Mixed, and Virtual Reality
Amit Kumar Tyagi (Research Division of Advanced Data Science, Vellore Institute of Technolgy, Chennai, India)
Engineering Science Reference • © 2021 • 310pp • H/C (ISBN: 9781799847038) • US $225.00

For an entire list of titles in this series, please visit:
http://www.igi-global.com/book-series/advances-computational-intelligence-robotics/73674

701 East Chocolate Avenue, Hershey, PA 17033, USA
Tel: 717-533-8845 x100 • Fax: 717-533-8661
E-Mail: cust@igi-global.com • www.igi-global.com

Table of Contents

Detailed Table of Contents

be realized. On the one hand, smart factories are almost exclusively multibillion-dollar enterprises. Their costs are simply too high for most manufacturers. On the other hand, intelligent machines are limited in what they can do because so many of the engineering tasks required to support them are still being done by people. Widespread use of automation requires expanding the use of artificial intelligence to manage data, create drawings, evaluate designs, and program machines.

In past decades, production has been characterized by the mass customization trend. This concept reaches its extreme with the one-of-a-kind production (OKP): every product is different for each customer. In order to develop unique product and complex processes in short time, it is mandatory to reuse the acquired information in the most efficient way. Several commercial software applications are already available for managing manufacturing information, such as product lifecycle management (PLM) and manufacturing execution system (MES), but they are not integrated. The aim of this chapter is to propose a framework able to structure and relate information from design and execution of processes, especially the ones related to anomalies and critical situations occurring at the shop floor, in order to reduce the time for finalizing a new product. To this aim, a central knowledge-based system (KBS), acting as integrator between PLM and MES, has been developed. The framework has been implemented with open source systems, and has been tested in a car prototyping company.

This chapter presents the recent methodological developments in demand management and demand forecasting subjects of the operations management. The background section provides detailed information on the domain of production management, operational analytics, and demand forecasting while providing introductory information on time series forecasting and related machine learning methodologies. The novel contribution of the chapter is the exploration developed in the solutions and recommendations section while examining the effect of stationarity in the time series forecasting methodologies of machine learning with improved benchmark results.

Preface

As editors with extensive experience in applying innovation and productivity in academia, research and industry projects. We have led and delivered large projects for public and private sectors, where we have seen the gap in driving sustainable automation towards innovation and productivity. We hope through this edited book we provide the professions, industry leaders, as well as academic and research communities with cases studies and example projects of productivity and innovation across the world with sustainable automation in mind.

Since the start of the first industrial revolution in the early 1700 century and through to 1800 century, creativity (ideation, vision and imagination) and engineering (formalization, manufacturing) has been at the heart of all enterprise and organization activities. To design, create and delivery new and innovative products for the needs of society based on pupil culture and market needs through to today's complex and sophisticated societies and marketplaces, where various business models are applied alongside digitalisation, trying to balance creativity and engineering with automation, and aiming to achieve sustainability and resilient factors in enterprises domains.

However, the gap in delivering sustainable automation and the ability to having an adaptive and generative infinite loop of creativity and engineering as the DNA of our products and services based on scientific and industrial experience to drive innovation and productivity still remains a challenge for many enterprises and organisations, where the adaption needs to not only factor in internal organization dynamics of people, culture, soft approaches and skills alongside external market and society forces. Scientists across universities and research institutes working with industry partners have been developing various frameworks, methods, models and techniques to deliver standards which can help towards sustainability, resilient, and generating economic growth. In this journey, learning from past experiences the enterprises have to consider that diversity and density will provide them with invention, and when innovative ideas are entered into marketplace to address society challenges is considered an innovation and when people with the enterprises and organisations structures are up-skilled or re-skilled the productivity increases.

In era of digitalisation, automation and knowledge economy where sustainability and innovation are at the forefront of the enterprises focus when addressing their challenges. If there is one constant thing in the market, then it is that things are changing faster and are more dynamic. The pressures on organisations and enterprises around the world to keep up with these changes are increasing. Markets are crowded; margins are squeezed. New challenges pop up seemingly overnight on all fronts, including the unseen pandemic faced by many organisations in 2020.

All this is nothing new, but the question is how organisations can tackle multiple business, information and technology changes in globalization, productivity, innovation, compliance, information overload, and at the same time to be productive and create resilient and sustainability, not to forget the changing nature of people and the work golden rule of business: where the customer comes first. The organizations are struggling to adapt their business model as well as operating model in this accelerating pace to identify where and how to create the needed value. Everything around them seems to be changing faster than they can keep pace. In such changing times, many things are important to consider, when trying to create superior value.

The aim of the editors in this book is to provide various case studies and examples of projects across the world which have driven by innovation and productivity through sustainable automation using different frameworks, approaches, methods, and techniques.

This book can be read on two different levels. Firstly, by professional and practitioners across industries and government agencies where practical elements of the chapters can provide them with new and innovative approaches based on scientific research and industry experience when it comes to driving innovation and productivity through sustainable automation. Although not all areas across all sectors are considered.

The second group of readers are scholars and academic institutions where the book providers sample case studies and example approach methods and techniques based on the result of in-depth scientific research and scholarly activities of the authors, usually over a period of years, making an original contribution to the field of study.

This book comprises of twelve chapters each representing a case study and a unique scenario on their own, where sustainable automation was considered to drive productivity and innovation.

Chapter 1: Analysis of the Impact of Customer Relationship Management on Innovation Acquisition Using Agent-Based Modelling

This chapter present study is conducted in order to examine the effect of Customer Relationship Management (CRM) on diffusion and acquisition of innovational products and services using Agent-Based Modeling (ABM) methodology in a municipality.

Chapter 2: Automation 4.0 – The Impact on Manufacturing and Engineering

This chapter describes the need for substantial changes in automation when it comes to use technology to reduce or replace human activity. Notably, the cost and capabilities of intelligent machines need to make automation a value proposition for smaller manufactures.

Chapter 3: Building a Factory Knowledge Base – Digitalization and Integration of Manufacturing Information

This chapter describes the framework to integrate data received from PLM and MES to reduce the number of trial-and-errors cycles to find the final production process of a new product. A specific attention will be given to the collection of data regarding anomalies occurring at the shop floor with specific focus on industry 4.0 technologies.

Chapter 4: Demand Forecasting Models With Time Series and Random Forest

This Chapter provides a scientific literature on the operations management with focus on transforming inputs to outputs to economically sustain companies, while making decisions based on available and limited resources.

Chapter 5: A Study of Green and Risk Resilient Supply Chain Strategy – Analysis of the Best Innovative Practices of Fortune Global 500 Companies

With the rapid development of the economy, environmental problems have become increasingly prominent. Environmental pollution and degradation have become global problems. In this Chapter the authors have conducted a research study with an attempted to identify and analyse the criteria of green innovation practices.

Chapter 6: Digital Preservation of Cultural Heritage – Digital Innovative Approach Towards Sustainable Development of South African Rural Communities

This chapter used literature review to investigate mechanisms or strategies being established in different parts of the world to safeguard cultural heritage towards sustainable development of rural communities.

Chapter 7: Low-Cost Home Automation System for Physical Disability and Limited Mobility People – A Case Study on Needy Brazilian Communities

This Chapter provides a scientific research into a low-cost home automation system with the main objectives to evaluate the benefits and challenges of using the home automation system in needy Brazilian communities by implementing a model for a small home.

Chapter 8: Supply Chain Sustainability in Food and Beverage Industry

This Chapter emphasizes on the necessities of the green supply chain processes as well as the strategies adopted by the firms particularly in the food & beverage industry with the focus on the trends, impacts, challenges and opportunities for a Green Supply Chain Management.

Chapter 9: Transition for Transformation for Sustainable Automation

This chapter aims to emphasis the characteristics of transition for transformation from a business perspective in the light of 21st century challenges.

Chapter 10: Automatic Photovoltaic Solar Panel Dust Cleaning System

Electricity plays a huge role in all shares of lives and the economy. We have become so dependent on this energy source that life without it seems impossible. This chapter will introduce effective ways of harnessing renewable energy with specific focus on solar energy.

Chapter 11: Negative Effects of Presence of Dorsal Diseases in Workers of a Metallic Industry in Mexicali, Mexico

An investigation of the negative effects in the health of workers in the metal industry located in Mexicali city, who suffered daily, of discomfort in the head, neck, back and spine.

Chapter 12: Successful Entrepreneurs Drive Innovation and Productivity Through Sustainable Automation

This chapter will look at how successful entrepreneurs drive innovation and productivity through sustainable automation. What would have cost in the tens of thousands or even hundreds of thousands of pounds to start a new venture, now it is a fraction in comparison to before Innovation in the technology sector has made this all possible than ever before.

This book consists of chapters with practical case studies alongside research and academic chapters that provides a wide range of knowledge and expertise in the field of innovation and productivity and approaches within different sectors as well as introducing the lessons learned and new methods, approaches and frameworks developed for industrial usage, addressing our current and future societal challenges.

Acknowledgment

We would like to express our special thank you to all the authors and reviewers for their contribution to this book, and to IGI team for their support and administrative assistance through development of this project.

During the editorial of this book we have lost one of our editors Mr Arshad Mahmood due to Covid-19, we would like to dedicate this book to his family in the honour of his memory and his professionalism and contribution to the development of this book.

Chapter 1
Analysis of the Impact of Customer Relationship Management on Innovation Acquisition Using Agent-Based Modeling

Maryam Ebrahimi
https://orcid.org/0000-0001-5837-8864
Independent Researcher, Germany

ABSTRACT

The present study is conducted in order to examine the effect of Customer relationship management (CRM) on diffusion and acquisition of innovational products and services using agent-based modeling (ABM) methodology in a municipality. CRM components include customer orientation, organizational structure, knowledge management, and information technology. The innovational products and services diffusion steps also include awareness, interest, evaluation, testing, and adoption. A researcher-made questionnaire is used to collect data which has been distributed among 110 participants after testing its validity and reliability. SmartPLS3.2.6 and anylogic softwares are applied to analyze hypotheses and modeling and simulation, respectively. ABM is validated on the basis of experts' viewpoints. According to the research findings, CRM affects the diffusion process of municipality's products and services. ABM shows that without CRM, customers are usually lower for each phase of diffusion process.

DOI: 10.4018/978-1-7998-5879-9.ch001

INTRODUCTION

With population growth and, as a result, increased urban traffic, labor costs, conflicts and psychological distress in today's cities, important organizations such as municipalities, which are considered as the beating heart of cities, must abandon the traditional methods and enter the electronic and virtual world. As a business strategy for creating mutual value, customer relationship management (CRM) identifies all aspects of the customer profile, creates customer knowledge, and forms relationships with the customer. Hence, it is important to look at such a valuable concept in the organizations that serving customer is their existential philosophy. Providing the best possible value to customers is undoubtedly important for service firms in today's competitive marketplace. Companies that have the ability to provide valuable service products to customers will have significant competitive advantage.

However, as many organizations fail to implement CRM properly, it is needed to identify the most important factors in CRM in order to increase their chances of success in this regard and attract the most valuable capital namely customers. In this study, the success factors of CRM are examined to study their effect on the diffusion or adoption of products and services. Adoption is to determine the needs, select, develop, and adopt strategies to meet those needs that are manifested in the form of services and support. The main purpose of this process is to convert different needs into products that meet the needs. The advantages of service diffusion include: 1) guaranteeing service quality, 2) Diagnosis and elimination of incorrect versions.

CRM helps the municipality to save time, provide services quickly and accurately, improve employee engagement, and take advantage of other CRM benefits, such as providing specific services to key customers, attracting customers faster and more efficiently and better understanding their needs, having a database of customer records, increasing profitability, improving customer satisfaction, making useful and reciprocal communication, and the ability to develop programs for strategic investment.

Services are the most important consideration for city managers and mayors in municipalities, and the adoption and diffusion of these services to provide better services to citizens and respect for citizenship rights is necessary so that senior managers and mayors consider critical success factors of CRM on product delivery and pay attention to the increasing and optimal growth of the innovational services and products provided based on the diffusion process, including the stages of awareness, interest, evaluation, test and adoption.

BACKGROUND

CRM is a term for a set of methodologies, processes, software, and systems that are managed by institutions and companies and help organize communication with their customers (Burnett, 2000). CRM means creating and maintaining a defined relationship with profitable customers through the proper use of information and communication technologies (Namjoyan et al., 2013). As a process, CRM consists of monitoring the customer (such as collecting their appropriate data), managing and evaluating the data, and ultimately creating a real advantage of the information extracted from their interactions (Hasanzadeh and Mahaleh, 2013). CRM combines intimate customer relationships with economic savings, enabling the organization to build close relationships between business representatives and their customers. CRM is treated equally and unequivocally regardless of the organizational channel (Reynolds, 2002).

Services refer to any action or work that is presented from one side to the other and is necessarily provided as intangible and does not lead to the ownership of anything. Service production may or may not depend on physical goods. The service diffusion or acquisition model is one of the most practical marketing models that introduces the steps that each customer goes through during the purchase process. In fact, this model helps marketing and sales experts to better understand the sales process.

Salah et al. (2018), provided an understanding of effective CRM implementation through focusing technological (Compatibility, IT Infrastructure, and Security), organizational (top management support, financial support, and social influence), and cultural factors (information integrity, attitude, information policies, and culture change).

Feiz et al. (2011) explained integrating people, process, and technology to achieve a successful CRM. They stated that the main business drives of CRM are increasing customer lifetimes, reducing costs, and improving efficiency. The main barriers to becoming customer-centric are poor performances in some areas.

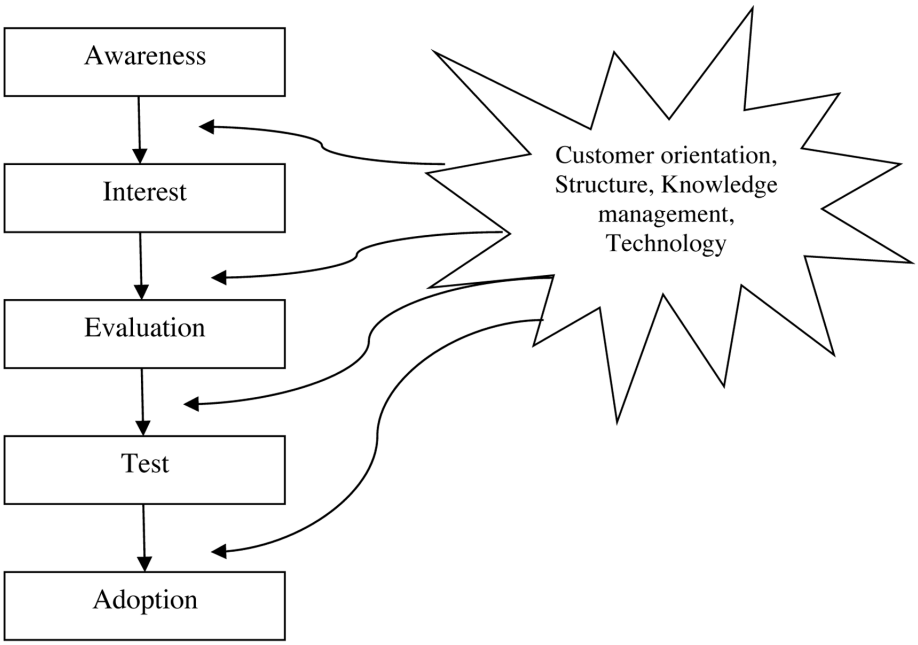
An integrated framework of factors affecting CRM success, not only knowledge management but also technological factors, organizational factors, customer orientation and experience is provided by Moreno and Melendez (2011). They finally concluded that organizational factors have the greatest impact on CRM success. The two researchers eventually examined the results of successful CRM implementation from both the financial and marketing dimensions.

In order to develop a valid measurement scale for CRM, Sin et al. (2005) declared four key dimensions of CRM including customer orientation, structure, knowledge management, and technology. Components for customer orientation include customer-centric marketing, key customer longevity value identification, personalization, and interactive marketing. Organizational structure, commitment to organizational

resources, and human resource management were considered as key components of the organization. Learning and creating knowledge, disseminating and sharing knowledge, as well as responding to knowledge were introduced as components of knowledge management. Finally, they examined the results of CRM implementation from both financial and marketing dimensions.

THE RESEARCH CONCEPTUAL MODEL

Figure 1. Conceptual model of the research



The steps of the diffusion model are:

- **Awareness:** The customer is informed of the existence of brand, product or service. The first and most important step in marketing and sales is to get the brand seen by customers. Today, in addition to advertising, social media also provides an opportunity for effective marketing activities to inform customers.
- **Interest:** The customers will be informed of the benefits of product or service and if it is considered important by them, they will be interested in researching

and receiving more information. The customer is somewhat interested in the product or service in this stage and hence, he/she starts searching and researching to get more information. Depending on the importance and value of the product, customer research may be an accurate and lengthy process.

- **Evaluation:** At this stage, the customer asks himself if this product/ service has these special benefits for me. He will probably pay attention to the opinions and recommendations of other customers and the advantages and disadvantages of the company's products over competing products. Today, customers pay a lot of attention to social networks and try to carefully read the opinions, questions and criticisms of other customers about their brand and product.
- **Test:** During the test phase, the customer examines the product or service on a small scale or at the first purchase. You should also be able to quickly and easily connect potential customers with the company's experts that social networks and online chats are among the best tools in this regard.
- **Adoption/ Acquisition:** At this stage, the customer will make a purchase or any other action you expect, such as subscribing to the newsletter and so on. Customer support in the buying process and providing a great experience for them will bring many benefits to the company in the future.

CRM components are:

- **Focus on key customers:** Focusing on key customers includes focusing on customer-centric decision-making and providing high and increasing value to key customers, which is made possible through dedicated and personalized contracts for them. The empowerment of an organization's customer base is at the heart of the organization's customer satisfaction, productivity, and performance assumptions. According to marketing theories, an organization must make every effort to satisfy the customers' needs and demands if wants to be successful, or in other words, manage customer needs profitably. This means that organizations need to deliver value to the customer in a way that is more effective than their competitors.
- **Knowledge management:** The need for organizations to acquire knowledge assets is significantly greater than in the past in today's competitive environment. Immutability, scarcity, value, and irreplaceability are among the characteristics of knowledge assets. Knowledge development involves all managerial efforts that consciously focus on the production of capabilities that have not yet been presented within the organization or even do not yet exist in or out (Joseph and Winston, 2005). From a knowledge-based perspective, any organization needs to produce, transfer, and implement knowledge. From a

CRM perspective, knowledge refers to the information gained from empirical studies of customer data.

- **Organizational structure:** Indeed, organizational structure is to select people in different parts of an organizational chart in job positions that affect people's organizational relationships. One of the uses of the above definition is work division. Within the organization, people are assigned different jobs. Another use is that the organization has a hierarchy of responsibilities (Robins, 1990). CRM inherently makes fundamental changes in the type of company organization and job processes. Companies should pay special attention to making changes in their organization to fit CRM at the beginning of CRM implementation.
- **Technology:** According to Guo and Niu (2007), CRM can be a business strategy and philosophy that uses technology designed to enhance people's interactions in the business environment. Therefore, CRM technology is not only a software program in the field of information technology, but also uses a technological structure to enable business information to share customer information and achieve the following:
    1. Identifying the specific needs of the customer,
    2. Identifying the most profitable customers to the business,
    3. Standard and effective customer care,
    4. Identifying the riskiest customers.

RESEARCH METHODOLOGY

Research Purposes

The research main purpose is to determine the impact of critical success factors of CRM on product / service diffusion steps. Thus, the sub-objectives include the following:

- Determining the impact of customer orientation on each stage of product/ service diffusion,
- Determining the impact of structure on each stage of product/ service diffusion,
- Determining the impact of knowledge management on each stage of product/ service diffusion,
- Determining the impact of technology on each stage of product/ service diffusion.

Research Method

The present study is descriptive-survey in terms of data collection approach, and because correlation is the mechanism governing confirmatory factor analysis and path analysis in modeling structural equations, so this research is of correlation type. On the other hand, in this research, agent-based modeling (ABM) methodology is used to model and simulate the relationships of variables.

Statistical Population and Sample

The research statistical population includes employees of a municipality. The statistical population of this study is 110 people and due to the low population, the census method has been used for sample size.

Data Collection Method

The research data are gathered through a questionnaire. After reviewing the theoretical bases and models presented and using the extracted dimensions and indicators that formed the research conceptual framework, the standard research questionnaire was obtained and after obtaining the expert opinions of respected professors, the final questionnaire was compiled to collect field data. The questionnaire questions are based on the Likert scale.

- Questions include 22 items that contain the relevant indicators of product/ service diffusion and acquisition (awareness, interest, evaluation, test, and adoption).
- Questions include 21 items that include CRM-related indicators (customer orientation, structure, knowledge management, and technology).

VALIDATION

Face Validity

In order to confirm the content validity, the questionnaire was provided to professors and for more comprehensive study, the questionnaire was distributed among several municipal employees and it was confirmed.

Table 1. Questions of diffusion stages of innovational services/ products

	Items
Awareness	In the field of service and product innovation, the necessary information is provided in the form of face-to-face consultation for customers.
	In the field of service and product innovation, the necessary information such as the site and the municipal portal for customers is provided electronically.
	In the field of service and product innovation, the necessary information is provided to customers through manuals or catalogs.
	The attitude of the municipal staff towards the customer in informing about the innovations of respectable products and services is fair and satisfactory.
	The municipality constantly examines the needs of the market and updates and improves the tools and methods of informing by continuously researching the market.
Interest	The municipality offers customers discounts on the demand for new products and services to attract them.
	By fulfilling its social responsibility such as creating green spaces including parks and public gardens, or preventing common diseases of animal and human epidemics with the cooperation of health institutions and aid to treatment, the municipality attract customers to demand new products and services.
	The municipality will make customers interested in the demand for their new products and services by removing barriers and facilitating service delivery.
	The municipality examines the needs of the market and updates and improves its efforts to create customer interest in the demand for new products and services by continuously researching the market.
	By providing its performance reports in specific periods, the municipality makes citizens and customers interested in the demand for their new products and services.
Evaluation	The municipality is aware of the criteria of customers' feeling, perceiving and purchase decision.
	The municipality uses the criteria of customers' feeling, perceiving and purchase decision in providing new services and products.
	The municipality periodically surveys customers.
	The municipality periodically corrects its activities and efforts based on the opinions of customers and their complaints.
	By continuous market researching, the municipality reviews the market and updates and improves its activities and efforts.
	The municipality considers the criteria of respect, attention and polite behavior with the customer and evaluates and controls its employees in this regard.
Test	Customers get the necessary information about new municipal products and services through the site, social networks with the presence of previous customers.
	Customers in the municipality can test new services and products.
	Customers in the municipality, test new services and products with the help of previous customers.
	Customers obtain the necessary information about customer feedback from municipal services and products through billboards.
Adoption	Customers are satisfied with new services and products and encourage their friends to use them.
	Customers are loyal to the municipality because of the quality of new services and products.

Construct Validity

To measure validity in the SmartPLS3.2.6 software, the AVE evaluation criterion (average variance extracted) is used, and the condition for acceptance is that the average mean value should be greater than 0.5. The results are provided in Table 3.

Table 2. Questions of CRM components

	Items
Customer orientation	Employees consider the customer needs.
	Employees consider the customer satisfaction.
	Employees consider the customer problems.
	Employees increase the quality of work for customer satisfaction.
	Employees consider their performance to provide better customer service.
Knowledge management	The organization has a common knowledge vision and strategy that is fully consistent with the organization's vision, mission, and goals.
	Performance improvement management promotes individual and organizational learning, knowledge sharing, knowledge creation, and recognizes and rewards innovation.
	Financial resources are allocated to knowledge management initiatives.
	Knowledge sharing and collaboration is actively encouraged and rewarded or adjusted.
	The organization has systematic processes for identifying, creating, storing, sharing, and applying knowledge.
	The organization has improved the quality of its services and products innovations as a result of using knowledge to improve business processes and customer relationships.
Structure	There is a written job description in this organization.
	Employees participate in the affairs of the organization.
	In this organization, employees follow the organization's guidelines, rules, procedures and policies when making decisions.
	There are many job responsibilities in this organization.
	The organizational hierarchy is short in this organization.
Information technology	There is information security in the organization.
	There is technical, hardware and communication infrastructure in the organization.
	There is a level of the Internet knowledge in the organization.
	Information technology is effective in the organization.
	There is integration between information systems.

Reliability

The composite reliability index is used to check the reliability of the structure. The condition for reliability is that the reliability values are greater than 0.7 and the composite reliability values for all indicators are more than 0.7 and acceptable.

The Cronbach's alpha method was also used to verify the reliability. In a preliminary study, 30 questionnaires were distributed among municipal staff. The Cronbach's alpha variables were calculated using SPSS21 software. The obtained value of

Table 3. Average variance extracted

Average variance extracted	Variable
0.67	Awareness
0.64	Interest
0.64	Evaluation
0.71	Test
0.69	Adoption
0.63	Customer orientation
0.66	Knowledge management
0.71	Organizational structure
0.62	Information technology

Cronbach's alpha (0.95) indicates the appropriate reliability of the questionnaire. The research variables reliability results are provided in the table below.

As can be observed in Table 4, all variables studied in this research had Cronbach's alpha above 0.70 and were measured as significant.

Table 4. Cronbach's alpha and composite reliability

Cronbach's alpha	Composite reliability	Variable
0.83	0.89	Awareness
0.81	0.84	Interest
0.80	0.85	Evaluation
0.81	0.87	Test
0.80	0.86	Adoption
0.80	0.82	Customer orientation
0.81	0.88	Knowledge management
0.75	0.80	Organizational structure
0.87	0.92	Information technology
0.95		Total

Model Validity

Municipal experts' opinions were used to check the accuracy of modeling and simulation.

DATA ANALYSIS METHOD

Structural Model

Structural Equation Modeling (SEM) is a very general and robust multivariate analysis of multivariate regression family and more precisely, the development of a general linear model, which allows the researcher to test a set of regression equations, simultaneously.

Analysis of covariance structures, or structural equation modeling, is one of the main methods of analyzing the structure of complex data and one of the new methods for investigating causal relationships and means analyzing various variables that, in a theory-based structure, show the simultaneous effects of variables on each other. Through this method, it is possible to test the acceptability of theoretical models in specific populations using correlational, non-experimental, and experimental data. The structural equation model is a comprehensive statistical approach for testing hypotheses about the relationships between observed variables and latent variables.

ABM

In this methodology, in which agents play a key role, each of the real-world agents are modeled as fully automatic entities. Each of these agents has a variety of parts for understanding, analyzing, and ultimately responding to the environment. ABM has been recently considered in the social sciences. In this approach, agents are people in a society with the desired characteristics. Then, factors are entered into the system and their effect on agent behaviors or population macro-level behavior is examined. Today, smart agents are widely used in operational and research projects.

RESULTS

Statistical Analysis

The main hypothesis:

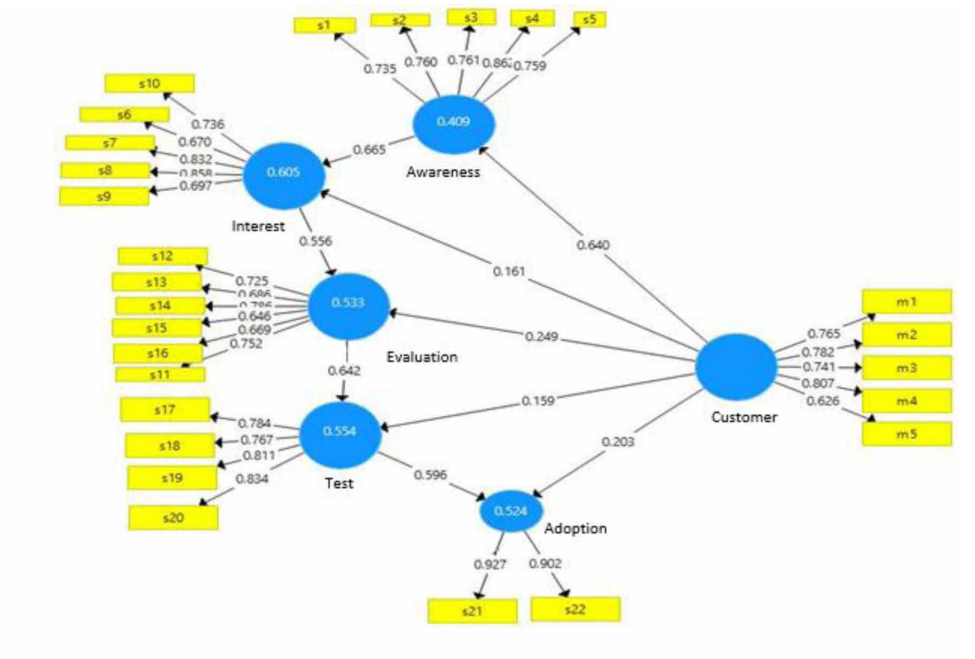
"Critical success factors of CRM affect the diffusion and acquisition of products/ services."

Sub-Hypothesis 1

"The customer orientation influences each stage of product/ service diffusion."

The hypothesis is examined using structural equations.

Figure 2. Standard model of the first hypothesis



Path Coefficients

The numbers written on the lines are standardized beta coefficients. Positive coefficients indicate the positive effects of one variable on another variable.

t Value

About the significance of the path coefficients, the t statistics should be greater than 1.96, to show a positive and significant effect at the level of 10%, and if the statistical value is less than 1.96, it indicates that the path is not significant.

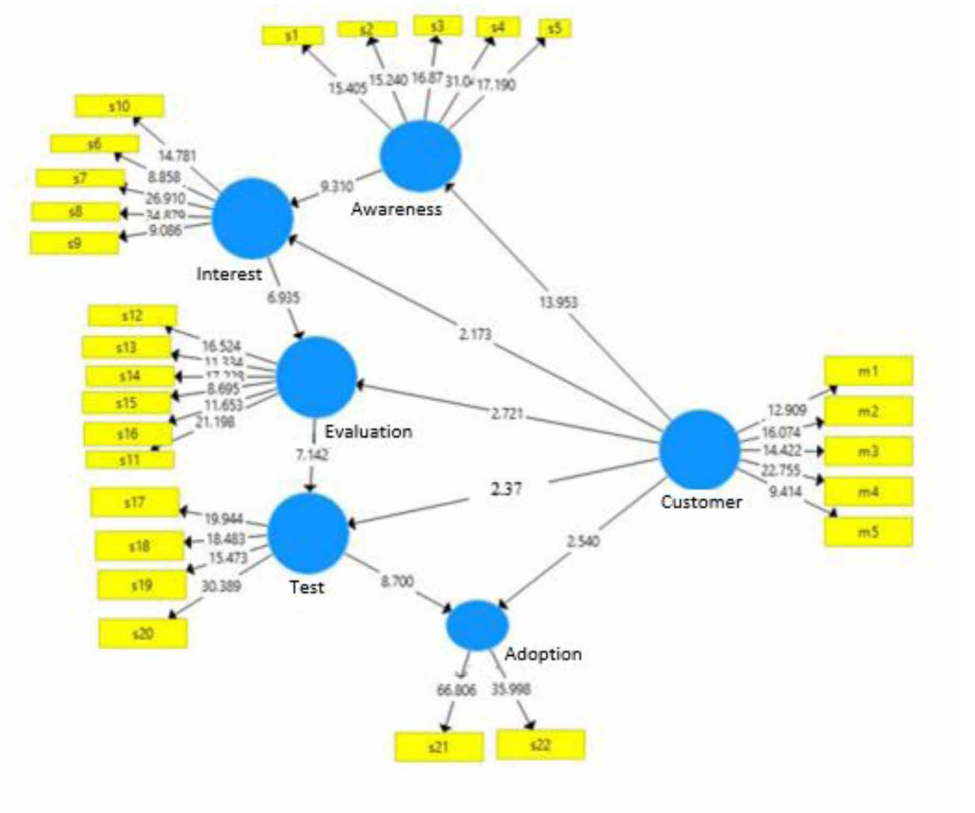
According to Table 5, all t statistics values are greater than 1.96, and this relationship is confirmed. Indeed, a linear relationship can be specified between customer and each stage of product/ service diffusion.

SUB-HYPOTHESIS 2

"Knowledge management affects every step of product/ service diffusion."

The hypothesis is examined using structural equations.

Figure 3. Model of t-value of the first hypothesis



Path Coefficients

The numbers written on the lines are standardized beta coefficients. Positive coefficients indicate the positive effects of one variable on another variable.

t Value

About the significance of the path coefficients, the t statistics should be greater than 1.96, to show a positive and significant effect at the level of 10%, and if the statistical value is less than 1.96, it indicates that the path is not significant.

According to Table 6, all t statistics values are greater than 1.96, and this relationship is confirmed. Indeed, a linear relationship can be specified between knowledge management and each stage of product/ service diffusion.

Table 5. Coefficients of the first hypothesis

Independent V. Dependent V.	Coefficient	T value	Result
Customer orientation Awareness	0.64	13.93	Has effect
Customer orientation Interest	0.16	2.17	Has effect
Customer orientation Evaluation	0.24	2.72	Has effect
Customer orientation Test	0.15	2.37	Has effect
Customer orientation Adoption	0.20	2.54	Has effect

Sub-Hypothesis 3

"Organizational structure affects every stage of product/ service diffusion."

The hypothesis is examined using structural equations.

Path Coefficients

The numbers written on the lines are standardized beta coefficients. Positive coefficients indicate the positive effects of one variable on another variable.

Figure 4. Standard model of the second hypothesis

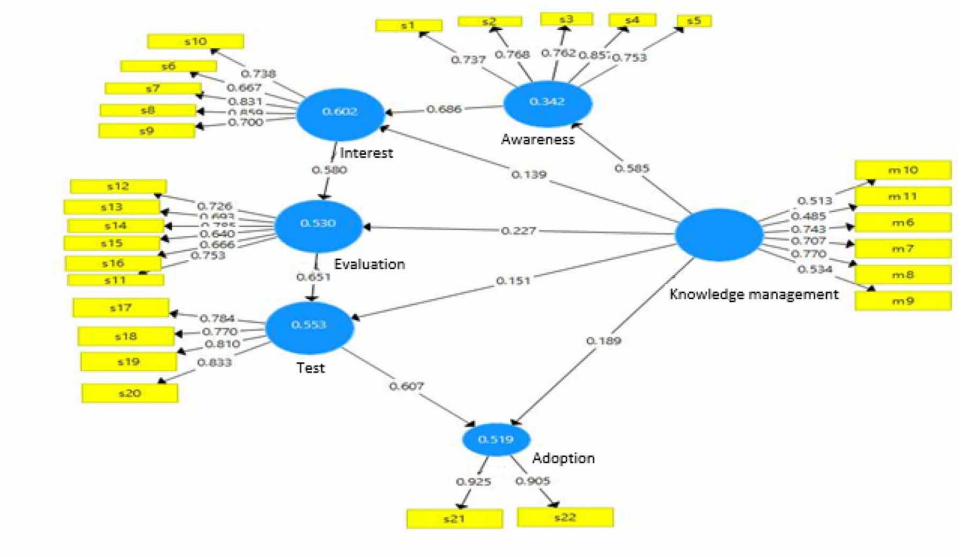
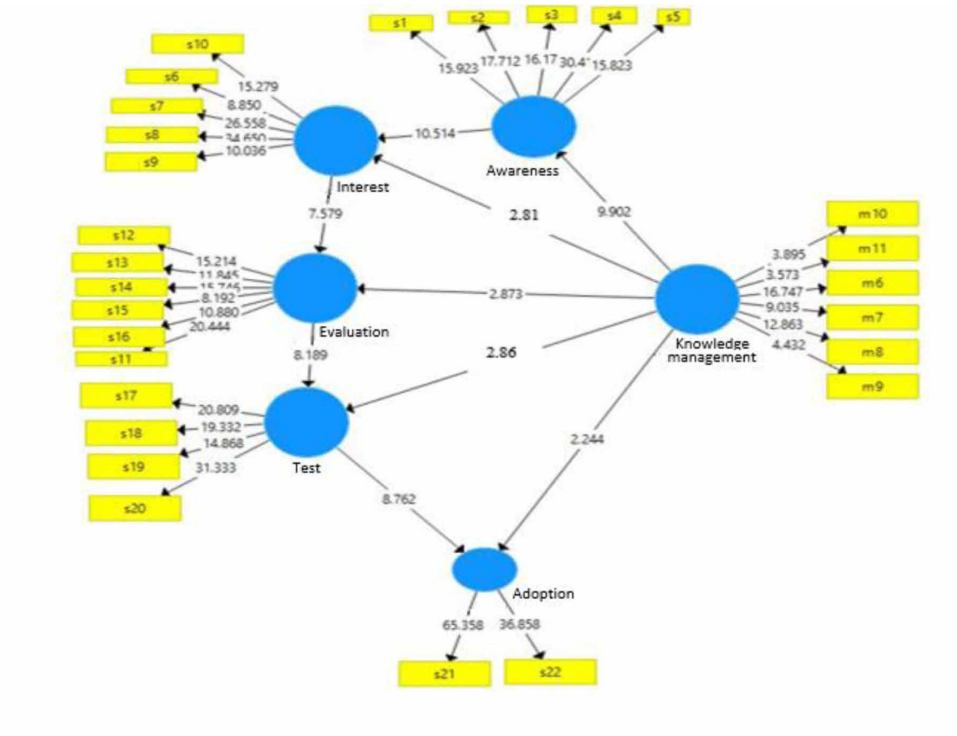


Figure 5. Model of t-value of the second hypothesis



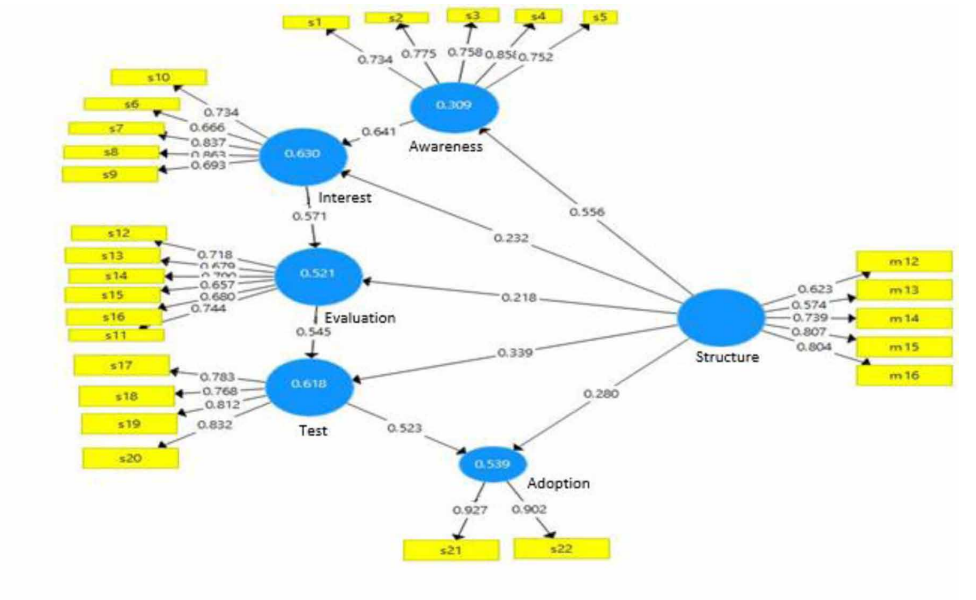
t Value

About the significance of the path coefficients, the t statistics should be greater than 1.96, to show a positive and significant effect at the level of 10%, and if the statistical value is less than 1.96, it indicates that the path is not significant.

Table 6. Coefficients of the second hypothesis

Independent V. Dependent V.	Coefficient	T value	Result
Knowledge management Awareness	0.58	9.90	Has effect
Knowledge management Interest	0.13	2.81	Has effect
Knowledge management Evaluation	0.22	2.87	Has effect
Knowledge management Test	0.15	2.86	Has effect
Knowledge management Adoption	0.19	2.24	Has effect

Figure 6. Standard model of the third hypothesis



According to Table 7, all t statistics values are greater than 1.96, and this relationship is confirmed. Indeed, a linear relationship can be specified between organizational structure and each stage of product/ service diffusion.

Table 7. Coefficients of the third hypothesis

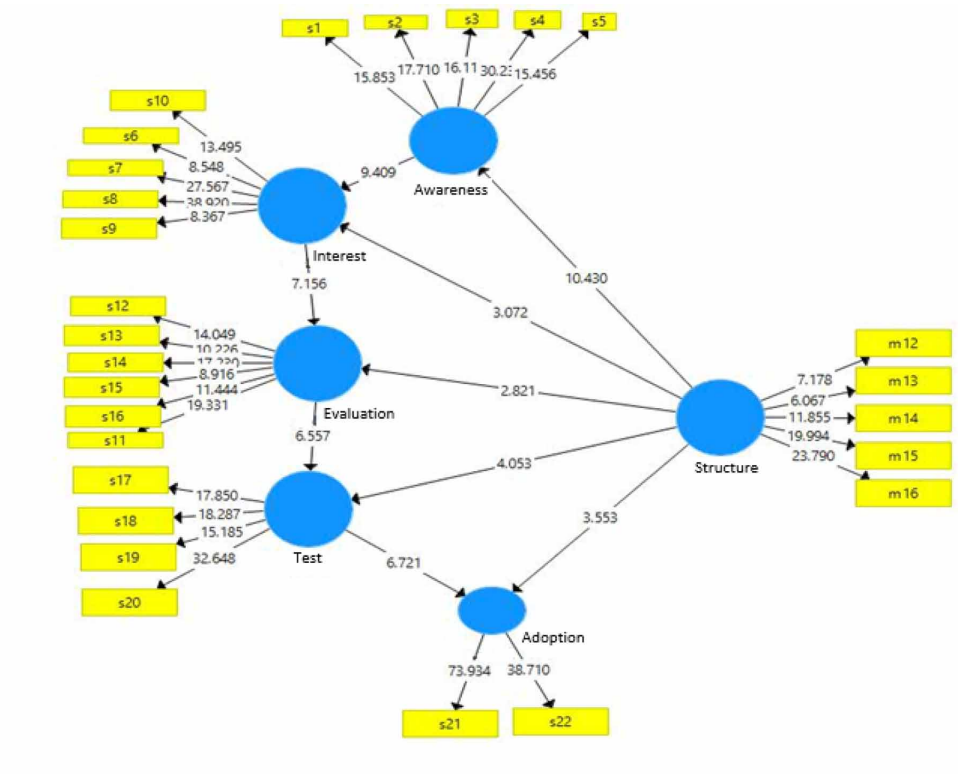
Independent V. Dependent V.	Coefficient	T value	Result
Structure Awareness	0.55	10.43	Has effect
Structure Interest	0.23	3.07	Has effect
Structure Evaluation	0.21	2.82	Has effect
Structure Test	0.33	4.05	Has effect
Structure Adoption	0.28	3.55	Has effect

Sub-Hypothesis 4

"Information technology affects every step of a product/ service diffusion."

The hypothesis is examined utilizing structural equations.

Figure 7. Model of t-value of the third hypothesis



Path Coefficients

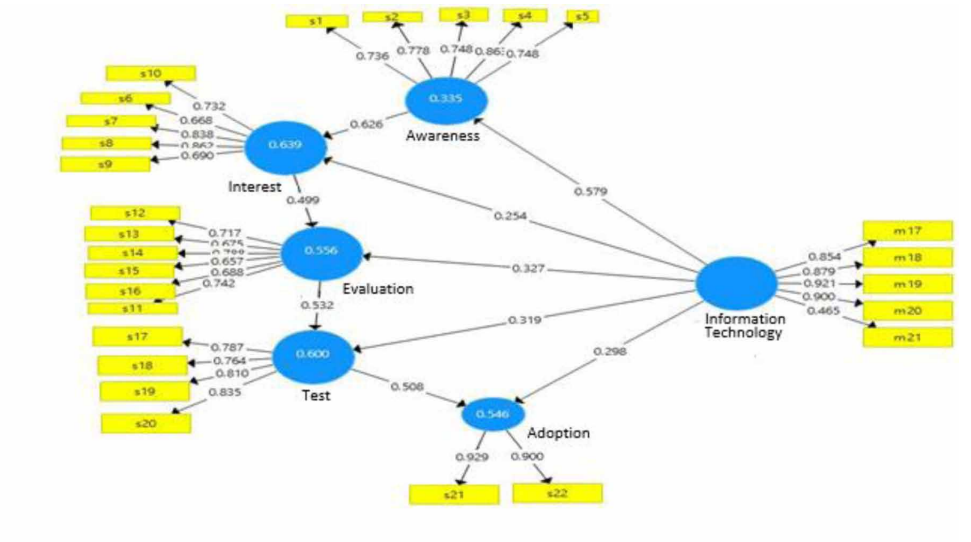
The numbers written on the lines are standardized beta coefficients. Positive coefficients indicate the positive effects of one variable on another variable.

t Value

About the significance of the path coefficients, the t statistics should be greater than 1.96, to show a positive and significant effect at the level of 10%, and if the statistical value is less than 1.96, it indicates that the path is not significant.

According to Table 8, all t statistics values are greater than 1.96, and this relationship is confirmed. Indeed, a linear relationship can be specified between information technology and each stage of product / service diffusion.

Figure 8. Standard model of the fourth hypothesis



ABM

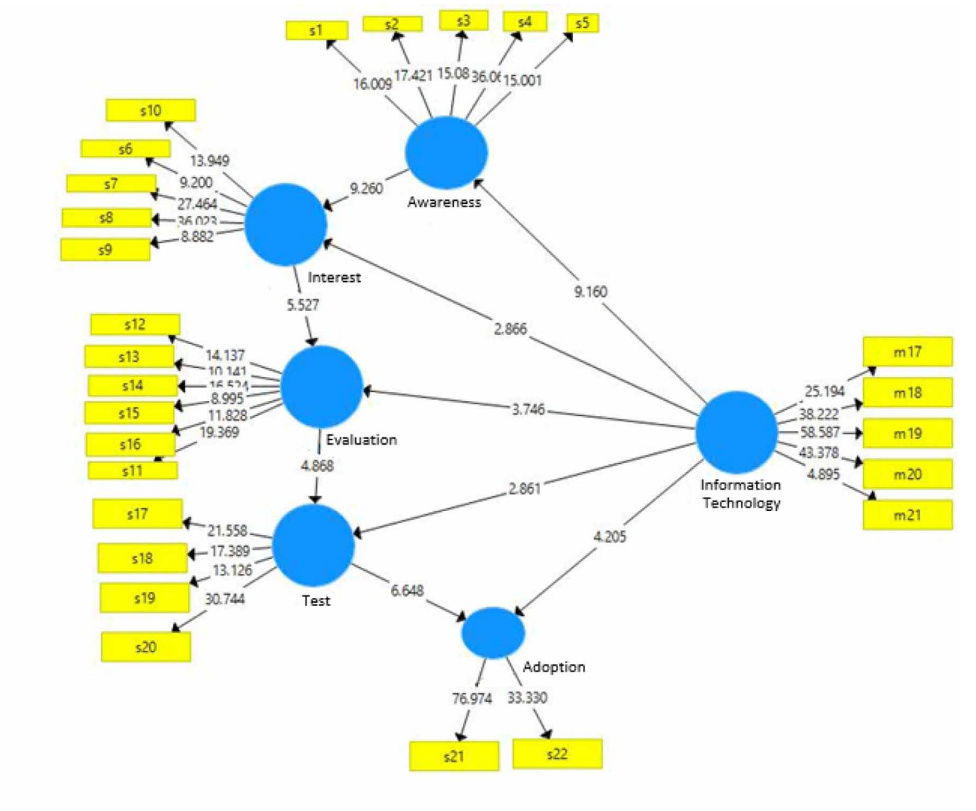
AnyLogic simulation software provides extensive possibilities to create and analyze ABM, and the behavior of agents is plotted using the StateChart in the software. StateChart of this research is as figure 10.

- Agents in this research are citizens.
- In this state chart, the transitions between the diffusion stages are the same as the impact factor between the diffusion stages in standard models.
- Transitions within each stage indicate the impact of CRM components on the diffusion process.
- Relationships are all of rate type, which is the same impact factors.

The First Hypothesis Simulation

According to the first hypothesis and the results extracted from Figure 2, the first hypothesis model has been drawn for 80,000 citizens considering the impact of customer orientation on the phases of diffusion process after almost 10 months.

Figure 9. Model of t-value of the fourth hypothesis



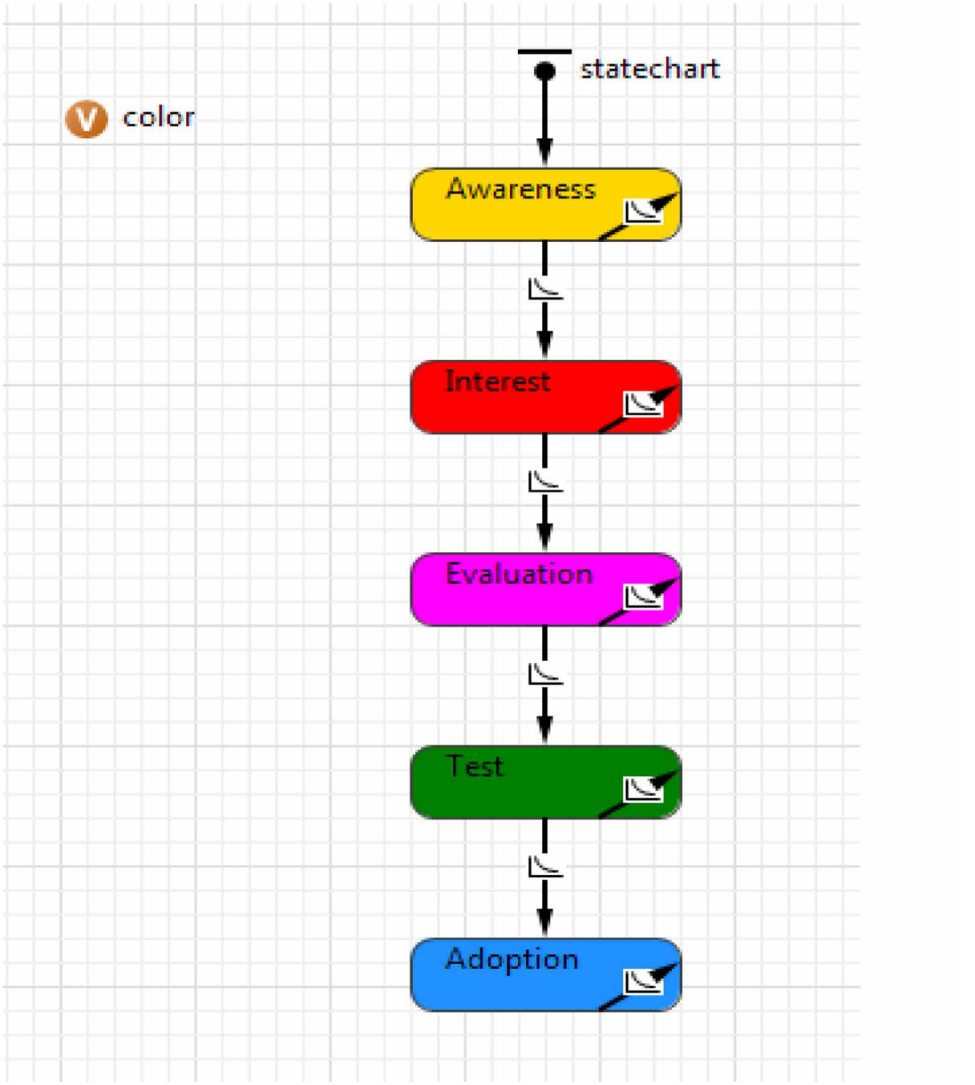
The Second Hypothesis Simulation

According to the second hypothesis and the results extracted from Figure 4, the second hypothesis model has been drawn for 80,000 citizens considering the impact of knowledge management on the phases of diffusion process after almost 10 months.

Table 8. Coefficients of the fourth hypothesis

Independent V. Dependent V.	Coefficient	T value	Result
IT Awareness	0.57	9.16	Has effect
IT Interest	0.25	2.86	Has effect
IT Evaluation	0.32	3.74	Has effect
IT Test	0.31	2.86	Has effect
IT Adoption	0.29	4.20	Has effect

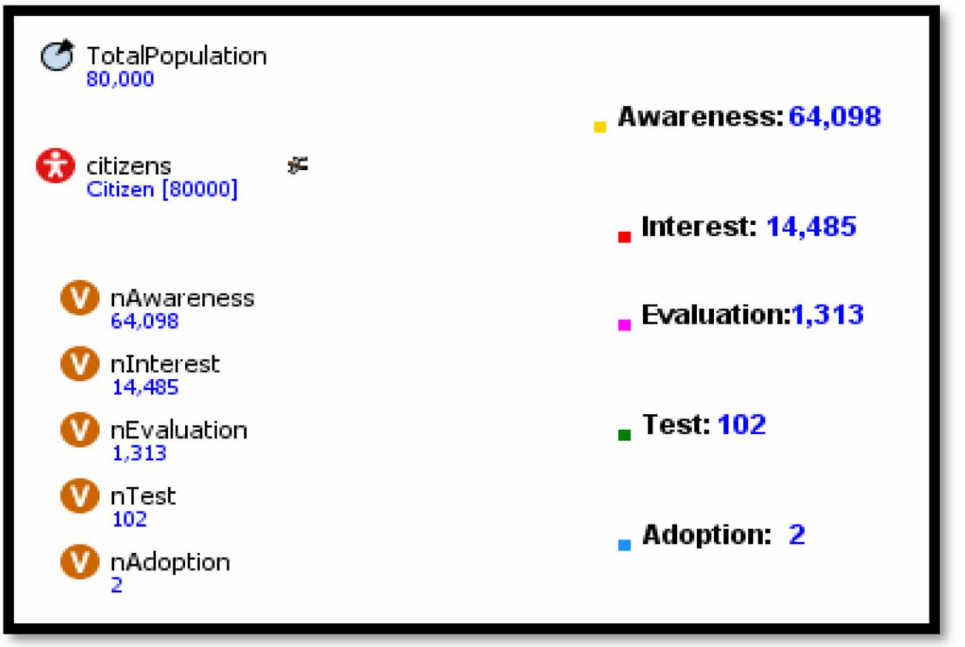
Figure 10. Statechart showing the phases of innovational services/products diffusion



The Third Hypothesis Simulation

According to the third hypothesis and the results extracted from Figure 6, the third hypothesis model has been drawn for 80,000 citizens considering the impact of organizational structure on the phases of diffusion process after almost 10 months.

Figure 11. The ABM result of the first hypothesis



The Fourth Hypothesis Simulation

According to the fourth hypothesis and the results extracted from Figure 8, the fourth hypothesis model has been drawn for 80,000 citizens considering the impact of IT on the phases of diffusion process after almost 10 months.

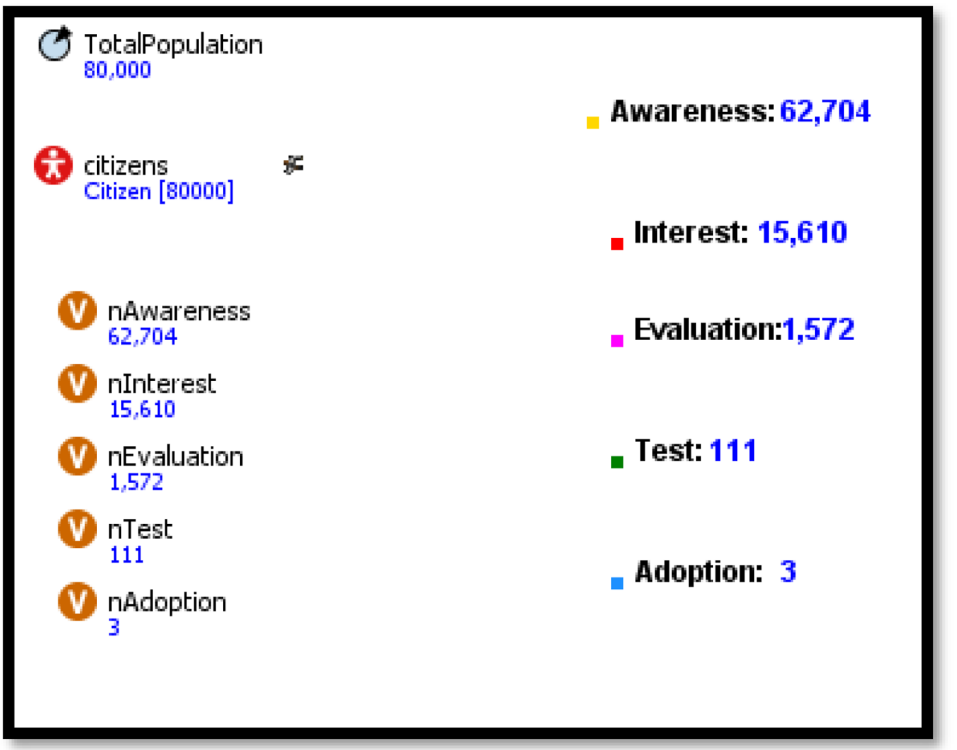
Without considering CRM in models, the population size is usually lower for each phase of diffusion process as shown in Figure 15.

CONCLUSIONS AND SUGGESTIONS

The present study sought to answer the question "Does customer relationship management (CRM) affect the acquisition of innovational products and services in the municipality?" in this regard, defining a framework of research theoretical foundations and previous studies and using statistical and agent-based modeling (ABM) methods corresponding the research subject, the research hypotheses were studied in a municipality based on the information collected through the questionnaire.

The first research sub-hypothesis was:

Figure 12. The ABM result of the second hypothesis



"The customer orientation has an impact on each stage of service diffusion in the municipality."

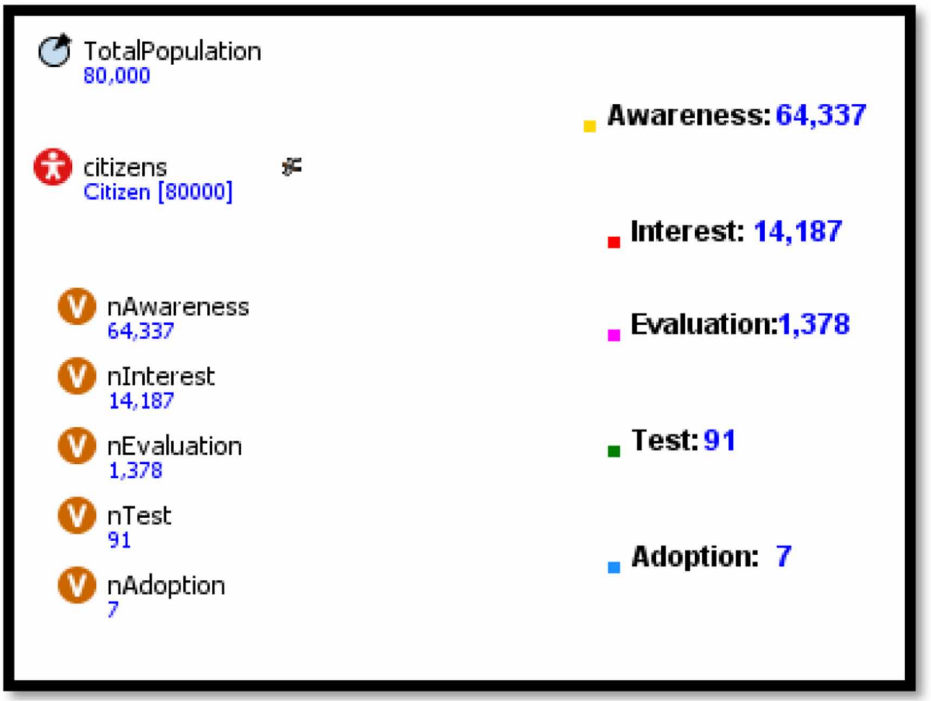
Based on the results of the first research sub-hypothesis, the customer orientation has an impact on each stage of service diffusion in the municipality and its effect is direct, *i.e.* service diffusion increases with increasing customer orientation and the effect between the two variables is significant. Therefore, the hypothesis is confirmed and customer orientation has a greater impact on awareness and less impact on test. Table 9 shows the results prioritization in terms of impact. ABM confirmed the positive impact of customer orientation on each stage of diffusion process.

The second research sub-hypothesis was:

"Knowledge management affects every stage of service diffusion in the municipality."

Based on the results of the second research sub-hypothesis, knowledge management has an impact on each stage of service diffusion in the municipality and its effect

Figure 13. The ABM result of the thrid hypothesis



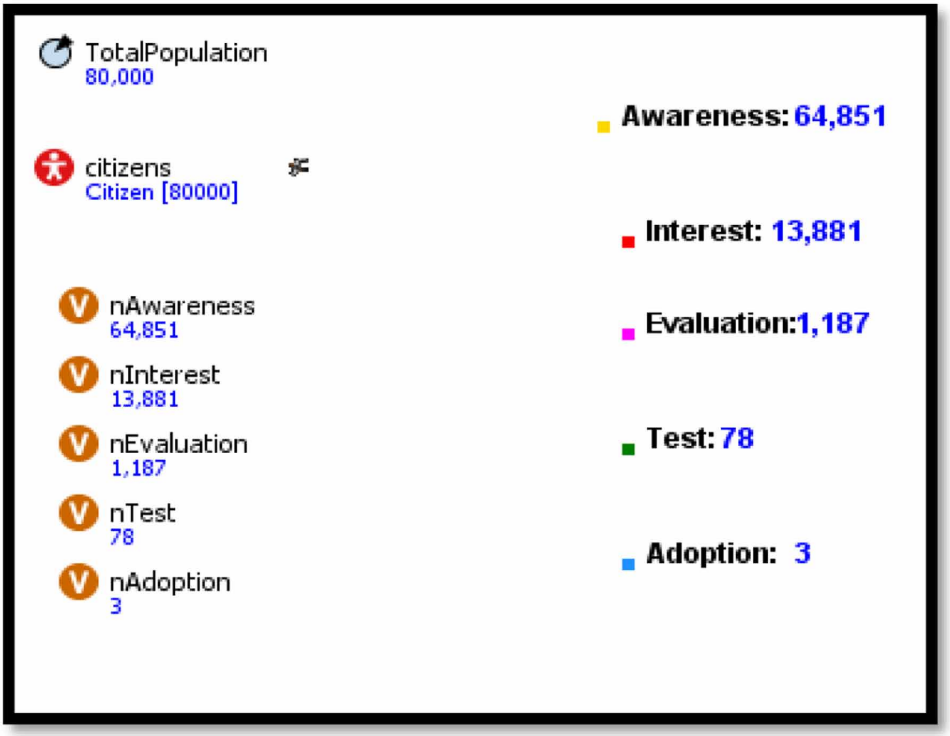
is direct, *i.e.* service diffusion increases with increasing knowledge management and the effect between the two variables is significant. Then, the hypothesis is confirmed and hence, knowledge management has a greater impact on awareness and has less impact on interest. Table 10 shows the results prioritization in terms of the impact. ABM confirmed the positive impact of knowledge management on each stage of diffusion process.

The third research sub-hypothesis was:

"The organizational structure affects each stage of service diffusion in the municipality."

Based on the results of the third research sub-hypothesis, organizational structure has an impact on each stage of service diffusion in the municipality and its effect is direct, *i.e.* service diffusion increases with increasing organizational structure and the effect between the two variables is significant. Then, the hypothesis is confirmed and hence, organizational structure has a greater impact on awareness and lower impact on evaluation. Table 11 shows the results prioritization in terms

Figure 14. The ABM result of the fourth hypothesis



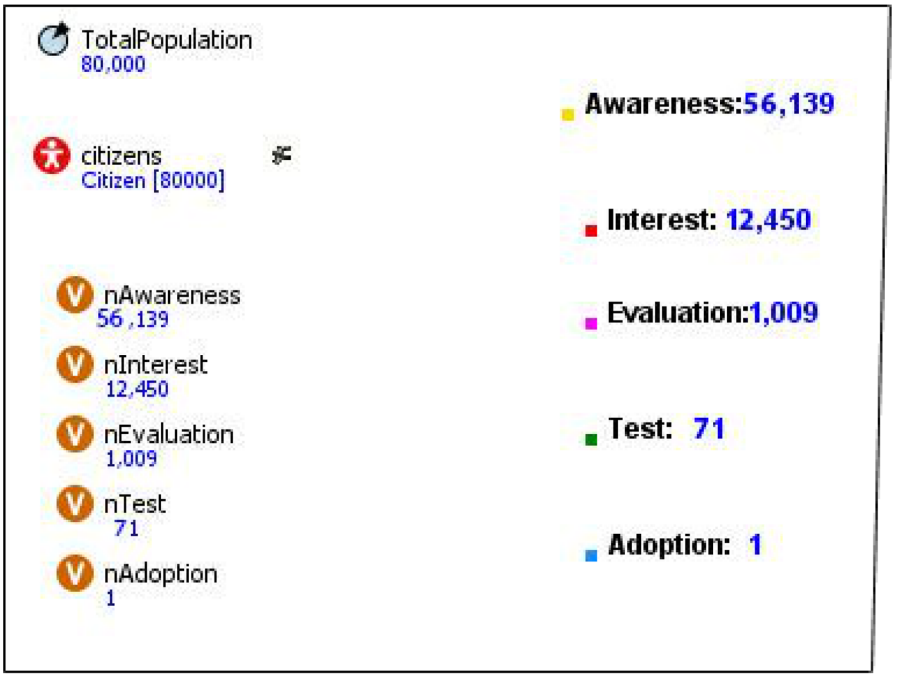
of the impact. ABM confirmed the positive impact of organizational structure on each stage of diffusion process.

The fourth research sub-hypothesis was:

"Information technology affects every stage of service diffusion in the municipality."

Based on the results of the fourth research sub-hypothesis, information technology has an impact on each stage of service diffusion in the municipality and its effect is direct, *i.e.* service diffusion increases with increasing information technology and the effect between the two variables is significant. Then, the hypothesis is confirmed and hence, information technology has a greater impact on awareness and less impact on test. Table 12 shows the results prioritization in terms of the impact. ABM confirmed the positive impact of information technology on each stage of diffusion process.

Figure 15. The ABM result without CRM



Suggestions

- It is recommended that companies first hire highly skilled and knowledgeable staff and then make every effort to attract and retain customers.
- Organizing and developing information technology and communication management by creating horizontal and vertical coordination between different departments.

Table 9. Results Prioritization of the first hypothesis

Independent V. Dependent V.	Results Prioritization
Customer orientation Awareness	(1)
Customer orientation Interest	(4)
Customer orientation Evaluation	(2)
Customer orientation Test	(5)
Customer orientation Adoption	(3)

Table 10. Results Prioritization of the second hypothesis

Independent V. Dependent V.	Results Prioritization
Knowledge management Awareness	(1)
Knowledge management Interest	(5)
Knowledge management Evaluation	(2)
Knowledge management Test	(4)
Knowledge management Adoption	(3)

Table 11. Results Prioritization of the third hypothesis

Independent V. Dependent V.	Results Prioritization
Structure Awareness	(1)
Structure Interest	(4)
Structure Evaluation	(5)
Structure Test	(2)
Structure Adoption	(3)

- Dissemination of knowledge obtained from customer throughout the organization and its optimal use by any employee who is in contact with the customer, in order to select the target market, provide services needed by the customer and assess current and future needs.
- Improving the quality of services and accelerating the process of meeting customer needs.
- Encouraging employees and providing the necessary training on customer relationship management as well as the knowledge of experienced and highly specialized employees to other employees. Creating the necessary technological infrastructure, including creating a system with high efficiency

Table 12. Results Prioritization of the fourth hypothesis

Independent V. Dependent V.	Results Prioritization
IT Awareness	(1)
IT Interest	(4)
IT Evaluation	(3)
IT Test	(5)
IT Adoption	(2)

and user-friendly interface, so that employees can easily share their knowledge with others by recording their experiences in this system.

- Because knowledge management is an important resource for customer relationship management, corporate managers and organizations are advised to build the infrastructure needed to share, transfer, and exchange knowledge among employees and teach them to interact, spread the new knowledge created widely in the company and use it in the production of new products in order to improve the company's performance.
- It is recommended to the company managers to invest more in the transfer of knowledge and experience of accomplished employees to other employees, to improve services.
- Using the experiences of other companies in establishing knowledge management infrastructures by creating appropriate interaction and communication with them.
- Equipping the company with new technologies and enhancing the level of employees' capability to use them.

REFERENCES

Burnett, K. (2000). *The handbook of key customer relationship management: The definitive guide to winning, managing and developing key account business*. Ft Press.

Feiz, S., Khalifah, Z. B., & Ghotbabadi, A. R. (2011). Custtomer relationship management in organizations. *International Conference on Management (ICM 2011) Proceeding*.

Guo, Y. C., & Niu, D. X. (2007). A knowledge-based intelligent system for power customer service management. *International Conference on Machine Learning and Cybernetics*. 10.1109/ICMLC.2007.4370648

Hasanzadeh, M., & Mahaleh, S. F. S. S. (2013). Effect of knowledge management on success of customers relationship management in Eghtesad Novin Bank of Tehran. *International Journal of Business Management and Economic Research*, *4*(6), 839–848.

Joseph, E. E., & Winston, B. E. (2005). A correlation of servant leadership, leader trust, and organizational trust. *Leadership and Organization Development Journal*, *26*(1), 6–22. doi:10.1108/01437730510575552

Moreno, A. G., & Melendez, A. P. (2011). Analyzing the impact of knowledge management on CRM success: The mediating effects of organizational factors. *International Journal of Information Management*, *31*(5), 437–444. doi:10.1016/j.ijinfomgt.2011.01.002

Namjoyan, M., Esfahani, A. N., & Allameh-Haery, F. (2013). Studying the effects of customer relationship management on the marketing performance (Isfahan Saderat Bank as a case Study). *International Journal of Academic Research in Business & Social Sciences*, *3*(9), 302–314. doi:10.6007/IJARBSS/v3-i9/211

Reynolds, J. (2002). *A practical guide to CRM: building more profitable customer relationships*. CRC Press. doi:10.1201/9781482280784

Robins, S. (1990). *Organization theory: Structure, design and applications*. Prentice Hall.

Salah, O., Yusof, Z. M., & Mohamed, H. (2018). Factors affecting customer relationship management system adoption in small and medium enterprise in Palestine. *International Journal of Information System and Engineering*, *6*(2), 52–75. doi:10.24924/ijise/2018.11/v6.iss2/52.75

Sin, L. Y. M., Tse, A. C. B., & Yim, F. H. K. (2005). CRM: Conceptualization and scale development. *European Journal of Marketing*, *39*(11/12), 1264–1290.

Chapter 2
Automation 4.0:
The Impact on Manufacturing and Engineering

Craig Eric Seidelson
University of Indianapolis, USA

ABSTRACT

Factories have employed automation for nearly 100 years. With the launch of Industry 4.0 in 2011, operations have expanded their use of robots on an unprecedented scale. As of 2017, there were roughly 2 million industrial robots in use globally. By 2030, it's estimated that 20 million manufacturing jobs around the world could be replaced by robots. Yet, substantial hurdles remain before predicted level of automation can be realized. On the one hand, smart factories are almost exclusively multibillion-dollar enterprises. Their costs are simply too high for most manufacturers. On the other hand, intelligent machines are limited in what they can do because so many of the engineering tasks required to support them are still being done by people. Widespread use of automation requires expanding the use of artificial intelligence to manage data, create drawings, evaluate designs, and program machines.

INTRODUCTION

Automation has been described as the use of technology to reduce or replace human activity. (McKay et. al, 2019). In the first phase of industrial automation, single purpose machines were used to perform simple, highly repetitive tasks. In the second phase, programmable logic controllers (PLCs) made it possible for machines to

DOI: 10.4018/978-1-7998-5879-9.ch002

undertake multiple tasks. By the third phase, intelligent machines were capable of making production decisions.

According to a 2015 McKinsey & Company report, with currently demonstrated technology 64% of time spent on manufacturing-related activities could become automated (Chui et. al, 2017). This chapter will show in order for this to happen substantial changes in automation are needed. Notably, the cost and capabilities of intelligent machines need to make automation a value proposition for smaller manufactures. As these issues are solved, manufacturing will enter a fourth phase. Automation 4.0 consists of smart machines cost effectively managing data, creating drawings, evaluating designs and programming themselves.

BACKGROUND

Car manufacturers have long been at the forefront of automation. In 1959, a General Motors plant in Trenton, New Jersey was home to Unimate the world's first industrial robot. Two years later, a fleet of Unimate 1900 robots were mass producing car bodies at General Motor's Inland Fisher Guide Plant in New Jersey. (Robotic Industries Association, 2020). By 2005, 90% of all robots in use globally were assembling cars in automobile factories (Robotics Technology, 2019).

Today, makers of cars, electronics, metals, chemicals, plastics and food routinely automate their operations. In terms of speed, robots typically work two to five times faster than humans. As far as precision, robots are capable of making one micron movements rendering them 10 times more accurate than the most experienced surgeons (Mathews, 2018). When it comes to finances, companies that automate were found to cut costs by an average of 17% (Robotics Online Marketing Team, 2016). And, many of the tasks being automated are those which are too "dirty, dull or dangerous" for humans to perform (Association for Advancing Automation, 2015).

By 2017, there were roughly 2 million industrial robots in use globally. China, Japan and South Korea lead the way accounting for nearly half of the world's robots (Dvorkin and Bharadwaj, 2019). Interest in robots is expected to grow with companies forecasted to spend $12 billion on Robotic Process Automation (RPA) by 2023 (Press, 2019). U.S. companies are among those investing heavily in automation. A nationwide survey of US manufacturers found 83% invested in automation between 2011 and 2016 (Waldmon, 2016).

ISSUES, CONTROVERSIES, PROBLEMS

For all the time and money being spent on automation the technology isn't without its fair share of problems. Chief among these are high costs and low flexibility. For example, the average price of a six axis robotic arm with an eight kilogram payload in 2018 was $25,000. After accounting for integration, safety, tooling, and programming, automation costs increase four to six times (Maw, 2018). This is a significant amount of money to spend on technology which is somewhat limited in scope. In 2016, the head of manufacturing at Mercedes voiced an all too common complaint about robots. "They can't deal with the degree of individualization and the many variants that we have today" (Abbosh et. al, 2019).

In light of automation's challenges, there were only 237,000 industrial robots in operation across all of North America in 2015 (West, 2015). To put this number in perspective, that same year there were approximately 72 million people employed in North American factories. This works out to roughly 1 robot for every 300 workers. A heavy reliance on people over robots is expected to dramatically shift in the near future. By 2025, it's predicted that one out of every four industrial tasks will performed by robots (Melanson, 2018). By 2030, 20 million manufacturing jobs around the world could be replaced by robots. (BBC, 2019). For automation to grow anywhere near its potential fundamental changes are needed.

Industrial robots have traditionally relied upon hardcoding. Hardcoding involves writing commands directly into a computer's source code. Since commands can't be changed, programmers must spend countless hours coding for every possible situation. Machines access programs based upon what sensors are telling them. As long as sensors are functioning correctly and inputs match all possible scenarios modeled by programmers, robots can make correct choices. Otherwise control is lost. Using robotic arms to load and unload machine tools illustrates the problem. Arms can only pick up parts when workpieces are in the correct position, arriving at the correct time, in the correct orientation and of the correct geometry. If any one of these assumptions are violated robots will either fail to act or act incorrectly. It doesn't help that coding languages (i.e. C++, Java, Fortran, Python, etc.) are seldom standardized across platforms. As a result, over 70% of automation costs are related to software (Nicols, 2018).

High volume, low mix operations present the type of routine environment where hardcoded automation has thrived. In the 1920's, A.O. Smith Corp. operated the world's first fully automated plant in Milwaukee, WI. Unmanned machines performed over 500 tasks producing one automobile frame every 8 seconds. By the 1960s, Polaroid Corp. was operating a fully automated assembly plant in Waltham, MA. In the 1980s, an IBM plant in Texas was running "lights out" keyboard assembly (Weber, 2019). However, such high volume, repetitive work environments are no

longer the norm in U.S. manufacturing. Of the 255,000 US manufacturing firms in 2011, three fourths had less than 20 employees (Manufacturing Institute, 2014). Even among U.S. carmakers, a 2018 study found 70% had fully implemented flexible manufacturing (El-Khalil and Darwish, 2019). The steady decrease in cognitively and manually repetitive tasks in US factories (Dvorkin, M. and Bharadwaj, A., 2019) means any hope of widespread automation hinges on its ability to support flexible manufacturing.

SOLUTIONS AND RECOMMENDATIONS

Human-robot collaboration is key to lowering automation cost and improving flexibility. Programming by Demonstration (PbD), as the name suggests, allows shop floor associates to teach robots not by downloading sophisticated code but by physically guiding them through required motions. Such collaboration involves robots (termed "cobots") sharing their work spaces with humans. Many in the field of automation, such as Tom Mitchell, professor and interim dean of the School of Computer Science at Carnegie Mellon University, see collaboration as the future of automation (Moran, 2019). The issue with is cost. For safety reasons cobots are generally restricted to carrying light loads. They're also programmed to slow down or stop when humans are nearby. Limited payload and frequent work interruptions explain why cobots are only five percent of the overall robotics market (Robotics Business Review, 2019). Increasing human robot collaboration requires advances in programming. PbB is a simple and inexpensive way to program, but it doesn't address the efficiency problem. Cobots need to know where people are and when future activities will put them in close proximity. To address these problems a research team at MIT has begun programming cobots using "partial trajectory" algorithms. Cobots track worker movements storing them as a collection of time and space reference trajectories (Science Daily, 2019). By predicting where humans will be, what they will be doing and when they will being do it, cobots in the study were able to reduce idle work time 85% (Tobe, 2015).

MITs cobots are an example of information technology (IT) and operations technology converging in the physical world. This new era of manufacturing, Industry 4.0, consists of Internet enabled devices collecting and sharing a constant stream of real time data. The assumption being the more data that machines share the more likely they'll be capable of making complex decisions without human involvement (Marr, 2018). The potential payback is huge. McKinsey & Company estimate 50% of companies that embrace smart technology over the next five to seven years could double their cash flow (Columbus, 2019). Such a high rate of return doesn't come cheaply. As of 2019, smart factories in the U.S. accounted for $116 billion in market

capitalization. By the end of 2027 global investment in smart manufacturing is expected to reach $275 billion (Shah, 2020). The massive amount of money being invested clearly shows that setting up smart factories is expensive. Almost half of all U.S. smart factories recorded over $2.5 billion in sales (Biron, 2017). Wide scale use of automation will require making smart technology affordable to small and medium sized enterprises. The best way to accomplish this, according to a recent European Commission report, is through public funding (Digital Transformation Monitor, 2017). The U.S. government is funding smart manufacturing through the Manufacturing USA program. Unfortunately, with federal contributions typically in the $70-110 million range at a minimum of 1:1 public-private cost share, government support goes almost exclusively to large corporations (Manufacturing.gov, 2020).

A significant amount of the expense it takes to operate smart factories involves IT. Traditionally, automation was about simple, linear decisions (i.e. when work piece #1 is under sensor #2 open machine gate #3) at the machine tool level. Such data exchanges could easily be done with Windows based OPC technology. In smart manufacturing much more data is being collected, stored and exchanged across many more systems. Common factory systems include: Materials Resource Planning (MRP), Supervisory Control and Data Acquisition (SCADA), as well as Enterprise Resource Planning (ERP). Since it's unlikely that a factory purchased all these systems at once they may all be running on different platforms. Open Platform Communication Unified Architecture (OPC UA) has shown promise migrating system to smart technology. OPC UA provides "a secure and reliable mechanism for information exchange between different enterprises systems" (Kalycito, n.d.).

If a cost effective data communication plan can be put in place the next challenge is managing the data. A single smart machine will generate on the order of 5 GB of data per week. To store and analyze all this data IT systems need to be organized into groups or Hadoop clusters. Cost are difficult to control because size of the cluster will increase linearly with the amount of data storage, computing and processing power. A typical petabyte Hadoop cluster will cost about $1 million (Widjaya, 2016). To control costs, data needs (i.e. granularity) must be defined in terms of the required level of analysis. Supervised Machine Learning doesn't require as much data because humans are providing training and feedback to machines. Unsupervised Machine Learning, or Deep Learning, requires a lot more data. This is because algorithms are continually retrieving and structuring data into layers, "creating a learning system in which the findings at one layer advance and improve the decision-making power of another layer" (Zelinski, 2019). A factory is "smart" to the extent answers to the following 10 statements are "yes."

1. Algorithms decide inventory and production levels.

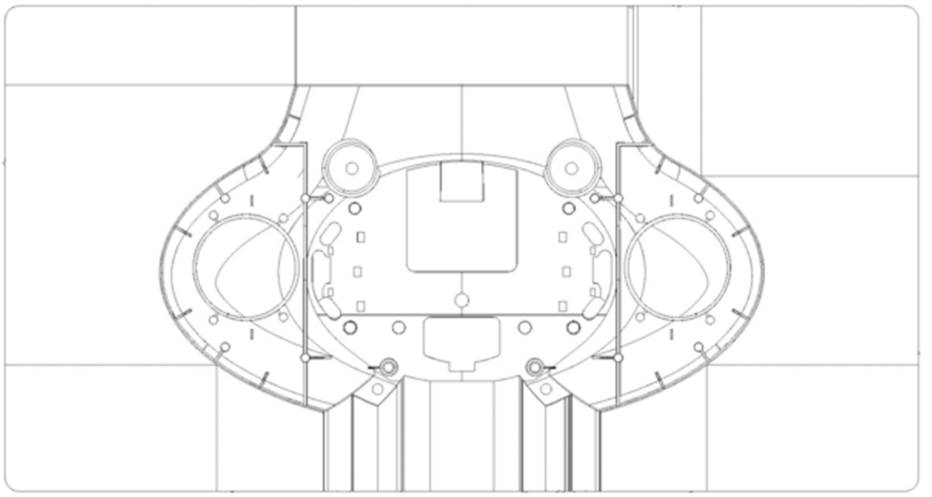
2. Machines provide customers and associates with real time answers to their questions.
3. Machines detect, sort and make corrections for nonconforming products.
4. Algorithms predict quality issues.
5. Algorithms predict maintenance needs.
6. Image recognition locates parts in storage and production.
7. Material handling equipment is self-directed.
8. Algorithms create and validate designs.
9. Production machines are self-operating.
10. Production machines are self-programmed.

Widespread use of smart manufacturing will require outsourcing more data management to "the cloud" and/or "the edge." As of 2020, there was over 1 billion gigabytes of data stored on the public cloud (CloudCheckr, 2019). Three providers (e.g. Amazon Web Services, Microsoft Azure, and Google Cloud) account for roughly 70% of the servers, routers, switches, and storage devices. Key benefits to cloud computing are no upfront hardware costs and infinite scalability as data requirements grow. Pricing is based on hours of computing time, gigabytes of data stored, gigabytes of data transferred, domains used, IT assistance provided, servers accessed and security. Weaknesses of cloud computing are data insecurity and latency. Running AI analysis on the cloud can be can be slow and expensive depending on the type of analysis being done. A commonly used gradient descent algorithm illustrates the problem. The algorithm is attempting to find the minimum value of a loss function which describes the cost of making wrong predictions. More and more parameters and their associated data fields are continually added to the model until losses are minimized. The final set of parameters is the machine learned model. A cheaper and far more efficient way for machines to learn is decentralizing processing to a network of internet connected machines (called the "edge"). At today's 4G network download speeds of 0.15Gbps edge computing is largely confined to basic analysis with most data processing happening on the centralized "cloud." The introduction of 5G networks will change all of this. With download speeds of 20 Gbps edge computing will able to handle most, if not all, of a smart factory's data needs. 5G processing speeds also opens the door to automating many engineering tasks.

Automating engineering would seem at odds with identified weaknesses in machine learning. For example, machines struggle to solve problems that require a great deal of contextual knowledge and a good understanding of causality (Suwelack, 2020). However, much of what engineers do is a collection of smaller tasks. For example, computer aided drafting (CAD) digitizes drawings (Figure 1).

It also automates bills of materials (BOMs) and engineering calculations. Adding a depth feature creates 3D CAD models (Figure 2).

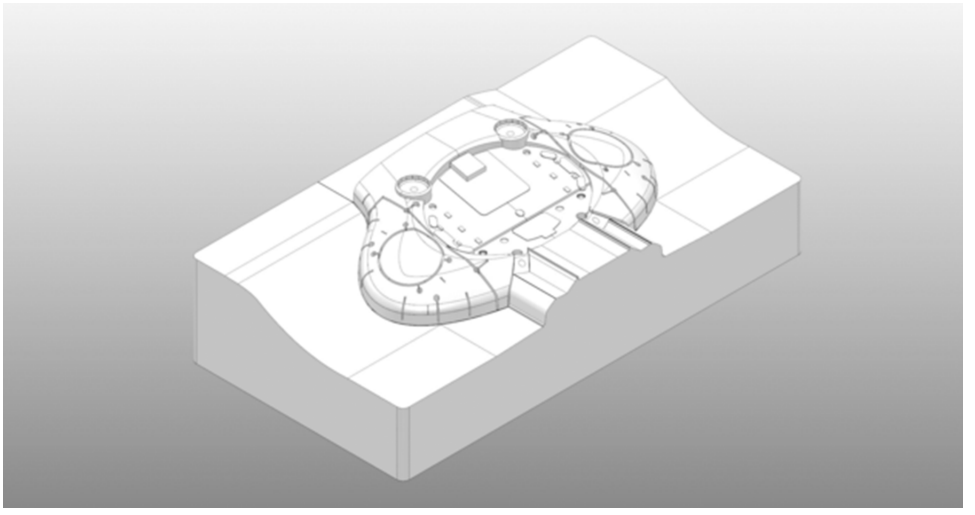
Figure 1. Digitized 2D drawing
Source: NexGenCAM,LLC



CAD models are much more than 3D images. They're metafiles containing three different types of data (i.e. metadata, design intent data and application data).

CAD metadata is the key to understanding how all engineering data fits together. Take drawing "P3aA1Z-1234" as an example. Product drawings are labeled (P)

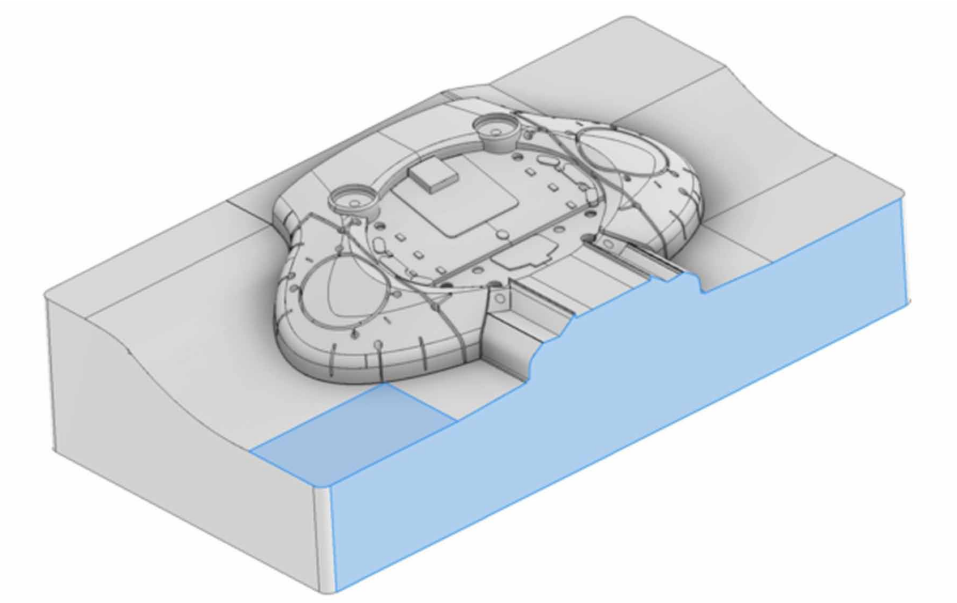
Figure 2. 3D model
Source: NexGenCAM,LLC



while tooling and machine part drawings are designated (T) and (M). Drawings are printed on paper sizes A0, A1, A2, A3, A4, and A5 and stored in locations marked A- Z. Major drawing revisions are identified with a number and minor revisions with a lower case letter. All of this information is metadata. In other words, its data which provides information about other data. In the file management system file name "P3aA1Z-1234" communicates that the drawing is the 3rd major and 1st minor revision of a product, designed to be viewed on an A1 sized frame, stored in location Z and used for making part number 1234. Computer drawing files are easy to work with, but they're also an extremely insecure method of storing information. They can be easily mislaid, corrupted or overwritten (Cooke, 2019). To ensure metadata is secure it should to be merged with Product Data Management (PDM) software. In this way smart factory AI algorithms would only need to access the PDM relational database in order to download any piece of information ever stored on a drawing.

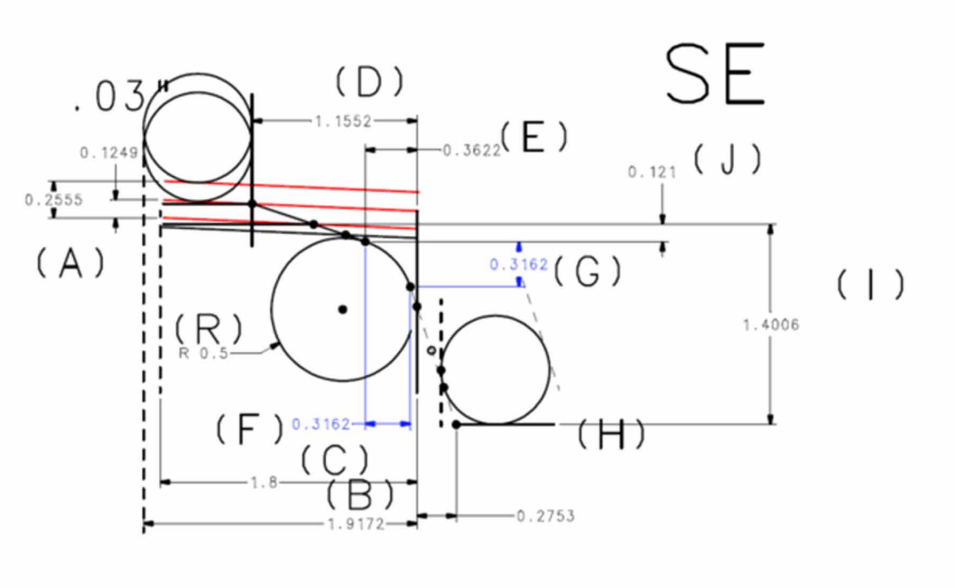
While CAD metadata automates data retrieval, CAD design intent data is the basis for automating drawing creation. When modeling, feature relationships (such as the end face shown in Figure 4) are identified.

Figure 3. Model with cross section feature relationship identified
Source: NexGenCAM,LLC



If any dimension on this cross section is changed all other features along the cross section will automatically update. Automating drawing changes isn't restricted to single models. It's possible to extend relationships across multiple models using "skeletons." In this way any design change to one feature in one model will automatically produce corresponding adjustments to ensure fit across all other models. It's even possible for computer programs to generate entire models. In this way, rather than assigning fixed values to drawing features, variables are assigned (such as variables A-R in Figure 5). Variables are then linked to equations inside digital engineering notebook files. When macroinstruction (i.e. macro) programs are executed models are automatically created.

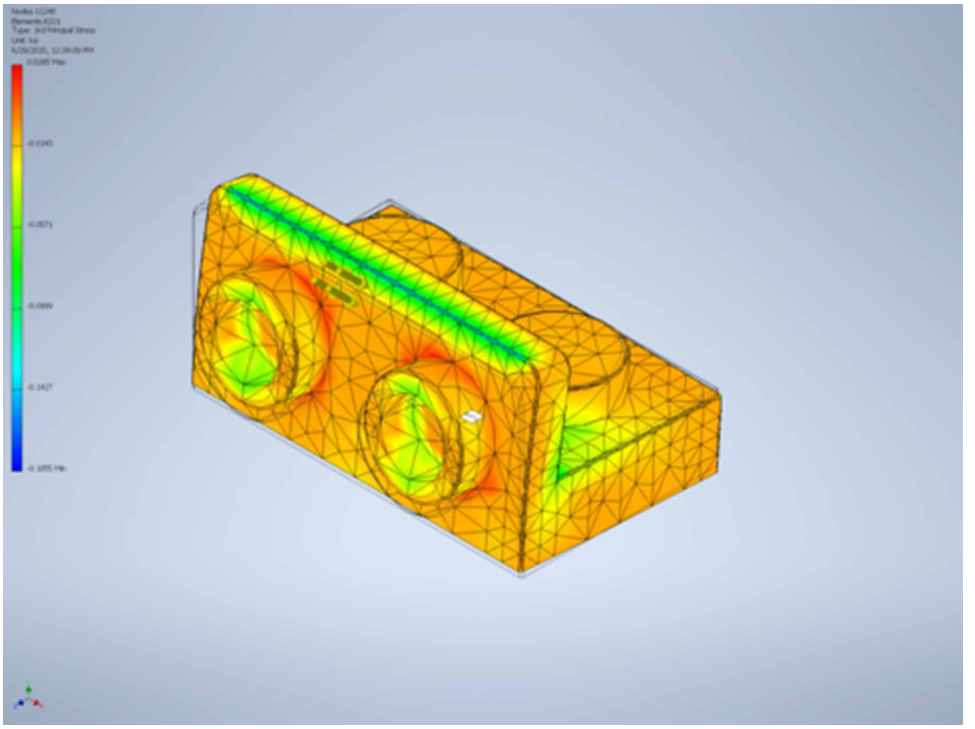
Figure 4. Drawing showing macro variables
Source: Roman Druessi



Macros are ideal for automating repetitive design tasks. Unfortunately, they're limited to executing the exact same operation over-and-over. If an Application Programming Interface (API) is placed in lines of macro code programs could automatically update. The possibilities are seemingly endless as APIs contain hundreds of functions based on Visual Basic for Applications (VBA), VB.NET, Visual C#, Visual C++ 6.0 and Visual C++/CLI (*Dassault Systems, 2015)*. The result is AI programs capable of producing drawings with any number of variations.

The third type of data in CAD metafiles is application data. Application data supports Computer Aided Engineering (CAE). Common CAE platforms include MATLAB, Solid Edge, and Mathematica. Each of these packages includes extensions for evaluating CAD models inside simulated environments. Common programs include Finite Element Analysis (FEA) for testing stress, strain and heat transfer in solids as well as Computational Fluid Dynamics (CFD) for evaluating thermodynamic interactions among solids, liquids and gasses. FEA and CFD are data intensive applications. Modeling starts with computer programs transcribing volumetric (or surface) data into millions of mathematical points called nodes. Nodes are arranged into a 3D mesh (Figure 5).

Figure 5. 3D Mesh
Source: NexGenCAM,LLC



Partial differential equations (PDEs) are assigned to every node. Calculations are done for each node and polynomial approximations are made for spaces between them. Solutions are then evaluated against application data to predict how designs will perform. Even with all of computational analysis being done it would be

incorrect to say these systems are completely automated. After all, more accurate geometric representation of objects doesn't necessarily produce more accurate force predictions. Human specialists are typically needed to define: meshing, element type, loads, supports and error estimation (Kurowski, 2012). In recent years, AI has been making some progress automating these tasks. For example, a single mesh is usually a poor description of an object. One option is creating different meshes for different regions of an object. Meshes can then be added together in a process called mesh generation (Roade, 2018). All this meshing takes a lot of time and requires a substantial amount of computing power. A quicker approach is to simplify or "defeature" objects. Defeaturing is particularly useful when dealing with curved surfaces since many dynamics packages assume linearity. Clearly, a balance is needed between the accuracy of mesh generation and the speed of defeaturing. AI is particularly useful in this regard. Through a process called iterative meshing AI programs can continually add nodes until simulation results are no longer affected by the size of the mesh.

Beyond predicting how parts will behave, CAD data extensions can also be used to automate how parts are made. The practice of Computer Aided Manufacturing (CAM) involves uploading CAD data into CAM software. CAM packages (such as Siemens NX CAM, Fusion 360, EdgeCAM, etc.) translate CAD data into numerical control (NC) code. Postprocessors take the NC code and translate it into G code which is necessary to guide computer numerical controlled (CNC) machines through linear movements (in the X, Y and Z planes) as well as rotational movements around these planes. Figure 6 is an example of G code.

CAM software automatically determines:

1. If CAD models have geometries which will make machining difficult.
2. How part layout patterns should be nested on raw materials to minimize waste.
3. Tool movements, tool changes, tool positions, clearances, material removal and processing time.

Any potential coding errors, collisions, or incorrect cutting paths are easily identified (per Figure 7).

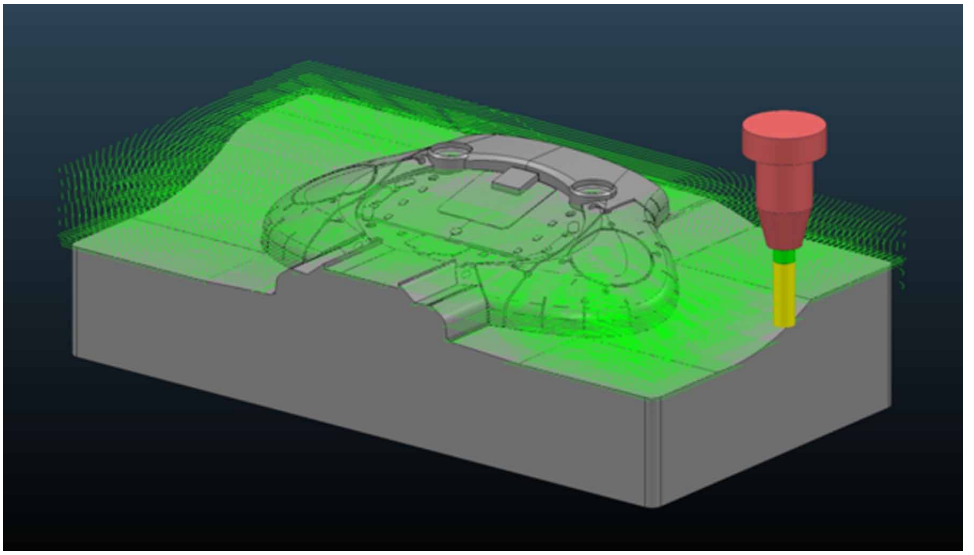
For all that CAM has automated, it would be incorrect to say once CAD models are translated CNC machines are capable of operating without human involvement. For example, many CNC controllers can only provide instruction for straight line movements or circular arcs. Arc movements may be restricted to the X, Y and Z planes. There may even be limitations in controllers themselves such as their ability to (1) receive positional data, (2) process data, (3) communicate data, and (4) feedback data. As a result, programs must be modified to account for software and hardware limitations. In recent years AI programs have started performing

Figure 6. Machine code
Source: NexGenCAM,LLC

```
N130 ( TOOL DIA    : 20.0 LENGTH 188.1)
N131 T1
N132 M6
N133 S1500 M03
N134 G00 G90 X61.056 Y-0.001 A0.0
N135 G43 Z125.47 H1
N136 M08
N137 G61.1
N138 G05 P2
N139 X2.587 Y-79.525
N140 Z120.47
N141 G01 Z105.45 F500.0
N142 X2.449 Y-79.716 F1000.0
N143 X2.4 Y-79.946
N144 G03 X3.535 I0.568 J0.0
N145 G03 X2.587 Y-79.525 I-0.567 J0.0
N146 G02 X0.34 Y-77.514 I-1.019 J1.123
N147 G01 X0.343 Y-77.51
N148 G03 X-2.036 Y-75.654 I-1.222 J0.887
N149 G01 X-3.052 Y-76.868
N150 X-3.15 Y-77.008
N151 X-3.223 Y-77.163
N152 X-3.569 Y-78.098
N153 X-3.629 Y-78.595
N154 X-3.769 Y-79.751
N155 X-3.569 Y-81.485
N156 X-3.359 Y-82.123
N157 X-3.289 Y-82.334
N158 X-3.221 Y-82.493
N159 X-3.127 Y-82.638
N160 X-2.256 Y-83.75
N161 X-1.17 Y-85.136
N162 X-1.073 Y-85.243
N163 X-0.961 Y-85.335
N164 X-0.819 Y-85.436
N165 X0.262 Y-85.869
N166 X1.729 Y-86.457
N167 X1.935 Y-86.515
N168 X2.149 Y-86.527
N169 X3.291 Y-86.473
N170 X4.479 Y-86.417
```

some of these adjustments. In 2018, at the Commonwealth Center for Advanced Manufacturing (CCAM) in Virginia, deep machine learning was used to auto calibrate CNC machines. The process was 30 times faster than humans (Control Designs,

Figure 7. Tool cutting path
Source: NexGenCAM,LLC



2018). At the University of Maribor in Slovenia researchers tested a combination of swarm intelligence and NSGA-II multi-objective optimization to determine tool paths, tools and cutting parameters (Klancnik et. al, 2016). In both sets of research, AI was being used to program machines. However, the machining approach was purely kinematic. Movements were based solely on geometric boundaries. For AI to truly program machines dynamics must be taken into account. Research out of the Department of Management and Engineering at Linköping University in Sweden has shown the importance of dynamics based programming. Robots controlled by reaction to force stimuli were able to assemble parts much more consistently. This was particularly true when working with compliant structures (Johsson, 2013).

In 2009, MasterCam-CNC Software Inc. introduced dynamic motion control in machining. Cutting paths are selected according to rule sets. Rules are based on maximizing metal removal and minimal tooling wear (Albert, 2014). While the dynamic motion option has proven effective for roughing, the same can't be said for finishing. The dynamics involved in finishing are much more complicated. Optimizing tool path smoothness requires algorithms capable of predicting deviations between a design surface and a cutter envelope surface. Researchers out of Huazhong University and JiaoTong University in China have shown that the shape of a cutter envelope surface presently can't be determined in real time at a machine tool. As material is being removed, the large number of parameters impacting the envelope surface are constantly changing. Hundreds of thousands of polygonal meshes would be needed

to describe dynamic interactions between a single tool and workpiece. (Ding et al, 2010). Even if 5G edge computing speed is available, dynamic motion software isn't yet able to predict chaotic forces during finishing. For example, today's dynamic tool packages assuming material removal is a "complicated system" allowing machine movements to be broken down into deterministic parts. In other words, the same machining parameter inputs always produce the same material removal dynamic outputs. Linearity is assumed. In finishing machining external disturbances introduce damped oscillations of tools relative to workpieces. These forced variations produce periodic waviness on workpiece surfaces "where the length of the delay is equal to the time-period of the revolution of the workpiece" (Gábor., 2001). Force variation is nonlinear. For AI to be able to self-program finish machining algorithms would need to predict nonlinear, deterministic behavior.

In deterministic systems the future state follows from a set of rule. However, in chaotic systems (such as finish pass material removal) the rules are nonlinear. In these deterministic, nonlinear systems even when the same rules are applied over-and-over very small "butterfly sized" changes in initial conditions produce totally different outcomes. Chaotic systems haven't been automated because they can't be predicted. In 2018 researchers at the University of Maryland attempted to predict the chaotic behavior of a flame flickering using reservoir computing. The hope was to transform inputs nonlinearly into a high-dimensional space where patterns could be identified without having to look at all the data. The researchers were able to predict system dynamics eight times further than had ever been done before (Wolchover, 2018). Their work suggests it may be possible to fully automate dynamics without generating a massive number of equations. Only massive amounts of data are needed which 5G networks should be able to handle. Unfortunately, while dynamic systems such as machining involve nonlinearity, it would be incorrect to say that they're totally deterministic. Any effort to produce self-programming machines needs to take into account the stochastic nature of dynamics.

Unlike deterministic processes, stochastic processes produce different outputs for the exact same inputs and initial conditions. Tool wear is one such example. To accurately predict tool path dynamics algorithms must be able to account for the randomness of tool wear. One way to approximate tool wear would be to use an array of extremely sensitive sensors which continuously collect tool displacement, vibration and acoustic emissions. All of this data would then need to be uploaded into a stochastic optimization algorithm. AI would then quantify probabilities of wear and find "the optima of an objective function that itself has randomness (or statistical noise)." (Brownlee, 2019). While companies like Caron Engineering in the U.S. offer Tool Monitoring Adaptive Control (TMAC) retrofits for CNC machines present technology is limited to rough machining.

FUTURE RESEARCH DIRECTIONS

At their core robots haven't changed all that much over the last 20 years. They're still a collection of bolts, nuts, electronics, wires and hoses. They still rely on solenoids, sensors and controllers to guide their movements. Their sources of power remain batteries, motors, pneumatics and hydraulics. If anything, improvements in motors, actuators and batteries have lagged far behind advances in processor speeds and memory cost (Marcus, 2012). Wide spread automation will require additional research and development into producing better robots.

Of the smart machinery which is available a big part of the problem deploying it is the high data cost and low bandwidth. Much more work needs to be done to determine how 5G's 130x faster download speeds will impact data storage, retrieval and processing strategies.

Automation has been successful reducing shop floor headcount at large, high volume operations. The same can't be said for small to medium companies. Their flexible operations will require smart machines a large numbers of engineers to support them? Algorithms have shown great progress creating some drawings, evaluating some designs and establishing some machining parameters. However, substantial gaps remain before these tasks can be fully automated. In terms of design, most automation is confined to creating variations not original content. While some machines are capable of self-programming they still rely heavily on people to fine tune them. This is particularly true when precision work is being done. Much more research is needed in predicting chaotic and stochastic systems before wide spread "lights out" automation is possible.

CONCLUSION

There's been a 100% rise in labor costs and 60% fall in robot prices since 1990 (tilley, 2017). Clearly the future of manufacturing is doing more with less people. Over the next 20 years it's expected that 47% of us occupations will potentially be automated (chui et. Al, 2015). Such predictions fail to explain the substantial hurdles which must be overcome before automation can realize its full potential. On the one hand, machines need to be smarter. On the other hand, they need to be cheaper. Both can be accomplished when machines are creating drawings, evaluating designs and programming themselves all without human intervention. For this to happen much more research is needed in using ai to predict chaotic and stochastic systems. In addition, the importance of expanded 5g networks and government support of small to medium smart enterprises cannot be overstated. As automation efforts continue care must be taken that development is done with people at the center. The "automation

paradox" warns when systems depend too much on automation they become more difficult to predict. As problems emerge there aren't enough people with enough expertise to fix them. (betz et. Al, 2019). The boeing 737 max provides a cautionary tale about the future of automation. The max was equipped with bigger engines to fly farther and carry more passengers than older 737 models (german, k. 2020). Unfortunately, bigger engines could cause the aircraft's nose to pitch up during flight. A maneuvering characteristics augmentation system (mcas) automatically pushed the nose down when a sensor on the fuselage detected the plane was pitched. Pilots were not part of mcas development. When the software didn't function correctly people flying the planes didn't know how to make corrections. Two crashes killed a total of 346 people. Automation 4.0 is about widespread use of machines because they provide cost effective solutions to everyday problems. This can only happen when ai systems are understood by the people benefiting from them.

REFERENCES

Abbosh, O., Nunes, P., & Downes, L. (2019). *Pivot to the future: Discovering value and creating growth in a disrupted world*. PublicAffairs.

Albert, M. (2014). *Dynamic motion moves past old boundaries. Modern Machine Shop.* https://www.mmsonline.com/articles/dynamic-motion-moves-past-old-boundaries

Association for Advancing Automation. (2015). *Robots: Masters of the dirty, dull, and dangerous.* https://www.a3automate.org/robots-masters-of-the-dirty-dull-and-dangerous/

BBC. (2019). *Robots to replace 20 million factory jobs by 2030.* https://www.bbc.com/news/business-48760799#:~:text=Up%20to%2020%20million%20manufacturing,by%20automation%2C%20the%20firm%20said

Betz, C., Gardner, C., O'Donnell, G., McKeon-White, W., Caldwell, J., & Lynch, D. (2019). *Beware the automation paradox: Prepare for an automated world full of surprises and requiring higher skills*. https://www.forrester.com/report/Beware+The+Automation+Paradox/-/E-RES158237#

Biron, J. (2017). *The state of the industrial internet of things 2017*. https://www.ptc.com/-/media/Files/PDFs/IoT/State-of-IIoT-Whitepaper.pdf

Brownlee, J. (2019). *What does stochastic mean in machine learning?* https://machinelearningmastery.com/stochastic-in-machine-learning

Built, In. (2019). *Robotics technology*. https://builtin.com/robotics

Chui, M., George, K., Manyika, J., & Miremadi, M. (2017). *Human + machine: A new era of automation in manufacturing*. https://www.mckinsey.com/business-functions/operations/our-insights/human-plus-machine-a-new-era-of-automation-in-manufacturing#

Chui, M., Manyika, J., & Miremadi, M. (2015). *How many of your daily tasks could be automated?* https://hbr.org/2015/12/how-many-of-your-daily-tasks-could-be-automated

CloudCheckr. (2019). *How to optimize smart manufacturing production with IIoT and the cloud.* https://cloudcheckr.com/cloud-automation/smart-manufacturing-iiot-cloud/

Columbus, L. (2019). *10 ways machine learning is revolutionizing manufacturing in 2019*. https://www.forbes.com/sites/louiscolumbus/2019/08/11/10-ways-machine-learning-is-revolutionizing-manufacturing-in-2019/#2321ca4c2b40)

Cooke, N. (2019). *The difference between files and databases – and what it means for CAD and product design*. https://www.onshape.com/cad-blog/the-difference-between-files-and-databases-and-what-it-means-for-cad-and-product-design

Dassault Systems. (2015). *Solidworks API help*. http://help.solidworks.com/2015/English/api/sldworksapiprogguide/Welcome.htm#_ga=2.14223664.686212411.1591105404-25c358d0-a4d5-11ea-b73a-a1d588fa93fd

Digital Transformations Monitor. (2017). *Key lessons from national industry 4.0 policy initiatives in Europe*. https://ec.europa.eu/growth/tools-databases/dem/monitor/sites/default/files/DTM_Policy%20initiative%20comparison%20v1.pdf

Ding, H., Bi, Q., Zhu, L., & Xiong, Y. (2010). Tool path generation and simulation of dynamic cutting process for five-axis NC machining. *Chinese Science Bulletin*, *55*(30), 3408–3418. doi:10.100711434-010-3247-7

Dvorkin, M., & Bharadwaj, A. (2019). *Which countries and industries use the most robots?* https://www.stlouisfed.org/on-the-economy/2019/november/robots-affecting-local-labor-markets

El-Khalil, R., & Darwish, Z. (2019). *Flexible manufacturing systems performance in U.S. automotive manufacturing plants: A case study.* https://www.tandfonline.com/doi/abs/10.1080/09537287.2018.1520318

Gábor, S. (2001). Modelling nonlinear regenerative effects in metal cutting. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, *359*, 1781.

German, K. (2020). *Boeing 737 max could stay grounded until late 2020*. https://www.cnet.com/news/boeing-737-max-8-all-about-the-aircraft-flight-ban-and-investigations

Johsson, M. (2013). *On manufacturing technology as an enabler of flexibility – Affordable reconfigurable tooling and force-controlled robotics*. https://www.diva-portal.org/smash/get/diva2:601924/FULLTEXT01.pdf

Kalycito. (n.d.). *What is OPC UA, industry 4.0 and the interoperability challenge?* https://www.kalycito.com/opc-ua-interoperability/

Klancnik, S., Brezocnik, M., & Balic, J. (2016). Intelligent CAD/CAM system for programming of CNC machine tools. *International Journal of Simulation Modelling*, *15*(1), 109–120. doi:10.2507/IJSIMM15(1)9.330

Kurowski, P. (2012). *When good engineers deliver bad FEA*. https://www.machinedesign.com/3d-printing-cad/fea-and-simulation/article/21831586/when-good-engineers-deliver-bad-fea

Manufacturing Institute. (2014). *Small companies dominate the industrial landscape.* https://www.themanufacturinginstitute.org/Research/Facts-About-Manufacturing/Economy-and-Jobs/Company-Size/Company-Size.aspx

Manufacturing.gov. (2020). *Funding*. https://www.manufacturing.gov/funding

Marcus, G. (2012). *Why making robots is so darn hard*. https://www.newyorker.com/news/news-desk/why-making-robots-is-so-darn-hard

Marr, B. (2018). *What is industry 4.0? Here's a super easy explanation for anyone*. https://www.forbes.com/sites/bernardmarr/2018/09/02/what-is-industry-4-0-heres-a-super-easy-explanation-for-anyone/#76efaaae9788

Mathews, K. (2018). *How robot precision has evolved, enabling more uses.* https://www.roboticsbusinessreview.com/manufacturing/robot-precision-evolves

McKay, C., Pollack, E., & Fitzpayne, A. (2019). *Automation and a changing economy.* https://assets.aspeninstitute.org/content/uploads/2019/04/Automation-and-a-Changing-Economy_The-Case-for-Action_April-2019.pdf?_ga=2.29984255.1325231099.1591271424-1863845613.1591271424

Melanson, A. (2018). *Robotic automation in manufacturing driving US growth*. https://aethon.com/robotic-automation-in-manufacturing-driving-us-growth/

Moran, G. (2019). *Your job will be automated—Here's how to figure out when A.I. could take over*. https://fortune.com/2019/08/01/predicting-job-automation-ai/

Nicols, G. (2018). *Paradigm shift: Can anyone be a robotics programmer with sensor-embedded clothes?* https://www.zdnet.com/article/paradigm-shift-can-anyone-become-a-robotics-programmer-with-sensor-embedded-clothes/

Press, G. (2019). *Predictions about automation and the future of work from Forrester.* https://www.forbes.com/sites/gilpress/2019/10/30/2020-predictions-about-automation-and-the-future-of-work-from-forrester/#33a2f1541318

Roade, M. (2018). *The future of finite element analysis*. https://www.midasoft.com/mechanical/learning-1/the-future-of-finite-element-analysis-meshfree

Robotic Industries Association. (2020). *Unimate: The first industrial robot*. https://www.robotics.org/joseph-engelberger/unimate.cfm

Robotics Business Review. (2019). *Cobot market will exceed $11B by 2030, ABI Research Says*. https://www.roboticsbusinessreview.com/research/cobot-market-will-exceed-11b-by-2030-abi-research-says/

Robotics Online Marketing Team. (2016). *How robots cut costs*. https://www.robotics.org/blog-article.cfm/How-Robots-Cut-Costs/11

Science Daily. (2019). *Algorithm tells robots where nearby humans are headed.* https://www.sciencedaily.com/releases/2019/06/190612141314.htm

Shah, M. (2020). *Smart Factory Market is expected to be valued at US$ 276.12 Billion globally by end of 2027, Says CMI.* https://www.globenewswire.com/news-release/2020/05/11/2031220/0/en/Smart-Factory-Market-is-expected-to-be-valued-at-US-276-12-Billion-globally-by-end-of-2027-Says-CMI.html

Suwelack, S. (2020). *What is AI-assisted engineering?* https://renumics.com/blog/what-is-ai-assisted-engineering/

Tilley, J. (2017). *Automation, robotics, and the factory of the future.* https://www.mckinsey.com/business-functions/operations/our-insights/automation-robotics-and-the-factory-of-the-future

Tobe, F. (2015). *Innovation and growth driver for robotics industry.* https://spectrum.ieee.org/automaton/robotics/industrial-robots/collaborative-robots-innovation-growth-driver

Waldmon, C. (2016). *Automation investment in U.S. manufacturing: An empirical picture*. https://static1.squarespace.com/static/58862301f7e0ab813935c244/t/58bf6e81440243643252b2b2/1488940682272/Rockwell_Automation_Investment_0.pdf

Weber, A. (2019). *Lights-out automation: Fact or fiction?* https://www.assemblymag.com/articles/94982-lights-out-automation-fact-or-fiction

West, D. (2015). *What happens if robots take the jobs? The impact of emerging technologies on employment and public policy.* https://www.brookings.edu/wp-content/uploads/2016/06/robotwork.pdf

Widjaya, I. (2016). *What are the costs of big data?* http://www.smbceo.com/2019/09/04/what-are-the-costs-of-big-data/

Wolchover, N. (2018). *Machine learning's 'amazing' ability to predict chaos.* https://www.quantamagazine.org/machine-learnings-amazing-ability-to-predict-chaos-20180418/

Zelinski, P. (2019). *10 takeaways on how artificial intelligence (AI) will influence CNC machining. Modern Machine Shop.* https://www.mmsonline.com/blog/post/10-takeaways-on-how-artificial-intelligence-ai-will-influence-cnc-machining

ADDITIONAL READING

Deloitte. (2017). *The smart factory: Responsive, adaptive, connected manufacturing.* https://www2.deloitte.com/content/dam/insights/us/articles/4051_The-smart-factory/DUP_The-smart-factory.pdf

Deloitte. (2018). *China's smart manufacturing: A steady push for the long term.* https://www2.deloitte.com/content/dam/Deloitte/cn/Documents/energy-resources/deloitte-cn-eri-2018-china-smart-manufacturing-report-en-190403.pdf

PWC. (2016). Industry 4.0: *Building the digital enterprise.* https://www.pwc.com/gx/en/industries/industries-4.0/landing-page/industry-4.0-building-your-digital-enterprise-april-2016.pdf

Reddy, M., & Kumar, S. (2013). *Flexible approach to test automation with measureable ROI*. https://www.tavant.com/sites/default/files/download-center/White%20Paper%20-%20Flexible%20Approach%20to%20Test%20Automation%20with%20Measureable%20ROI.pdf

West, D. (2015). *What happens if robots take the jobs? The impact of emerging technologies on employment and public policy.* https://www.brookings.edu/wp-content/uploads/2016/06/robotwork.pdf

West, D., & Allen, J. (2018). *How artificial intelligence is transforming the World.* https://www.brookings.edu/research/how-artificial-intelligence-is-transforming-the-world/

KEY TERMS AND DEFINITIONS

Artificial Intelligence: Machines with the capability to respond to stimulation as humans with contemplation, judgment, and intention.

Automation 4.0: Machines possess the ability to perform tasks as well as the engineering necessary to support those tasks without human involvement.

CAD: Computer-aided drafting. Computer software used to create, revise, or analysis digital designs.

CAE: Computer-aided engineering. Computer software capable of evaluating digital designs under simulated environments meant to match application dynamics and kinematics.

CAM: Computer-aided manufacturing. Computer software capable of generating numerical control (NC) code necessary guide CNC machine movements.

Coding: Use of a programming language to interface with a computer in order to guide performance of a machine.

Industry 4.0: The fourth industrial revolution. The digital world is connected to the physical world through intelligent machines.

Smart Factory: A digitalized manufacturing environment where machines are able to self-improve processes.

Chapter 3
Building a Factory Knowledge Base:
Digitalization and Integration of Manufacturing Information

Giulia Bruno
Politecnico di Torino, Italy

Emiliano Traini
Politecnico di Torino, Italy

Alberto Faveto
https://orcid.org/0000-0002-4652-0306
Politecnico di Torino, Italy

Franco Lombardi
Politecnico di Torino, Italy

ABSTRACT

In past decades, production has been characterized by the mass customization trend. This concept reaches its extreme with the one-of-a-kind production (OKP): every product is different for each customer. In order to develop unique product and complex processes in short time, it is mandatory to reuse the acquired information in the most efficient way. Several commercial software applications are already available for managing manufacturing information, such as product lifecycle management (PLM) and manufacturing execution system (MES), but they are not

DOI: 10.4018/978-1-7998-5879-9.ch003

integrated. The aim of this chapter is to propose a framework able to structure and relate information from design and execution of processes, especially the ones related to anomalies and critical situations occurring at the shop floor, in order to reduce the time for finalizing a new product. To this aim, a central knowledge-based system (KBS), acting as integrator between PLM and MES, has been developed. The framework has been implemented with open source systems, and has been tested in a car prototyping company.

INTRODUCTION

The technologies provided by the Industry 4.0 paradigm help to improve business organization and automate industrial processes by adding the concept of interconnection between devices and information systems to the existing technologies. Among the most important advantages of interconnection there are the creation of 'intelligent' production thanks to data collected and analyzed in real time by machining centers, machine tools and devices and the production of a large amount of data (Big Data) that can be processed to plan new strategies. In this context the production mostly focuses on the personal needs of the consumer: companies innovate and introduce new products on the market led by the consumers, trying to anticipate their needs. Thus, lean development approaches are needed to quickly test the products and reduce the time to market. The past decades have been characterized by this trend, known as the concept of mass customization. This concept reaches its extreme with the One-of-a-Kind Production (OKP): every single product is different for each customer. With the new technologies of the Fourth industrial revolution, meeting the demands of customers and innovating continuously are not only possible, but they are an essential requirement for any company, in particular small and medium sized, that wants to compete in the market (Muffatto 2000, Wortmann 1997, Tu 1997, Dean 2009).

An increasing number of industrial operators and manufacturers are adding industrial connectivity to their assets. The Internet of Things (IoT), a now fundamental concept of the Information Technologies (IT), provides for machines, operators and all the resources are able to interact among each other sharing data about their status and all the issues that happen during the production. The ability to store, integrate and use these data is an important feature to accomplish for a company of the fourth

industrial revolution. This feature can be seen from three different points of view: horizontal integration, vertical integration, and end-to-end integration (Vaidya 2018). Horizontal integration refers to data along various business functions like for example production, design, R&D, purchasing, human resource or accounting and finance. Vertical integration requires the involvement of players and partners who interact with the company. Integrating the systems of various companies along the value chain is essential to allow a coordinated and efficient work. Finally, the end-to-end integration operates throughout the life cycle of the product and makes it possible to achieve excellent results that go further the production line and the supply chan.

To achieve system integration, it is necessary that IT platforms implemented in a company cover the process of product design, to allow innovation towards customer needs, and the production activity itself, to minimize costs and lead times. The goal of PLM systems is to allow the interaction and coordination among people (not only designers), thus enabling the knowledge exchange, transfer and reuse. The purpose of a MES is to control and manage the production in detail, providing real-time information of the whole process, right through to the completion of the order. MES, creating knowledge from the activity of machines, operators and sensors, creates a digital twin of the system through which it is possible to control the progression of tasks and compare it with the production planning.

Through the integration between PLM and MES, designers could observe what is happening in production, receive feedback and check where anomalies have occurred to ensure that these errors or complications do not occur again in the future. If made easy to use, his knowledge could be of great importance during the design of a new product, especially in the case of OKP, where it is usual to design a new product for each customer, customizing the characteristics according to its needs.

These companies need several trial-and-errors cycles before find the final one to design a new process for the new product. Actually, in the most of these companies, the knowledge of the trial-and-errors cycles remains in the minds of the people, or, at best, transferred verbally, and then, over time, inevitably lost (Bruno 2014, Bruno 2018). Similarly, it is also difficult for a production manager to find information related to the checks to perform before and after the execution of an operation on a machine, and for an operator to report in a structured way the occurrence of problems and anomalies during the production. Oral communication and knowledge based on the experience of the operators do not allow companies to compete in the global market and therefore this implies the need for a knowledge-based information system (KBS) that can contain and make this design knowledge easy to consult.

The aim of this chapter is to propose a framework able to structure and relate information from design and execution of processes, especially the ones related to anomalies and critical situations occurring at the shop floor, in order to reduce the time for finalizing a new product. To this aim, a central KBS, acting as integrator

between PLM and MES, has been developed. The proposed system will allow (i) to collect all the information regarding the critical realizations of new components in a structured way, so that the added values of the experience breakthrough, as well as other useful tips, could be provided to the users, and (ii) to reuse the knowledge, i.e. help designers to define more reliable processes for new products, reducing the "trial-and-error" cycles in the development of forming processes.

BACKGROUND

Before describing the state of the art on the integration of plm and mes, in this chapter these two business information systems are introduced to provide a knowledge base for readers who are new to these concepts.

Product Lifecycle Management

Product Lifecycle Management (PLM) refers to the management of a product at all stages of its lifecycle. The acronym PLM was originally introduced (70s-80s) in the environmental compatibility studies of industrial products, to indicate how a given physical good should be designed and manufactured in respect of the environment, considering the different phases of its lifecycle, including recovery and disposal. In general, lifecycle means the set of those phases that are recognized as the single stages that a given product goes through, i.e., its (i) conception, (ii) design, (iii) planning, (iv) implementation, (v) distribution, (vi) disposal and possible recovery (Verschoor 1999). Towards the end of the 1990s, extending the eco-compatible vision, PLM began to be understood as the management and traceability (Soga 1999) of the entire product system and all the activities connected to it, during its various stages of life, thus changing the meaning of the term. The PLM environment is obviously different according to the type of product system considered:

- in manufacturing production, the concept of PLM refers to the tangible physical asset, conceived, designed, and manufactured in ad hoc production systems, distributed along an appropriate network, and disposed of or recovered with an equally appropriate network;
- in engineering and contracting, the PLM refers instead to the plant/work designed and built on a specifically sized site, built, and subsequently managed/maintained;
- in the world of services, finally, PLM refers to the service conceived, installed, and provided through a special infrastructure.

Considering the history of the term, PLM can be defined as the new integrated business approach that, with the help of IT, implements an integrated, cooperative, and collaborative product information management along the different phases of its life cycle. In this sense, the PLM includes:

- a strategic orientation to the creation of value "on" and "through" the "product";
- the application of a collaborative approach for the valorization of the core-competences of different actors;
- the use of a consistent number of IT solutions for the practical implementation of the consequent coordinated, integrated and secure management of all the information necessary for the creation of value.

Ultimately, PLM is not only an integrated software tool (Verschoor 1999), it is not only an organizational choice, it is not only a technical choice. In a more complex dimension, the PLM indicates a new phenomenon of integration that is currently underway in the industrial context and that combines organizational (processes), economic (costs and revenues), technical (activities and people) and technological (IT systems) dimensions. Perhaps it is precisely because of the complexity of the context that a universally accepted definition of PLM is not yet available: suffice it to say that in the last two years numerous acronyms have been coined to indicate approaches similar to the one generally understood for PLM.

The acronym PLM is certainly right to exist when it refers to the complex set of phenomena tending to a complete overhaul of the enterprise system in order to better respond to market needs with the use of IT technologies that enable communication, sharing and collaboration. In a company, "doing PLM" means knowing how to manage the company system in its complexity, looking for efficient solutions in technological offerings that are consistent with business objectives. In particular, "doing PLM" means efficiently managing all the information useful for satisfying the company's core-business.

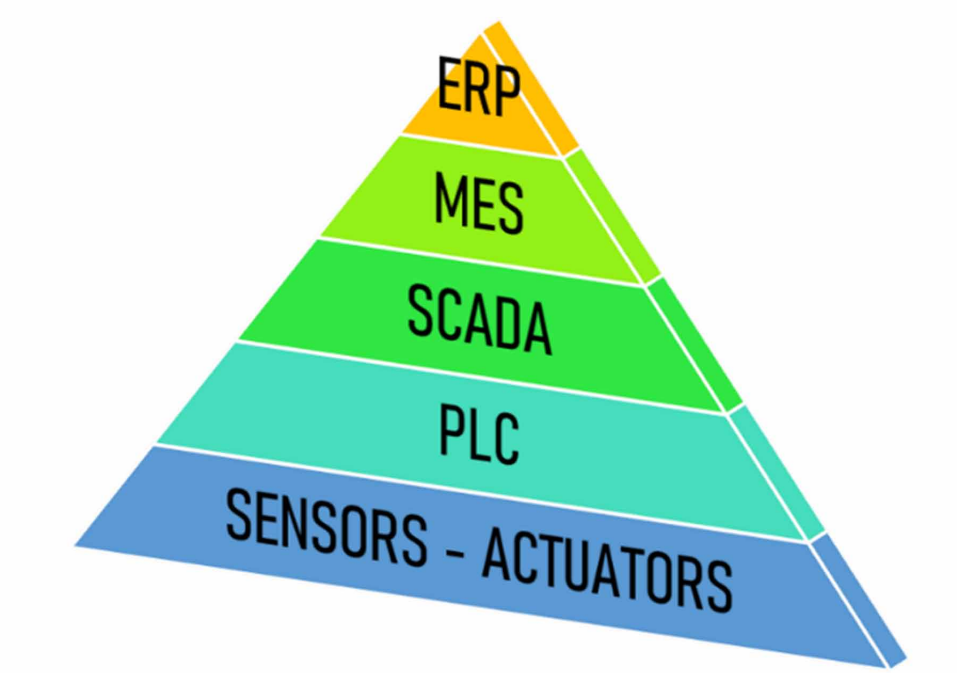
PLM provides different benefits, especially financial, due to the cost savings resulting from the adoption of a portal and the increase in earnings. First, there are more efficient use of human resources, thanks to the development of self-service applications that can be used independently by employees, customers, and partners. Some examples are interactive training, order tracking and product information retrieval. Second, the technology costs are reduced thanks an extensive framework for storing, sharing, and accessing business content. This reduces storage requirements, email attachments and the need to print marketing and sales material. This increase the efficiency: in addition to economic benefits, implementing a PLM process

improves production efficiency, allowing the company to remain competitive in the marketplace especially in the design phase of the product and of the process.

Manufacturing Execution System

The manufacturing information systems could be represented hierarchically through the automation pyramid depicted in Figure 1.

Figure 1. The pyramid of industrial automation represents different hierarchical layers of information systems



At the top of the pyramid, it is possible to find the structure that supports the entire business by planning, coordinating, and controlling the operational activities, i.e., the Management Level. The software used at this level is called ERP (Enterprise Resource Planning), and it is the heart of the enterprise system. The ERP makes it possible the integration various business functions such as sales, accounting, management purchases, management human resources, and control warehouse. The ERPs is used to support long term decision making (Bartodziej 2017).

Below the management level of the pyramid, there is the plant level. Here the software used is the MES (Manufacturing Execution System), which allows the control and management of the production, providing almost real-time feedback of the entire process until completing the job. The MES, thanks to the data obtained by sensors installed along the process, could create a digital copy of the plant in real-time. Inside the plant, there are the SCADA (Supervisory Control And Data Acquisition) systems; thanks to that tools, the operators can interface with the production system. SCADA connects and manages all the plant's peripherical unities using a complex communication network, allowing humans to interface with the machines below this system.

Finally, at the bottom of the pyramid, there is the shop floor with machines controlled by PLC (Programmable Logic Controller).

By analyzing in more details the plant level, several tasks can be executed by a MES. Such tasks were firstly defined by the Manufacturing Enterprise Solutions Association (MESA), a US global community of manufacturers, producers, industry leaders, and solution providers. MESA provides a list of 11 functions an MES should perform (MESA International 1997, D'Antonio 2016):

1. **Operations/Detail Scheduling**. MES helps to find the best job sequence to optimize the processing time minimizing setup and failure times
2. **Process management**. Data provided and stored could be used to support the manager in the decision-making process.
3. **Document control**. the MES ensures the maintenance of historical documentation (work instructions, drawings, specifications, environmental compliance requirements, safety instructions, etc. and make them easily accessible to staff when necessary
4. **Data collection/acquisition**. Manufacturing data is collected using sensors both manually and automatically
5. **Labor management**. Provides a human resources management tool, keeping track of hours worked, absences, vacations, etc., through a database of information regarding staff skills and responsibilities ensures a perfect allocation of resources.
6. **Quality management**. Keeping track of data on the line ensures quality control allowing drifts' interception, out of scale tolerances, and production errors.
7. **Dispatching Production Units**. the system helps to adjust the production flow considering the events that are occurring in the plant
8. **Maintenance management**. The MES allows to track the use of tools and operational materials to plan periodic and preventive maintenance, ensuring their availability according to the scheduled activities. Saved historical data could help to find correlations that could make predictive maintenance possible.

9. **Product tracking and genealogy**. A historical trace of every product can be obtained: the source of the raw material, the batch number, reworking, who performed the job, etc.
10. **Performance analysis**. Producing a dashboard of indicators, it is possible to keep the enterprise and the plant under control and verify the actual improvements of the policies activated
11. **Resource allocation and status**. Coordination and control of resource status, any resources associated with the production, consider staff, machines, tools, etc.

According to MESA, MES is the software tool that has brought the most significant advantages in production processes, such as an average reduction in cycle times of 45%, increased business flexibility, and compliance with regulatory and customer requirements (Saenz de Ugarte 2009).

State of the Art for the PLM-MES Integration

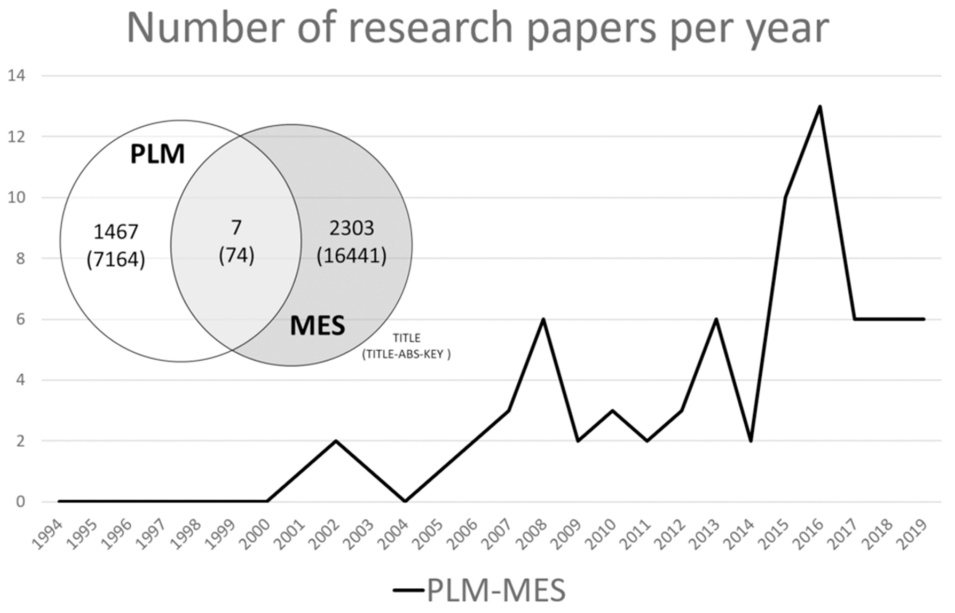
Several papers underline the benefits of the symbiosis between design and manufacturing that coincide with an IT point of view, the integration between PLM and MES (Ming 2007, Pouchard 2000). However, there is not much framework description of developing and managing a knowledge system, and an integrated knowledge is still too far for many manufacturing companies.

This gap in research on the integration between PLM and MES is also revealed by the recent increase of published papers on the topic. Figure 2 shows the result of a search in the Scopus database of papers about PLM-MES integration.

The Venn diagram in Figure 2 compares the number of papers addressing separately PLM and MES, and the number of papers addressing both. This last number is significantly low than the others: only 7 papers contain both PLM and MES words in the title (74 papers if the search is also extended to abstract and keywords). However, the interest in this topic is quickly growing, as shown by the line chart, which represents the distribution of the 74 papers among the years.

The oldest work between this seven (Joshi 2009) proves, also using simulation technique, that the business strategy of a company needs the information contained in a PLM-ERP-MES integrated system. This publication discusses methodologies and advantages of this integration. The most cited one (Khedher 2011) is a PLM-MES integration proposal that aims to overcome the problem of data heterogeneity by proposing a mediation system that takes into account also the ERP. In this work it is cited the ISA95-IEC62264 standard (ISA 95 2000) of MES functions and MES-PLM data transferring, for which the author gives a classification in CAD model, plans, BOM, manufacturing process, work instructions and machine setup for the

Figure 2. Results of Scopus search: papers published on PLM-MES integration. Numbers in Venn diagram between brackets, as the trend graph, refer to a research carried out on title, abstract and keywords. Free numbers, instead, refer to a research only on the title.



flow from PLM to MES, while from the MES is considered to receive reports about production problems. Furthermore, this paper introduced a mediation system based on ontologies to manage this integration. Another interesting article is a PLM-MES integration proposal for a collaborative design of a spur gear production (D'Antonio 2015): an appealing case-study because the accuracy required for this product is very high with a consequential very high unitary cost. The same authors elaborated a PLM-MES integration applied to automotive manufacturing (D'Antonio 2015) by focusing on how the real-time monitoring activity of the MES can improve the PLM. A survey submitted to a set of Italian companies to measure their digital maturity and their proneness in implementing further PLM and MES solutions and their integration was also presented (D'Antonio 2017). The main results of this work are the awareness that none of the companies own both a PLM and a MES and that the half of them stated that a PLM-MES collaboration could be an advantage for their business. Another research activity in the intersection is an extension of the ISA95 standard (ISA 95 2000) for manufacturing PLM integration with a data flow between ERP and MES (Moones 2015). The last article of the list describes the integration

between product management and system monitoring by using ontologies (Asmae 2006). The authors considered the ontology the most suitable tool to design the PLM-MES-ERP integration according a metric taken from the literature (Morel 1992).

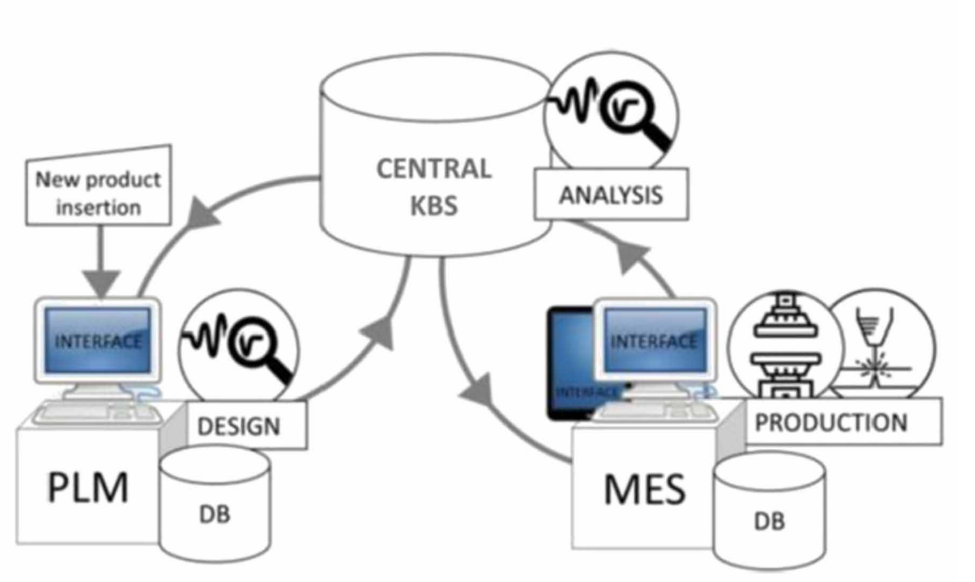
Our work addresses two gaps identified in the literature research. The first one is lack of an analysis related to highly customized and/or prototypal production, where the presence of many alternative routings and operations makes very difficult to manage all the manufacturing variables together, in an efficient way, without increasing wastes of time and costs. The second one is that there is not an explicit formalization of the structure designed for collecting data related to failures and anomalies occurring at the shop floor, and make them available for designers that can effortlessly learn past problems about designing new products and processes. Referring to this second aspect, our framework proposed the following main technical innovations with respect to previous works: (i) an open source architecture for PLM-MES integration trough a central Knowledge Based System (KBS), (ii) an advanced data model to relate data from PLM and MES, and (iii) the allowance of storing data related to anomalies occurred during the production.

In this work, the efforts are focused on the PLM and MES integration. The ERP was not considered, but we plan to integrate it in a following step. This choice was made because, after having analysed the literature, the integration between PLM and MES is the least investigated and standardized. However, the information structure presented in this work was designed to easily accommodate the information from the ERP adding and connecting new entities in the data model.

KNOWLEDGE-BASED FRAMEWORK

The proposed framework is a knowledge management system able to collect and store data both form process design and process execution. As shown in Figure 3, this framework is based on a central database, called Knowledge based System (KBS), containing the subset of data relevant for both PLM and MES and acting as a bridge between them. Even if a MES can store all the information regarding the monitoring of the production, in our opinion, it is important to mantain in a central system the information from both the MES and the PLM. For istance, without the KBS, it would not be possible for the company to retrieve, for a given product ordered by a customer, the previous similar products already produced, because the information about product dimension, product category, production cycles, raw material, etc. are ususlly not presented in the MES, but only in the PLM.

Figure 3. Framework for PLM and MES integration



Procedure for KBS Development

In order to implement a Knowledge-Based System, a set of preliminary steps have to be done. Here is described a draft checklist of such steps.

First of all, it is necessary to analyze the context in which the company operates and analyze all those factors, internal and external, that may impact business processes and performance. In literature, there are lot of examples of complete approach useful to assess the background in which a company operates, such as the PESTEL analysis (Political, Economic, Socio-cultural, Technological, Environmental and Legal factors), the CATWOE analysis (Customers, Actors, Transformation process, Weltanschauung or Worldview, Owner Environment) and the CAUSE analysis (Criteria, Alternatives, Stakeholders, Uncertainty, and Environment) (Belton 2010).

Through the context assessment, the company defines a clear picture of its objectives and possible risks and how they should be monitored. Those factors should be grouped in three clusters, depending on their hierarchy: strategical, tactical, and operational, following the classification of the Anthony's pyramid.

To implement all the information system aspects, it is possible to define three further steps. Starting from its knowledge of the context, the company must decide what functions it expects to obtain from the system: which key performance indexes are monitored, who can see them, and what improvement function they can have on the process. It is possible to define this phase Functional.

After the Functional Phase, it should be performed in the Technical Phase. This step defines how the chosen functions will be performed. What is the structure of the selected database, which tables will be interrogated, and how frequently. Knowing the frequency of requests and data updating rate in these preliminary stages is fundamental due to the third step.

The third step is the Technological Phase, during which the investments are made, the company should choose what kind of hardware and software is needed to achieve the goals. It is necessary to know the technologies on the market to have a solution as tailored as possible.

At the end of these phases, the company should have an information system based on knowledge, but nothing guarantees that this is in line with its objectives. It should be defined as a map of metrics to verify the system's effectiveness and efficiency; the verification creates a loop aiming to generate a continuous improvement process.

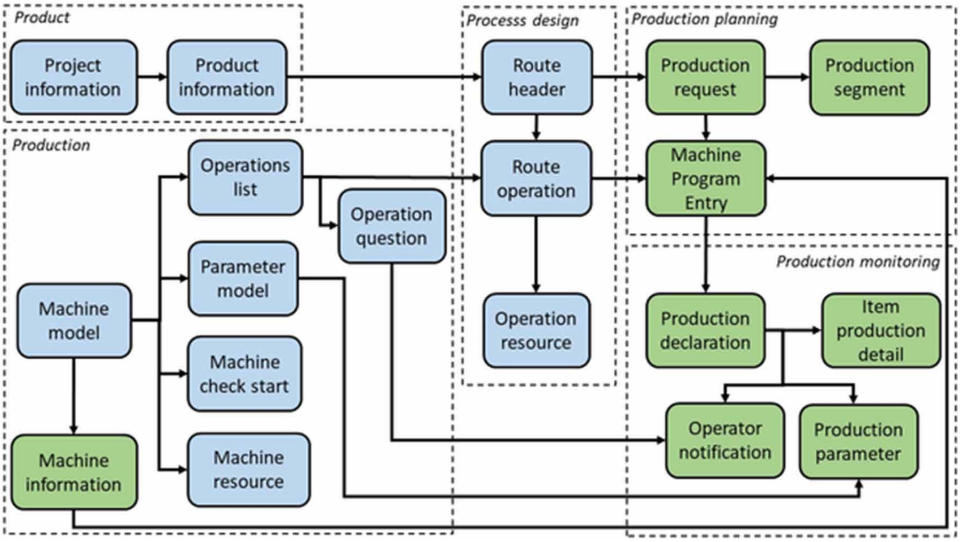
KBS Data Model and Information Flows for Manufacturing Companies

The data needed to develop a KBS belong to the following five categories:

1. product data, related to the products, including the information of customer orders;
2. production data, related to the resources and operations that can be executed by the company;
3. process design data, related to the design of the production cycles for each product;
4. production planning data, related to the assignment of the operations of production cycles to the resources in order to meet customers' requests;
5. production monitoring data, related to the monitoring of operations in real time, including the actual starting and finishing time of operations and the quality assessment on the produced parts.

For each category, several entities are needed to represent the data belonging to the category. Figure 4 shows the entities of the KBS through an entity-relationship-like model. For readability reason, only the foreign key relations are represented by the arrows. Blue entities represent data coming from the PLM system, while green entities contain data coming from the MES system. The detailed description of each entity is reported in the following.

Figure 4. KBS data model.



Product Data

In this category, two entities are present:

- *Project information*, which contain the data of an order coming from a customer, i.e., the code, name, etc. of the customer, the quantity, and the deadline for receiving the products;
- *Product information*, which contain the data of a product, i.e., the family classification, the raw material and the CAD files with the drawings.

Production Data

In this category, seven entities are present:

- *Machine model*, which represent the types of machines available in the plant (i.e., 3D laser cutting, press of 1000 tons)
- *Machine check start*, which collect the checks to be done before staring the execution of the operations on a machine (e.g., door closure check, cleaning check, correct positioning check).
- *Parameters model*, which represent the parameters to be set on a machine before executing an operation (e.g., press speed, power, spindle rotation), together with their allowed maximum and minimum values.

- *Machine information*, which represent the physical machines available in the plant, each of which belongs to a specific machine model.
- *Operation list*, which contains the list of operations that can be executed on each machine model.
- *Operation questions*, which list the questions to be asked to the operators after the execution of an operation, to check if the result is fine.
- *Resource information*, which contains data related to the other resources needed by a machine model to work correctly, (e.g., oil, rasp, nylon).

Process Design

In this category, three entities are present:

- *Route header*, which represent the production cycles associated to each product (for each product, several revisions of the production cycle can be stored). The production cycle is the list of ordered operations executed to produce a specific product.
- *Route operation*, which represent the operations used in each cycle.
- *Operation resource*, which represent the resources used in each operation, such as the dies for the pressing operations.

Production Planning

In this category, three entities are present:

- *Production request*, which reports for each production cycle, the earliest start time, the latest end time, the estimated duration, and the quantity of products to produce with that cycle
- *Production segment*, which reports for each operation of the production cycle, the assigned machine, the earliest start time, the latest end time, and the estimated duration.
- *Machine program entry*, which represent, for each machine, the schedule of operations, i.e., their panned start date and end date.

Production Monitoring

In this category, four entities are present:

- *Production declaration*, which represent the actual start date and end date of operations executed on the machines, together with the dated of the eventual

downtimes and the corresponding reasons; here, also the quantity of good and discarded parts is reported.
- *Production parameters*, which reports the values of the parameters set in each operation executed on each machine.
- *Item production details*, which reports for the discharged parts of an operation, the reason of the discard.
- *Operator notifications*, which reports the answers of the operations at the questions defined in the Operation questions, for the operations executed on each machine.

As reported in the diagram, almost all the entities of the first three categories (i.e., product, production and process design) contain data coming from the PLM, while all the entities of the remaining categories (i.e., production planning and production monitoring) contain data coming from the MES. The only exception is Machine information, because the list of actual machines available in the plant, even if it is an information known before starting the production planning, is an information usually stored in the MES system.

The data flow between PLM and KBS can be of two types: an occasional flow and a continuous one. The first flow refers to the information that is entered or updated in the PLM at irregular and distant time intervals, such as one year or more. For example, if the company decides to buy a new machine with different characteristics from those already present (e.g., a press with a maximum power higher than the other presses) or if a new type of manufacturing operation is needed in the plant, it is necessary to insert new entries in the corresponding entities of the PLM. The second flow, instead, is the one related to the insertion of new production cycles. This flow is continuous because each new customer order corresponds to one or more production cycles, thus data are generated in the order of hours. These data are not only transferred between PLM and KBS, but also between KBS and MES, where they are available to produce the production planning of the new cycles. In fact, as soon as a new production cycle is inserted in the KBS, the MES receive the new data and use it to update the production planning.

The data flow from MES and KBS contains all the information deriving from the production monitoring in real time. During the execution of the planned activities, operators can store the information regarding the starting and finishing date and time of each operation, the number of finished and discarded products, and any other comment or annotation they want to include as additional information. This is particularly useful, because in case of a failure, the manager can check the intermediate results reported for each operation and decide an alternative procedure to obtain a better result.

KBS Software Implementation

The open source PLM software ARAS (www.aras.com) was exploited to digitalize and store the information related to the product, production, and process design. Through an automatic procedure, the data related to the identified entities are periodically extracted from the PLM system and inserted in the KBS.

The commercial MES platform JPiano (https://www.aecsoluzioni.it/wp/en/jpiano-panoramica/jpiano-prodotti) was used to implement the MES system. Also, in this case, an automatic procedure allows the synchronization between MES and KBS.

The KBS was implemented as a PostgreSQL database (www.postgresql.org).

Node-RED is the open source application used to call REST API's, to process the data and push the data to KBS database. With Node-RED, the system gets the data via REST API 'GET' request, clean and structure the data accordingly to the KBS format and sends to the KBS database via 'POST'/'UPDATE' request. As REST API is a request/response based, the system performs several iterations based on time interval and compares the acquired data with the existing data in KBS database. If the data is new, then it will 'POST' the data into the KBS database or, if a value of specific property of an entity is changed, it will perform 'UPDATE' operation. In the same way, if new data available in the KBS, it performs 'POST'/'UPDATE' operation on the corresponding uri in the application database. In PLM, the process plan and the manufacturing operations have lifecycle states i.e., preliminary state, released state, in-change state, and obsolete state. These states define the data flow into KBS. If a user creates a new process plan with its corresponding operations, and the state is set as preliminary, the data are not transferred to KBS. In fact, the preliminary state means that the process plan is not fully designed or properly validated. If the state is promoted to released, then the data are synchronized in the KBS, thus allowing the MES to plan the production. The in-change state is used to do changes to an existing process plan that has been already released. When a process plan won't be used anymore to produce products, then its state is set to obsolete.

APPLICATION

The described framework was applied in an Italian company, which produces components for car prototypes. The main issue the company is trying to solve is that the information generated during the production process is not digitalized and it only persists in operators' memories.

Company Description

The use case company is a tier 2 supplier for worldwide known automotive manufacturers. The strength of the company relies in its ability of developing complex manufacturing processes in short time providing prototypes and pre-series products. According to this goal the company is a perfect example of the OKP approach to produce customized products based on requirements of individual customers.

Due to the production nature of the company, it is difficult to forecast the production trend, and there may be problems and mishaps that prevent the plant from having a linear production. Unlike series production, the production of prototypes is characterized by an extremely variable production rate, with high material waste.

Some of the problems faced by the company can be attributed to the separation between the design phase and the production execution phase. When the design of the dies is approved by the responsible person, his role is over, and the designer does not receive any feedback on possible problems caused by the dies during production. Furthermore, the shop floor operators do not receive the results of the simulation that should theoretically indicate which zones of the piece are the most critical.

This lack of bidirectional information flow impedes the process of continuous learning for both parties: the designer who, without receiving feedback on his work, cannot modify his work methodology or make the simulation more reliable. For the operators, the lack of information about the results of the simulation makes their job harder, since they do not know what the outcome of their work should be.

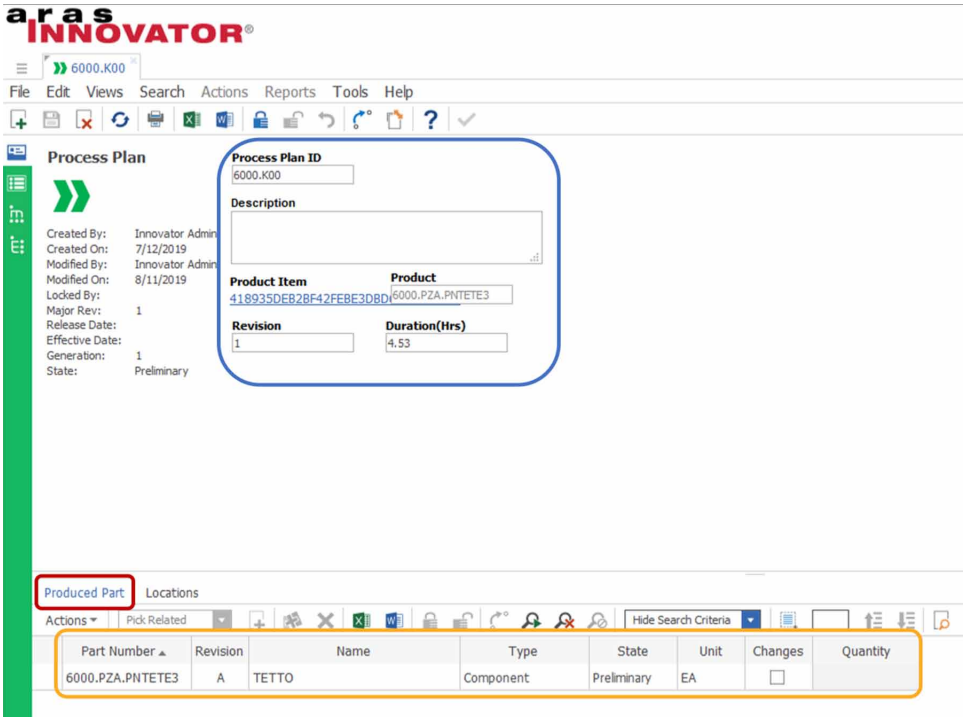
Another cause of problems is the absence of data collection during production. The only relevant data is the quantity of pieces produced at the end of the shift. No data is collected about the exact quantity of defectives or of material waste. No information is stored, about the main problems that the operators had to face during the shift: such information, if available, is found only in the minds of experienced operators, this lack of a structured knowledge management system results in production mishaps and delays when such key employees are absent and creates a dependency on specific personnel which is not efficient for a production plant.

Framework Application

The developed framework was firstly initialized to represent the company features, and then used to store data regarding production cycles.

The following screenshots show an example on how to insert the data related to the process design into ARAS. In this example, as reported in Figure 5, the product is identified by the code 6000, and we are defining the first production cycle associated to the product, thus the code of the production cycle is 6000.K00. Also, the estimated duration of the production cycle is required: in this case it is 4.53 hours.

Figure 5. Creation of a new process plan in ARAS.



After the creation of the process plan, the ordered list of activities to be executed

Figure 6. Creation of a new activity in a process plan in ARAS.

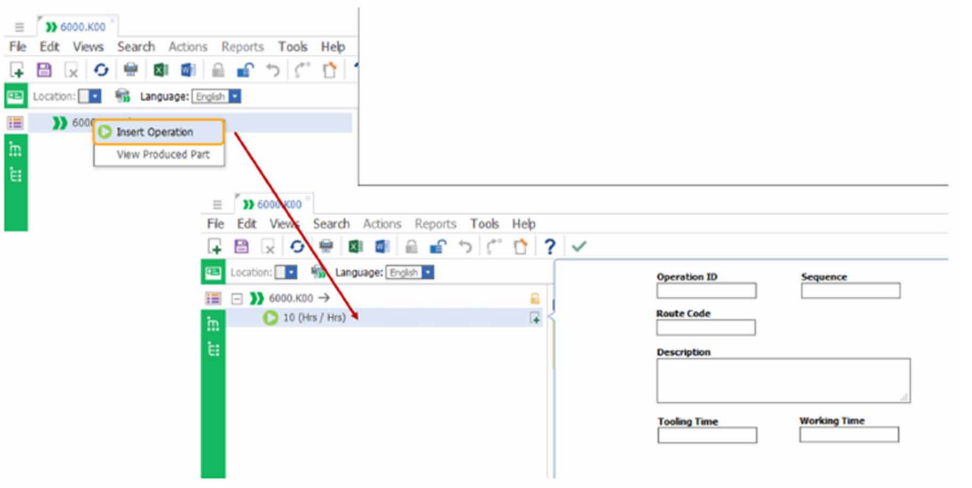
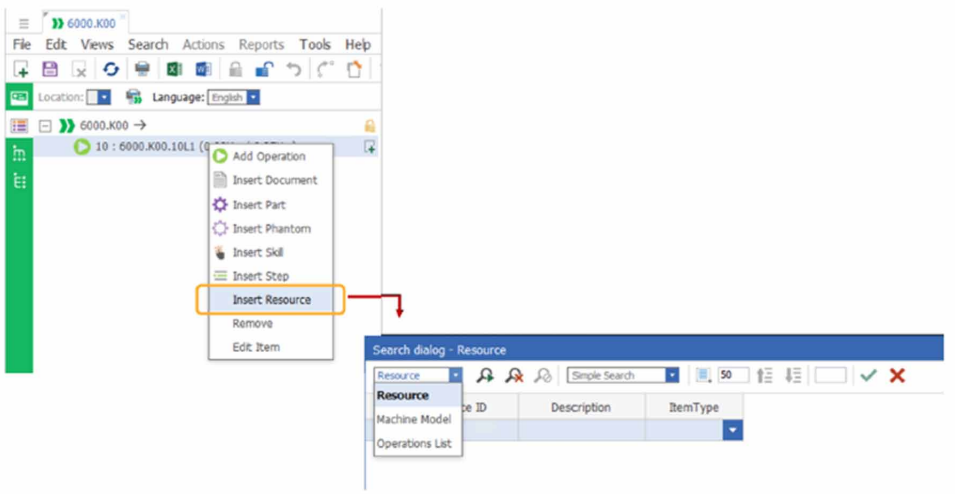


Figure 7. Insertion of the machine model, the operation type and the resources associated to an activity in ARAS.



in the production cycle has to be inserted. Figure 6 shows the insertion of the first activity and its attribute (i.e., setup time and working time), while Figure 7 shows the insertion of the machine model, the operation type and the resources associated

Figure 8. Example of a process plan composed by three activities in ARAS.

ProcessPlan : 6000.K00 -

Operation 10 : 6000.K00.10L1

Setup time: 0.08Hrs, Cycle time: 0.27Hrs

Resource Number	Name	Type
10L1	Taglio laser 2D "PLATINO"	Operations List
FTL2	Taglio laser 2D	Machine Model

Operation 20 : 6000.K00.20I1

Setup time: 1Hrs, Cycle time: 0.16Hrs

Resource Number	Name	Type
20I1	Imbutitura con 1600 ton	Operations List
FPI1	Pressa idraulica 1600t	Machine Model

Operation 30 : 6000.K00.30S1

Setup time: 0.08Hrs, Cycle time: 0.27Hrs

Resource Number	Name	Type
30S1	Taglio laser sgrossatura	Operations List
FTL3	Taglio laser 3D	Machine Model

to the first activity. Finally, Figure 8 shows an example of a final process plan composed by three activities.

FUTURE RESEARCH DIRECTIONS

The main future work that is expected is to use the data in the KBS to obtain insights that can help the company in the optimization of processes: analysis of work cycles, costs, maintenance, and all activities linked to the manufacturing. This KBS enable an artificial intelligence tool with the goal of automatizing the process design phase: Although this is a task of high complexity, an open research point is to investigate the feasibility of creating a Decision Support System that can simplify the role of designers, minimizing the number of test production cycles needed to find the optimal one.

In a context of small and medium enterprises, it is interesting investigate new on the available software and open source solutions. This would make possible a classification of optimal approaches applied to possible uses, trying to answer the question "what is the best solution for a company operating in a particular industry with certain characteristics?"

A future improvement of this work could be the integration of the MES-PLM system with the company Enterprise Resource Planning (ERP), a deep analysis on which data must be provided to different ERP modules must be conducted. We believe it is possible to introduce a new integration paradigm, an *outright enterprise system integration* (OESI), which represents a system integration between different functional units, the ERP modules, with the MES which has detailed data of production system and throughout the lifecycle of the products thanks to the PLM, from the product design, to its disposal.

A final improvement concerns the investigation about the scalability of the concept. From an industrial point of view, it is fundamentally important to understand which types of manufacture and which sizes make an investment aimed at complete information integration profitable.

CONCLUSION

The integration of MES and PLM through the definition of a common Knowledge Base System can significantly improve automation and communication within the intelligence factory. The proposed framework is particularly simple to implement, and it could be very useful for all those enterprises that, despite the small-medium dimension, manage a great number of orders with frequent requests of redesign and

reengineering. The formalization of a general method of integrating information systems is still too dependent on the types of production: it is enough to think about the enormous difference between additive manufacturing processes and classic subtraction processes, for example. However, the interest in promoting and spreading the philosophy and methodologies to obtain with integrating, managing, and processing the greatest possible percentage of data in the company's possession, is something alive in the scientific manufacturing world. This ability remains a fixed point in the objectives of companies that want to maintain international competitiveness trough the automation, the innovation and the cost saving.

As future work, it will be interesting to perform an evaluation of the proposed framework by computing some key performance indicators of interest for the company. Sine we are still in the prototypal stage of the development, we don't have results yet. Furthermore, the current system is also missing the ability to extract and interpret the information collected, creating a dynamic tool that makes the decision-making processes easier and more effective for those who manage the company, conferring the ability to fully exploit digitization benefits. Thus, we are studying the development of a dashboard tool to visualize relevant information to drive company decision-making.

ACKNOWLEDGMENT

This research was supported by the project "Hierarchical Open Manufacturing Europe" (HOME, 2018-2020), funded by the Piedmont Region as part of the POR-FESR 2014/2020 Regional Operational Program, under the "Intelligent Factory" technological platform.

REFERENCES

Asmae, A., Southail, S., El Moukhtar, Z., & Hussein, B. (2006). *Using ontologies for the integration of information systems dedicated to product (CFAO, PLM…) and those of systems monitoring (ERP, MES)*. IEEE.

Bartodziej, C. J. (2017). The concept industry 4.0. In *The concept industry 4.0* (pp. 27–50). Springer Gabler. doi:10.1007/978-3-658-16502-4_3

Belton, V., & Stewart, T. (2010). Problem structuring and multiple criteria decision analysis. In *Trends in multiple criteria decision analysis* (pp. 209–239). Springer. doi:10.1007/978-1-4419-5904-1_8

Ben Khedher, A., Henry, S., & Bouras, A. (2011). Integration between MES and Product Lifecycle Management. *IEEE International Conference on Emerging Technologies and Factory Automation (ETFA'11)*, Toulouse, France. 10.1109/ETFA.2011.6058993

Borgo, S., & Leitão, P. (2007). Foundations for a core ontology of manufacturing. *IntegratedSeries in Information Systems*, *14*(1), 751–775. doi:10.1007/978-0-387-37022-4_27

Bruno, G. (2015). Measuring product semantic similarity by exploiting a manufacturing process ontology. *International Conference on Industrial Engineering and Systems Management (IESM'15)*, 1251-1257. 10.1109/IESM.2015.7380313

Bruno, G., Antonelli, D., Korf, R., Lentes, J., & Zimmermann, N. (2014, September). Exploitation of a semantic platform to store and reuse PLM knowledge. In *IFIP International Conference on Advances in Production Management Systems* (pp. 59-66). Springer. 10.1007/978-3-662-44739-0_8

Bruno, G., Korf, R., Lentes, J., & Zimmermann, N. (2016). Efficient management of product lifecycle information through a semantic platform. *International Journal of Product Lifecycle Management*, *9*(1), 45–64. doi:10.1504/IJPLM.2016.078864

Bruno, G., Taurino, T., & Villa, A. (2018). An approach to support SMEs in manufacturing knowledge organization. *Journal of Intelligent Manufacturing*, *29*(6), 1379–1392. doi:10.100710845-015-1186-6

Bruno, G., Traini, E., & Lombardi, F. (2019). A Knowledge-Based System for Collecting and Integrating Production Information. *20th IFIP Working Conference on Virtual Enterprises, PRO-VE 2019*, Turin, Italy. 10.1007/978-3-030-28464-0_15

Chungoora, N., Young, R. I., Gunendran, G., Palmer, C., Usman, Z., Anjum, N. A., Cutting-Decelle, A.-F., Harding, J. A., & Case, K. (2013). A model-driven ontology approach for manufacturing system interoperability and knowledge sharing. *Computers in Industry*, *64*(4), 392–401. doi:10.1016/j.compind.2013.01.003

D'Antonio, G. (2016). *Manufacturing Execution Systems for lean, adaptive production processes* (Doctoral dissertation). DIGEP, Politecnico di Torino, Torino.

D'Antonio, G., & Bedolla, J. (2015). PLM-MES Integration: A Case Study in Automotive Manufacturing. *12th IFIP International Conference on Product Lifecyle Management (PLM)*, Doha, Qatar.

D'Antonio, G., Macheda, Li., Bedolla, J. S., & Chiabert, P. (2017). *PLM-MES Integration to Support Industry 4.0*. Springer International Publishing. doi:10.1007/978-3-319-72905-3_12

D'Antonio, G., Sauza, B. J., Chiabert, P., & Lombardi, F. (2015). PLM-MES integration to support collaborative design. *International Conference on Engineering Design*, Milan, Italy

Dean, P. R., Tu, Y. L., & Xue, D. (2009). An information system for one-of-a-kind production. *International Journal of Production Research*, *47*(4), 1071–1087. doi:10.1080/00207540701543593

ISA-95. (2000). *Enterprise Control System Integration*. www.isa-95.com/

Joshi, S. (2009). ERP-MES-PLM integration-making information technology strategy compliment business strategy. *IADIS International Conference on Information System, IS 2009*, Barcelona, Spain.

MESA International. (1997). *MES functionalities & MRP to MES data flow possibilities*. Technical report.

Ming, X. G., Yan, J. Q., Lu, W. F., Ma, D. Z., & Song, B. (2007). Mass production of tooling product families via modular feature-based design to manufacturing collaboration in PLM. *Journal of Intelligent Manufacturing*, *18*(1), 185–195.

Moones, E., Kermad, L., Vosgien, T., & El Mouloudi, D. (2015). *PLM Standards Modelling for Enterprise interoperability: A Manufacturing Case Stady for ERP and MES Systems Integration Base on ISA-19*. Enterprise Interoperability 6th International IFIP Working Conference, IWEI 2015, Nîmes, France.

Morel, G. (1992). *Contribution de l'automatisation et à l'ingénierie des systèmes intégrés de production*. Habilitation à Diriger des Recherches de l'Université Henri Poincaré.

Muffatto, M., & Roveda, M. (2000). Developing product platforms: Analysis of the development process. *Technovation*, *20*(11), 617–630.

Pouchard, L., Ivezic, N., & Schlenoff, C. (2000, March). Ontology engineering for distributed collaboration in manufacturing. In *Proceedings of the AIS2000 Conference* (pp. 1012-7). Academic Press.

Saenz de Ugarte, B., Artiba, A., & Pellerin, R. (2009). Manufacturing execution system–a literature review. *Production Planning and Control*, *20*(6), 525–539.

Soga, S., Hiroshigo, Y., Dobashi, A., Okumura, M., & Kusuzaki, T. (1999). Product lifecycle management using radio frequency identification technology. *Emerging Technologies and Factory Automation. ETFA '99, 7th IEEE International Conference on, 2*, 18-21.

Stark, J. (2015). Product Lifecycle Management – Volume 1: 21st Century Paradigm for Product Realisation. Academic Press.

Tu, Y. (1997). Production planning and control in a virtual one-of-a-kind production company. *Computers in Industry*, *34*(3), 271–283.

Vaidya, S., Ambad, P., & Bhosle, S. (2018). Industry 4.0–a glimpse. *Procedia Manufacturing*, *20*, 233–238.

Verschoor, A. H., & Reijnders, L. (1999). The use of life cycle methods by seven major companies. *Journal of Cleaner Production*, *7*, 375–382.

Wortmann, J. C., Muntslag, D. R., & Timmermans, P. J. (1997). Why customer driven manufacturing. In *Customer-driven Manufacturing* (pp. 33–44). Springer.

ADDITIONAL READING

Alemanni, M., Grimaldi, A., Tornincasa, S., & Vezzetti, E. (2008). Key performance indicators for PLM benefits evaluation: The AlcatelAlenia Space case study. *Computers in Industry*, *59*(8), 833–841. doi:10.1016/j.compind.2008.06.003

Boucher, T., & Yalcin, A. (2010). *Design of industrial information systems*. Elsevier.

Efthymiou, K., Sipsas, K., Mourtzis, D., & Chryssolouris, G. (2015). On knowledge reuse for manufacturing systems design and planning: A semantic technology approach. *CIRP Journal of Manufacturing Science and Technology*, *8*, 1–11. doi:10.1016/j.cirpj.2014.10.006

Elgammal, A., Papazoglou, M., Krämer, B., & Constantinescu, C. (2017). Design for customization: A new paradigm for product-service system development. *Procedia CIRP*, *64*(1), 345–350. doi:10.1016/j.procir.2017.03.132

Fenves, S. J., Foufou, S., Bock, C. E., Bouillon, N., & Sriram, R. D. (2004). *Cpm2: A revised core product model for representing design information, Internal report nistir no.7185, National Institute od Standards and technology*. NIST.

GolA, A. (2019). Reliability analysis of reconfigurable manufacturing system structures using computer simulation methods. Eksploatacja i Niezawodność, 21(1).

Grieves, M. (2005). *Product Lifecycle Management: Driving the Next Generation of Lean Thinking: Driving the Next Generation of Lean Thinking: Driving the Next Generation of Lean Thinking*. McGraw Hill Professional.

Igba, J., Alemzadeh, K., Gibbons, P. M., & Henningsen, K. (2015). A framework for optimising product performance through feedback and reuse of in-service experience. *Robotics and Computer-integrated Manufacturing*, *36*, 2–12. doi:10.1016/j.rcim.2014.12.004

Jin, J., Fox, M. S., & Bilgic, T. (1996). A requirement ontology for engineering design. *Concurrent Engineering, Research and Applications*, *4*(4), 279–291. doi:10.1177/1063293X9600400307

Kletti, J. (Ed.). (2007). *Manufacturing execution system-MES*. Springer Science & Business Media. doi:10.1007/978-3-540-49744-8

Koren, Y., Gu, X., & Guo, W. (2018). Reconfigurable manufacturing systems: Principles, design, and future trends. *Frontiers of Mechanical Engineering*, *13*(2), 121–136. doi:10.100711465-018-0483-0

Moutarlier, P., Geneste, L., & Grabot, B. (2000). Tapas: A modular framework to support reuse in scheduling software development. *Production Planning and Control*, *11*(7), 648–659. doi:10.1080/095372800432115

Petrucciani, M., Marangi, L., Agosta, M., & Stevanella, M. (2019). A platform for product-service design and manufacturing intelligence. In *Models, Methods and Tools for Product Service Design* (pp. 45–61). Springer. doi:10.1007/978-3-319-95849-1_4

Saaksvuori, A., & Immonen, A. (2008). *Product lifecycle management*. Springer Science & Business Media. doi:10.1007/978-3-540-78172-1

Stark, J. (2011). Product lifecycle management. In *Product Lifecycle Management* (pp. 1–16). Springer.

Tomovic, C. L., Ncube, L. B., Walton, A., & Grieves, M. (2010). Development of product lifecycle management metrics: Measuring the impact of PLM. *International Journal of Manufacturing Technology and Management*, *19*(3-4), 167–179. doi:10.1504/IJMTM.2010.031366

Tu, Y., & Dean, P. (2011). *One-of-a-kind Production*. Springer Science & Business Media. doi:10.1007/978-1-84996-531-6

Wang, G. X., Huang, S. H., Yan, Y., & Du, J. J. (2017). Reconfiguration schemes evaluation based on preference ranking of key characteristics of reconfigurable manufacturing systems. *International Journal of Advanced Manufacturing Technology*, *89*(5-8), 2231–2249. doi:10.100700170-016-9243-7

KEY TERMS AND DEFINITIONS

ERP (Enterprise Resource Planning): It is a high-level software for business management, it consists of two basic elements: a database, and a set of application modules. The modules are generally identifiable with the individual business functions that the software manages.

KBS (Knowledge-Based System): It is a central database acting as integrator of the ERP, PLM and MES. The KBS allows to collect information regarding the production process a structured way, and it allow to reuse the knowledge.

MES (Manufacturing Execution System): It is a job shop level software which allows the control and management of the production providing almost real time feedback of the entire process. The MES, thanks to the data obtained by sensors installed along process, could create a digital copy of the plant in real time.

OESI (Outright Enterprise System Integration): It is a new system integration paradigm, the enterprise, manages to access information and data on the product along its lifecycle and integrate it with data coming from various Business Units (ERP) and the production plant (MES).

OKP (One-of-a-Kind Production): It is a new manufacturing paradigm which manage to achieve economies of scale with very different products to such an extent that each customer could have his customized personal product. It uses flexible manufacturing system (FMS), reconfigurable manufacturing systems (RMS) and mass customization principles

PLM (Product Lifecycle Management): PLM is a strategic approach to managing information, processes and resources to support the lifecycle of products and services, from conception, development, market launch and recall. PLM is not only an IT platform, but rather an integrated approach, based on a set of technologies, collaborative work organization methodologies and process definition.

Chapter 4
Demand Forecasting Models With Time Series and Random Forest

Halit Alper Tayali
https://orcid.org/0000-0002-2098-6482
Istanbul University, Turkey

ABSTRACT

This chapter presents the recent methodological developments in demand management and demand forecasting subjects of the operations management. The background section provides detailed information on the domain of production management, operational analytics, and demand forecasting while providing introductory information on time series forecasting and related machine learning methodologies. The novel contribution of the chapter is the exploration developed in the solutions and recommendations section while examining the effect of stationarity in the time series forecasting methodologies of machine learning with improved benchmark results.

INTRODUCTION

The contemporary business organization, or a company, is based on three core functions, namely marketing, operations, and finance. The discipline of operations management, which serves as the major function of both service and manufacturing organizations, aims to organize the activities related to producing goods and services. The scientific literature on the operations management focuses on transforming inputs to outputs for to economically sustain the companies, while making decisions based on available and limited resources. Therefore, a key issue in operations

DOI: 10.4018/978-1-7998-5879-9.ch004

management is to augment the decision processes while sustaining a business certainly requires good decisions. Heizer, Render, & Munson (2017) address the strategic decisions that operations managers make in relation to design of goods and services, managing quality, strategies of process, location, layout, human resources, supply-chain, inventory, scheduling and maintenance. These operational decisions typically include processes of quantitative modelling, calculation, forecasting and prediction to enhance profitability, and service to society.

The chaotic and global business dynamics change at an even more accelerating speed as new technologies persist to evolve, and companies are one of the central figures in the 4th Industrial Revolution for the significant impacts of digitization immediately unfold here. The wide scope of the Industry 4.0 includes concepts such as automation, internet of things, and knowledge-based, decision support or embedded systems. The automation efforts in the Industry 4.0 include methodologies of artificial intelligence and one of its major interdisciplinary subfields, machine learning. Artificial intelligence is seen as the governor of the Industry 4.0. Although the humans are the scriptwriters, machines can now write their own automated scripts as well. One can easily argue that the student becomes the master. However, according to a computer scientist, a computer just performs calculations and remembers the results (Guttag, 2013). Therefore, assigning subjective attributes and prediction tasks to artificial intelligence might be a little bit of overshooting for the distinction between the scope of the objectivity of the machine, and that of the subjectivity of the human remains a mystery. In fact, this is quite like asking whether the theory of mathematics is an invention or a discovery. Another challenging question is based on the definition of forecasting, the art and science of future event prediction (Heizer et al., 2017); but, is what the machines do really art *or* science? If the answer is yes, then art or science might also have to include the term machine within their linguistic definitions.

The humans make predictions about the future all the time -even at when we are unaware of this phenomenon. The ability to create scenarios and thinking ahead is one of the distinguishing attributes of the humankind and perhaps the biggest reason that the society is evolving towards an automated future. There is very little doubt that the issue of prediction accuracy might have been easily resolved as the physiological nature of the prediction phenomenon gets solved. Humans use their prediction and forecasting abilities in the organizations that they form. Tetlock & Gardner (2015) explain the super forecasting and prediction abilities of humans. However, the concept of forecasting is often confused with that of the prediction and Everett & Ebert (1986) clearly separate these two concepts: Forecasting requires quantitative modelling, yet prediction requires skill, experience, and judgement on top of that. However, although forecasting casts past data, which have been combined in a predetermined way, systematically forward, and prediction uses subjective

considerations that does not need a predetermined combination, both prediction and forecasting are processes of estimation. Krajewski, Malhotra, & Ritzman, (2016) define forecast as a future event prediction for the purpose of planning.

This chapter presents the recent methodological developments in demand management and demand forecasting subjects of the operations management using statistical time series modelling with methodologies from machine learning. The structure of the chapter is as follows: The background section provides detailed information on the domain of production management, operational analytics, and demand forecasting. This section also provides introductory information on time series forecasting and related machine learning methodologies with a brief literature review of applications of these methods on demand forecasting. The novel contribution of this chapter to the related scientific literature is the exploration developed in the solutions and recommendations section while examining the effect of stationarity in the time series forecasting methodologies of machine learning with improved benchmark results. To the author's knowledge there is no study in the literature that examines the performance effect of presence of stationarity in machine learning time series forecasting of demand management and shows the improvement with an implementation of a non-stationary time series into the features of the dataset using a random forest algorithm for forecasting sales demand. The chapter comes to an end with emerging trends for future research directions and a further discussion of the overall coverage of the chapter with concluding remarks.

BACKGROUND

This chapter examines the subject of demand forecasting with an econometric perspective using time series modelling and related machine learning methodologies. The first part in the background section provides information related to operational analytics and demand forecasting, whereas the second part examines studies on time series modelling for forecasting demand, and the last part introduces the literature review for the demand forecasting using time series and machine learning methodologies.

Production Management and Operational Analytics

The significance of the operations' function of a company is quite distinguishable from those of marketing and finance with regards to its contribution to profitability and sustainability. Heizer, Render, & Munson (2017) explain this through a striking example where a company has three options to evaluate the contribution of each strategic function of the company to the net profit: Increasing sales revenue by

50%, reducing financial costs by 50% or reducing production costs only by 20%. The calculations of a profit-and-loss statement shows that the minor reduction in production costs might provide the greatest contribution when compared with the other options related to increase in sales or decrease in financial costs.

The production environment is full of operations, in other words, the transformations of abstract thinking or physical substances into services or goods. Therefore, the reduction in related operational costs needs to be achieved through an analysis of these operations. This analysis usually requires mathematically modelling the production processes, yet these models need not be highly complex for innovativeness. For instance Tetlock & Gardner (2015) points out that "*not using math is even a point of pride for the math professor*". However, this does not mean that a person that works within a production environment does not need to spare time on careful thought, nuanced judgment, and a broad perspective on modelling operations, whether it be deterministic optimization or stochastic forecasting. Even though an operation's scope is limited to an activity on the product or service, the accumulation of all operations effect the company immensely. The operations function within a company can be examined in three temporal categories of long-term, intermediate-term and short-term where each category includes strategical, tactical, and operational planning and control decisions (Nahmias & Olsen, 2015). Examples of long-term strategic decisions are selection of facility location and decoupling points to position inventory, whereas intermediate tactical and short-term operational decisions are generally related to capacity planning and production scheduling (Jacobs & Chase, 2018).

The intertwined disciplines of operations management, operations research and business analytics present various opportunities for companies to improve themselves. Fuller & Martinec (2005) explain that operations management and operations research differ since operations management is oriented towards management and the related design, creation, technology, production, development, procurement, delivery or coordination activities of the products or services, whereas operations research is mathematically oriented for modelling a problem and trying to find an optimal solution for it (Omor, 2020). Kandiller (2007) defines operations research as "*the application of scientific models, especially mathematical and statistical ones, to decision making problems*". The operations management literature, on the other hand, is in relation to the operational activities of companies for sustainability and profitability through decision-making based on available and limited resources.

Business analytics, as a subdiscipline of the management science, studies data to understand the business performance and provide different kinds of support for the functions of the company in strategical or tactical development. Business analytics incorporates the use of technology, skills, and applications to get value from data by quantitative modelling, like operations research applying mathematical and

statistical models to decision-making problems to obtain an optimal -or a nearly optimal- solution. Albright & Winston (2017), for instance, use "*quantitative modelling to help companies make better decisions and improve performance*" in their book of business analytics. Business analytics includes thorough analysis of the events, whereas business intelligence, another commonly referred term, takes a snapshot of the current situation.

A widely used classification for business analytics is made according to the type of analytics used in relation to the complexity of the analytics and its contribution to the company, namely, descriptive, predictive and prescriptive types of analytics, with their order of increasing complexity and the added-value contribution of the type of analytics to the company. A survey ('Global Data and Analytics Survey', 2016) with 2,100 business executives of 15 industries from different countries indicate that 56% of business executives use descriptive approaches, whereas 29% use predictive analytics, and 13% use systems, tools or methodologies of the prescriptive analytics.

The business analytic approaches can also be used in conjunction with any of the analytics of the business function as well. Nguyen, Zhou, Spiegler, Ieromonachou, & Lin (2018) provide a comprehensive literature review for the use of analytics in supply chain management where the authors propose a classification for the scope of business analytical framework of the various operational activities such as manufacturing, procurement, and demand management. Furthermore, business analytics can be classified according to the functions of the company, such as operational analytics or financial analytics and the impact that the use of operational analytics creates is underlined in various sectoral reports. Thieullent, Colas, Buvat, Kvj, & Bisht (2016) emphasize the importance of operational analytics that allows for a diverse set of improvements such as accurate forecasting capability and reduced downtime and report numerous examples from various industries of steel manufacturing, railway, automotive, semiconductor, healthcare, mining, and electricity that use operational analytics to improve their operating effectiveness.

Finding ways to strengthen the link between the company's supply and the client's demand leads to significant improvement in company performance. Zhao & Huchzermeier (2015) define the operations function of the company as the backbone of financial performance, and the finance function as the supporter of real investment in operations. The authors also emphasize that the operations management aims to match the supply with demand. In other words, the key for robust operations management is to effectively match supply with demand (Cachon & Terwiesch, 2012). The scope of this chapter is limited to forecasting production demand and the next section reviews the recent scientific literature of demand forecasting in relation to the production and operations management.

Demand Forecasting

The emerging field of data science enjoys a wide application area in business analytics as managing the demand requires extensive quantitative work since there might always be a great variability in demand due to a wide range of reasons, predictable or not. Nguyen et al., (2018) review the issues of demand management in the production literature and defines three classes for managing demand; demand forecasting, demand sensing and demand shaping, and the article positions demand forecasting and detecting sourcing risks within the predictive analytics class of business analytics. The authors also emphasize that although forecasting is within the scope of prescriptive analytics, there are limited works on demand forecasting with respect to prescriptive analytics.

The concept of forecasting and the discipline of econometrics are very commonly combined. Economists and econometricians frequently use prediction and forecasting techniques for to grasp a sense of the future of economic indicators such as inflation and unemployment rates, manufacturing capacity utilization or producer price index. Forecasting is not only an indispensable part of economics, econometrics or business analytics, but it is also used widely across many scientific areas of health, engineering, meteorology, finance, traffic, telecommunication, and pattern recognition (Alpaydın, 2016; Bontempi, Ben Taieb, & Le Borgne, 2013; Shumway & Stoffer, 2017).

Demand forecasts are made for to project the company's amount of sales for each period in the planning horizon. With the ever-increasing rate of chaos in the current state of the global economy, it is challenging for a company to be able to sustain its operational advantage with better prediction and forecasts. However, many functions of the company require quantitative modelling and estimation processes that uses historical data. In production and operations function of a company, quality control, inventory planning, facility layout, sequencing, and demand management are just a few areas of study that apply forecasting and other business analytics approaches for managerial decision-making. Demand forecasting can also be used in planning capacity requirements of an organization (Krajewski et al., 2016). Nahmias & Olsen (2015) point out that forecasting demand is closely related to inventory management and all phases of production planning, scheduling, and sales and operations planning start with demand forecasts.

Organizations use economic, technological and demand forecasts for production and operations planning as well as other functions of the company. For instance, the function of human resources also uses forecasting, with regards to the requirements of hiring, training and laying off of workers in the company (Heizer et al., 2017). There are many applications of forecasting in the finance literature (Brealey, Myers, & Marcus, 2017; Tsay, 2010, 2013, 2014) as well as in the finance function of the

company, such as budget planning, portfolio optimization, cash flow optimization (Anderson et al., 2016).

There are many methodologies in the scientific literature for forecasting demand to serve for the needs of the companies. Heizer et al., (2017) classify forecasts according to their future time horizons, as short-range, medium-range and long-range forecasts while providing a seven-step procedure as a guide to forecasting demand. These steps are determining the forecast use, selecting items to be forecasted, determining forecast horizon, selecting the forecast model, collecting data, making forecast, and finally the validation and implementation of the forecasting results. The authors outline two forecasting approaches as quantitative forecasts which use mathematical modelling, and qualitative forecasts that makes use of the intuition, emotion, experience, the value system, and the judgements of the decision makers.

Jacobs & Chase (2018) classify the demand forecasting used in production and operations management into two categories of strategic and tactical forecasts. Strategic forecasts include medium and long-term forecasts made for strategy and aggregate demand related decisions, whereas tactical forecasts are concerned with meeting routine and relatively short-term demand. An example of a strategic forecast is provided in Chopra & Meindl (2016) within the scope of aggregate production planning model where long-term demand for a rolling horizon of 6 months is the input of the linear programming problem. The problem is also analysed for the optimal solution under varying demand forecasts. Cachon & Terwiesch (2012) provide detailed information on developing a demand forecast using normal distribution while emphasizing the fact that point estimates might not suffice as variability exists in the nature of uncertain demand forecasting and thus a distribution function is necessary to construct a demand forecast. The authors also emphasize the importance of data collection for reducing uncertainty via the implementation of a useful demand forecast while providing detailed information on revenue management and supply chain coordination as important application areas of demand forecasting.

Krajewski et al. (2016) states that forecasting methodologies are diverse and there is no single proper model to use in all situations while broadly classifying forecasting techniques to three types of methods, as judgement methods, quantitative methods and methods derived from a combination of the two types of methods. The authors indicate that forecasting techniques based on mathematical modelling use past data whereas qualitative methods include subjective considerations, experience, or judgments, as attributed to the concept of prediction in the Introduction section.

Referring to variability in forecasts as the temporal scale of the planning horizon changes, Nahmias & Olsen, (2015) underline the importance of stable forecasts produced by an automated demand forecasting method. The authors point out the key characteristics of forecasts by mentioning the fact that almost all forecast models are false, as every quantitative modelling effort of the reality, nearly all the

time. This natural discrepancy is measured by the error of forecasting. The authors classify the forecasting methods as subjective and objective forecasting methods.

Apart from the qualitative approaches, or predictions that include subjective opinions of the predictors, this chapter deals with the quantitative approaches used in demand forecasting. There are many quantitative approaches and methods to demand forecasting in the related literature such as naïve approach, simple and weighted moving averages, exponential and adaptive smoothing, trend projection, linear regression, additive and multiplicative seasonal, Holt's method, models of time series, Box-Jenkins models, vector autoregression, Kalman and Wiener filters, cointegration, game theory and Monte Carlo simulation. Furthermore, there are a variety of error measures such as cumulative sum of forecast errors, mean squared error, standard deviation of the errors, mean absolute deviation, and mean absolute percent error, that measure the difference between the actual and the forecasted demands, along with various information criteria, such as Bayes, Schwarz or Akaike for the selection of a proper demand forecasting model (Chase, 2016; Chopra & Meindl, 2016; Heizer et al., 2017; Jacobs & Chase, 2018; Krajewski et al., 2016; Nahmias & Olsen, 2015). Chase (2016) writes on demand-driven companies and provides detailed information on demand sensing and shaping while reporting that the most preferred statistical tool used in demand forecasting is Excel spreadsheets, and the model is moving averages. This chapter aims to equip the readers with recent developments on demand forecasting that includes a set of methodologies related to time series forecasting with machine learning models. Therefore, the next section presents information on machine learning models and time series forecasting available for demand forecasting subject of the production and operations management.

Time Series Forecasting with Machine Learning

The use of statistical models based on time series forecasting in demand management is a widespread practice both in the industry by the practitioners, and in the academic field by the scholars. The domain of time series is applicable to any field of science and the volume of the studies on time series is immense. The beginners of the subject might refer to the online textbook by Hyndman & Athanasopoulos (2018) that use R computer programming language and many applications of demand forecasting throughout the book.

In their classical textbook on econometrics Stock & Watson (2015) classify data sources and types and include a versatile set of time series models for demand forecasting. The readers can refer to the definitions of, and the distinctions in between the types of experimental, observational, cross-sectional, time series, and panel data that are frequently used in time series forecasting. Time series, a common data format in business analytics, is an historical measurement sequence, collected for a

single observable or measurable variable or an entity -such as, a person, company, or an economic actor- at multiple and equal time intervals. A purpose of studying time series is to be able to forecast the future planning horizon using this historical time series data (Bontempi et al., 2013). Another one is about examining dynamic casual effects (Stock & Watson, 2015).

The concept of stationarity is a feature of a stochastic process of a time series. In vague terms, stationarity refers to the assumption that what happens in the past is likely to persist in the future, and that the time series do not vary depending on the time. A time series might include a stochastic trend component that would jeopardize the requirement of the first two statistical moments of mean and variance of a series. These statistical moments are required to be time invariant. Unit root tests, such as the augmented Dickey-Fuller (ADF) test, are carried to decide whether the time series is stationary or not. The relevant analysis should be continued depending on that result. More detailed and theoretical information on the concepts and characteristics of univariate and multivariate time series analysis, unit root hypothesis, and detecting the order of integration can be found at Hyndman & Athanasopoulos, (2018); Pfaff (2008); Stock & Watson (2015); and Tsay (2014).

Machine learning is an interdisciplinary study field that uses data and mathematical modelling to increase the decision-making performance of machines, and thus, their users. This field of computer science, which uses data to teach a system a set of procedures to perform better, increases the cooperation between human and machine, thus helps the endeavour in understanding the chaotic nature, and provides more preciseness in decision processes, compared to a process that involves human bias. Both the developments in the scientific literature and contemporary generation of companies are towards the use of real-time data to incorporate machine learning algorithms for various applications of Industry 4.0. Mackenzie (2015) discusses implications of machine learning in the society while providing historical information on the development of data mining and machine learning and their predictive practices. The author also mentions that commonly used techniques include models related to decision trees, logistic and regression analysis, discriminant analysis, neural networks, association rules, random forests, support vector machines, k-nearest neighbours, principal components analysis, and other classifier models. Ahlemeyer-Stubbe & Coleman (2014); Alpaydın (2014) and Alpaydın (2016) provide precise definitions and detailed information on the theories related to machine learning and data mining.

Machine learning enjoys many areas in various industrial applications. Abadi et al., (2016) provide detailed information on a machine learning system with a detailed literature review on related learning applications. There are numerous studies across many areas that merge machine learning methodologies with business analytics such as production optimization for digital twin strategy (Min, Lu, Liu, Su, & Wang, 2019), portfolio optimization (Tayalı & Tolun, 2018), credit risk assessment, market

basket analysis (Mackenzie, 2015), ranking objects (Tolun & Tayalı, 2016), machine maintenance (Thieullent et al., 2016), healthcare (Chakrabarti, 2009; Roderick, Marko, Sanchez, & Aryasomajula, 2016), accounting (Fischer, Pohl, & Ratz, 2020), knowledge management (Delen, Zaim, Kuzey, & Zaim, 2013) and scheduling (Shaw, Park, & Raman, 1992).

Besides the manufacturing and business process automation approaches that use the methodologies of machine learning field, most learning applications from the field of production and operations management are on demand forecasting. Cao et al., (2016); Carbonneau, Laframboise, & Vahidov (2008); Li, Mahbobur Rahman, Vega, & Dong (2016) provide some applications of time series-based demand forecasting using methodologies of machine learning.

The next section examines the effect of stationarity on the results of the demand forecasting via the supervised machine learning algorithm of random forests. The novelty of the proposed solution stems from the fact that, to the author's knowledge, there is no study in the literature that underlies the presence of the importance of the differenced series within the features of the training dataset for keeping the stationarity assumption of the time series.

SOLUTIONS AND RECOMMENDATIONS

This section uses the R programming language for time series forecasting modelling the demand forecasting problem with machine learning algorithm of random forest. Detailed information on time series analysis and forecasting with machine learning models using R is provided in Krispin, (2019b). The following computer programming code is based on Krispin (2019a). The execution starts after the installation of R language and packages of pacman, TSstudio, dplyr, lubridate, h2o and plotly.

The first library installed is a library for managing packets of R.

```
library(pacman)
```

This command loads all the libraries of the installed packages.

```
p_load(TSstudio, tseries, dplyr, lubridate, h2o, plotly)
```

The USVSales is the dataset of total monthly vehicle sales in the US which is available in the TSstudio package.

```
data(USVSales)
ts_info(USVSales)
```

```
The USVSales series is a ts object with 1 variable and 528
observations
 Frequency: 12
 Start time: 1976 1
 End time: 2019 12
```

The adf.test function from the tseries package is an implementation of the augmented Dickey-Fuller test. The statistical and hypothetical test examines whether the USVSales dataset contains a unit root and if the dataset is thus stationary or not.

```
adf.test(USVSales)
```

The results of the stationarity test for the dataset points out to the non-stationarity of the time series because it contains a unit root (Stock & Watson, 2015).

```
data:  USVSales
Dickey-Fuller = -2.5214, Lag order = 8, p-value = 0.3576
alternative hypothesis: stationary
```

There is no need to increase differencing or using a lag operator since the dataset is assumed to be stationary after the first differencing operation on the time series. The differenced time series is going to be included in the input dataset as a feature and part of the feature engineering process.

```
USVSalesdiff <- diff(USVSales, differences = 1)
adf.test(USVSalesdiff)
        Augmented Dickey-Fuller Test
data:  USVSalesdiff
Dickey-Fuller = -14.209, Lag order = 8, p-value = 0.01
alternative hypothesis: stationary
Warning message:
In adf.test(USVSalesdiff): p-value smaller than printed p-value
```

The following code plots the time series object

```
ts_plot (USVSalesdiff,
title = "US Total Monthly Vehicle Sales",
Ytitle = "Thousands of Units",
Xtitle = "Year")
```

The following code is written to create a sample dataset that includes the dates beyond 2010, January.

```
dataset <- ts_to_prophet (window (USVSales, start = c(2010,1)))
datasetdiff <- ts_to_prophet (window (USVSalesdiff, start =
c(2010,1)))
head(datasetdiff)
          ds        y
1 2010-01-01 -336.801
2 2010-02-01   80.893
3 2010-03-01  290.591
4 2010-04-01  -86.619
5 2010-05-01  120.236
6 2010-06-01 -117.115
tail(datasetdiff)
            ds        y
115 2019-07-01 -110.801
116 2019-08-01  241.395
117 2019-09-01 -369.710
118 2019-10-01   64.548
119 2019-11-01   66.303
120 2019-12-01  118.540
```

The following code adds the differenced time series to the dataset.

```
dataset <- cbind.data.frame(dataset, datasetdiff[,2])
names(dataset) <- c("date", "y", "diff")
dataset <- dataset %>% mutate(month =
factor(lubridate::month(date, label = TRUE), ordered = FALSE))
dataset$trend <- 1:nrow(dataset)
head(dataset)
        date        y     diff
1 2010-01-01  712.469 -336.801
2 2010-02-01  793.362   80.893
3 2010-03-01 1083.953  290.591
4 2010-04-01  997.334  -86.619
5 2010-05-01 1117.570  120.236
6 2010-06-01 1000.455 -117.115
tail(dataset)
          date        y     diff
```

```
115 2019-07-01 1443.947 -110.801
116 2019-08-01 1685.342  241.395
117 2019-09-01 1315.632 -369.710
118 2019-10-01 1380.180   64.548
119 2019-11-01 1446.483   66.303
120 2019-12-01 1565.023  118.540
```

The dataset consists of 120 observations of 3 variables, namely date, the actual demand series and the differenced time series of the actual series.

```
str(dataset)
'data.frame':        120 obs. of  3 variables:
 $ date: Date, format:  ...
 $ y   : num  712 793 1084 997 1118 ...
 $ diff: num  -336.8 80.9 290.6 -86.6 120.2 ...
```

The following code splits this dataset into training and test datasets. The last 12 months (h) is spared as test data, and the remaining as the training data.

```
h <- 12
train_dataset <- dataset[1:(nrow(dataset) - h), ]
test_dataset <- dataset[(nrow(dataset) - h + 1):nrow(dataset),
]
```

The following code builds the linear regression model as a benchmark to compare it with the output generated by the random forest algorithm.

```
lr_model <- lm(y ~ diff + month + trend, data = train_dataset)
summary(lr_model)
Call:
lm(formula = y ~ diff + month + trend, data = train_dataset)
Residuals:
    Min      1Q  Median      3Q     Max
-166.32  -77.14   13.56   59.73  163.57
Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept)  966.1532    51.2276  18.860  < 2e-16 ***
diff           0.4930     0.1065   4.631 1.17e-05 ***
monthFeb    -115.4412    70.7513  -1.632  0.10610
monthMar     101.9109    81.8427   1.245  0.21615
```

```
monthApr     159.5010    47.1723   3.381  0.00105 **
monthMay     143.7177    67.7764   2.120  0.03660 *
monthJun     163.3972    52.1019   3.136  0.00229 **
monthJul     102.4381    54.6010   1.876  0.06374 .
monthAug     114.9820    63.2824   1.817  0.07241 .
monthSep      84.7254    49.1134   1.725  0.08780 .
monthOct       4.0187    55.0956   0.073  0.94201
monthNov     -21.0555    56.9633  -0.370  0.71249
monthDec      90.2369    77.7811   1.160  0.24893
trend          5.3012     0.2623  20.208  < 2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
Residual standard error: 84.39 on 94 degrees of freedom
Multiple R-squared:  0.8758,        Adjusted R-squared:
0.8586
F-statistic: 50.98 on 13 and 94 DF,  p-value: < 2.2e-16
```

The following code provides the mean absolute percentage error of the forecasting model provided by the linear regression model as approximately 12.5%.

```
test_dataset$yhat <- predict(lr_model, newdata = test_dataset)
mape_lr <- mean(abs(test_dataset$y - test_dataset$yhat) / test_
dataset$y)
mape_lr
```

[1] 0.1250037

The next code provides a connection to the h2o package for executing the random forest model.

```
h2o.init(max_mem_size = "32G")
train_h <- as.h2o(train_dataset)
test_h <- as.h2o(test_dataset)
x <- c("diff","month","trend")
y <- "y"
```

The following code and parameters build the time series forecasting model with the supervised random forest algorithm.

```
rf_model <- h2o.randomForest(training_frame = train_h,
nfolds = 5,
```

```
x = x,
y = y,
ntrees = 500,
stopping_rounds = 10,
stopping_metric = "RMSE",
score_each_iteration = TRUE,
stopping_tolerance = 0.0001,
seed = 1234)
tree_score <- rf_model@model$scoring_history$training_rmse
```

The following code provides the variable importance plot of the built model.

```
h2o.varimp_plot(rf_model)
```

The summary of random forest model can be obtained using the next command.

```
rf_model@model$model_summary
Model Summary:
  number_of_trees number_of_internal_trees model_size_in_bytes
             43                        43               34498
  min_depth max_depth mean_depth min_leaves max_leaves mean_
leaves
         9        13   10.46512         47         69
59.25581
```

The following lines of code plot the trained score history of the random forest model.

```
tree_score <- rf_model@model$scoring_history$training_rmse
plot_ly(x = seq_along(tree_score), y = tree_score,
type = "scatter", mode = "line") %>%
layout(title = "Trained Score History of the Random Forest
Model",
yaxis = list(title = "Root Mean Squared Error"),
xaxis = list(title = "Number of Trees"))
```

The next code tests the trained model on the test dataset and provides the mean absolute percentage error for the random forest model of the sales forecasting dataset with only 3 variables.

```
test_h$pred_rf <- h2o.predict(rf_model, test_h)
test_1 <- as.data.frame(test_h)
mape_rf <- mean(abs(test_1$y - test_1$pred_rf) / test_1$y)
mape_rf
```

[1] 0.02295706

The forecasting error of the model is approximately %2.3 and better compared to the mean absolute percentage error of the linear regression model which is %12.5.

The following line of codes plot an interactive graphic for the demand forecasting models of linear regression and random forest tree for total vehicle sales dataset. Figure 1 depicts this plot.

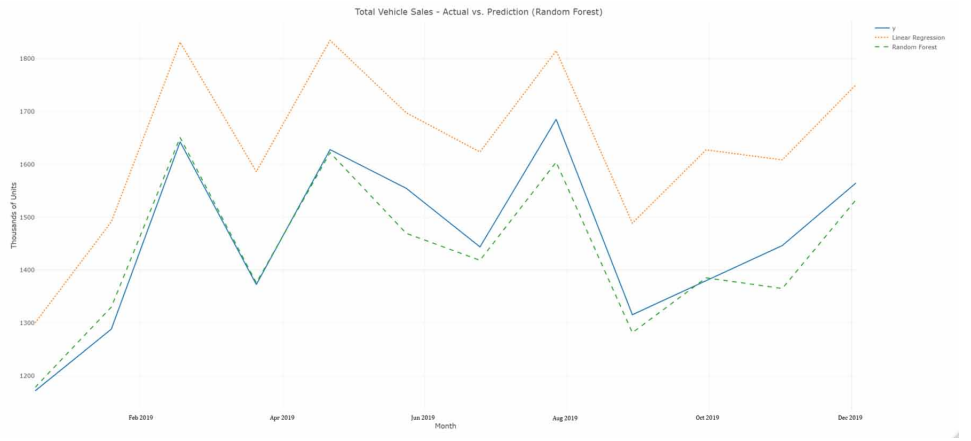
```
plot_ly(data = test_1) %>%
add_lines(x = ~ date, y = ~y, name = "y") %>%
add_lines(x = ~ date, y = ~ yhat, name = "Linear Regression",
line = list(dash = "dot")) %>%
add_lines(x = ~ date, y = ~ pred_rf, name = "Random Forest",
line = list(dash = "dash")) %>%
# add_lines(x = ~ date, y = ~ rf_grid, name = "Random Forest
(grid)", line = list(dash = "dash")) %>%
layout(title = "Total Vehicle Sales - Actual vs. Prediction
(Random Forest)",
yaxis = list(title = "Thousands of Units"),
xaxis = list(title = "Month"))
```

As can be followed from Figure 1, the model that incorporates the supervised machine learning algorithm of the random forest captures the actual demand better, compared to the time series-based forecasting model built using the linear regression approach. Therefore, the time series model built for the demand dataset using the random forest methodology can be further used in forecasting future demand for the specified dataset.

FUTURE RESEARCH DIRECTIONS

The interdisciplinary field of machine learning presents many opportunities for business to automate their processes. These automation efforts should be converted to decision support systems and knowledge-based systems in the future, for providing the users with better decision-making alternatives. Sweenor et al. (2020) report the

Figure 1. The random forest model provides more accurate results than the linear regression model for this demand dataset according to the mean absolute percentage error measurements which measures the average percentage absolute error of the demand forecasting models



importance of realizing the value of data science through operationalising these automation efforts with the sequence of build, manage, deploy, integrate, and monitor.

The scientific literature on modelling univariate time series forecasting with machine learning methodologies are recently emerging. Brownlee (2020) provides extensive evidence for this claim. The findings of the econometrics theory should merge with these emerging techniques from the data mining and machine learning perspectives to provide better performance in forecasting and prediction accuracies. There is a lot of room to improve before engineering the features of the inputs as this study tries to show.

CONCLUSION

Data science is an emerging field with a bright future ahead. It presents many novel approaches with regards to science, mathematics, statistics, and even art. Although there are many debates on whether the machine and human interaction will shift the paradigm as the previous industrial revolutions did, one cannot think of any instances where a machine can achieve a task without a supervisor. Machines can forecast just as well as humans can predict, yet prediction requires skill, experience, and judgement. Therefore, it is still a controversy whether machines will seek the assistance of humans in the future or not.

There is an extensive research in the field of production management for quantitative modelling of automated production processes. This chapter presents the recent methodological developments in demand management and demand forecasting subjects of the operations management. Demand forecasting is one of those vital issues with regards to the operations planning practice. Many methodologies in demand forecasting requires a data analysis perspective. The background section provides introductory information on time series forecasting and machine learning in relation to the business and forecasting applications.

This chapter provides detailed information on the various methodologies used in demand forecasting of the operations management with an exemplary application. To the author's knowledge there is no study in the literature that examines the performance effect of the presence of the unit root in the time series dataset of demand forecasting while using the supervised machine learning algorithm of random forest. The study shows the improvement with an implementation of a non-stationary time series into the features of the dataset. As can be followed in the solutions and recommendations section of this chapter, especially a machine learning approach combined with the methodologies of the econometrics theory provides promising solutions for better forecasts.

REFERENCES

Abadi, M., Barham, P., Chen, J., Chen, Z., Davis, A., Dean, J., ... Zheng, X. (2016). TensorFlow: A system for large-scale machine learning. *Proceedings of the 12th USENIX Symposium on Operating Systems Design and Implementation, OSDI 2016*.

Ahlemeyer-Stubbe, A., & Coleman, S. (2014). A Practical Guide to Data Mining for Business and Industry. In A Practical Guide to Data Mining for Business and Industry. doi:10.1002/9781118763704

Albright, S., & Winston, W. (2017). *Business Analytics: Data Analysis and Decision Making* (6th ed.). Cangage Learning.

Alpaydın, E. (2014). *Introduction to Machine Learning* (3rd ed.). The MIT Press.

Alpaydın, E. (2016). *Machine Learning: The New AI*. MIT Press.

Anderson, D., Sweeney, D., Williams, T., Camm, J., Cochran, J., Fry, M., & Ohlmann, J. (2016). *Quantitative Methods for Business* (13th ed.). Book Only.

Bontempi, G., Ben Taieb, S., & Le Borgne, Y. A. (2013). Machine learning strategies for time series forecasting. *Lecture Notes in Business Information Processing, 138*, 62–77. doi:10.1007/978-3-642-36318-4_3

Brealey, R., Myers, S., & Marcus, A. (2017). *Fundamentals of Corporate Finance* (9th ed.). McGraw Hill.

Brownlee, J. (2020). *Deep Learning for Time Series Forecasting: Predict the Future with MLPs ... - Jason Brownlee - Google Kitaplar*. Retrieved from https://books.google.com.tr/books?hl=tr&lr=&id=o5qnDwAAQBAJ&oi=fnd&pg=PP1&dq=jason+brownleed+ deep+learning&ots =yG8avKoh19&sig= 0XIzVsPbMQec1K9OJ9niB0qHSnk &redir_esc=y#v=onepage&q= jasonbrownleeddeeplearning &f=false

Cachon, G., & Terwiesch, C. (2012). *Matching Supply with Demand: An Introduction to Operations Management*. McGraw-Hill/Irwin.

Cao, Q., Banerjee, R., Gupta, S., Li, J., Zhou, W., & Jeyachandra, B. (2016). Data driven production forecasting using machine learning. *Society of Petroleum Engineers - SPE Argentina Exploration and Production of Unconventional Resources Symposium*. 10.2118/180984-MS

Carbonneau, R., Laframboise, K., & Vahidov, R. (2008). Application of machine learning techniques for supply chain demand forecasting. *European Journal of Operational Research*, *184*(3), 1140–1154. doi:10.1016/j.ejor.2006.12.004

Chakrabarti, S. (2009). *Data Mining: Know It All*. M. Kaufmann.

Chase, C. (2016). *Next Generation Demand Management: People, Process, Analytics, and Technology*. Wiley. doi:10.1002/9781119449591

Chopra, S., & Meindl, P. (2016). *Supply Chain Management* (Global Edition).

Delen, D., Zaim, H., Kuzey, C., & Zaim, S. (2013). A comparative analysis of machine learning systems for measuring the impact of knowledge management practices. *Decision Support Systems*, *54*(2), 1150–1160. Advance online publication. doi:10.1016/j.dss.2012.10.040

Everett, A., & Ebert, R. (1986). Production and Operations Management: Concepts, Models, and Behavior (3rd ed.). Prentice-Hall.

Fischer, J. A., Pohl, P., & Ratz, D. (2020). A machine learning approach to univariate time series forecasting of quarterly earnings. *Review of Quantitative Finance and Accounting*, *55*(4), 1163–1179. Advance online publication. doi:10.100711156-020-00871-3

Fuller, J., & Martinec, L. (2005). Operations Research and Operations Management: From Selective Optimization to System Optimization. *Journal of Business & Economics Research*, *3*(7), 16.

Global Data and Analytics Survey. (2016). Retrieved 5 September 2020, from https://www.pwc.com/us/en/services/consulting/analytics/big-decision-survey.html

Guttag, J. (2013). *Introduction to computation and programming using Python*. Academic Press.

Heizer, J., Render, B., & Munson, C. (2017). *Operations Management: Sustainability and Supply Chain Management* (12th ed.). Pearson Education Limited.

Hyndman, R. J., & Athanasopoulos, G. (2018). Forecasting: Principles and Practice (2nd ed.). Retrieved from OTexts.com/fpp2

Jacobs, F. R., & Chase, R. B. (2018). *Operations and supply chain management* (15th ed.). McGraw-Hill/Irwin.

Kandiller, L. (2007). Principles of Mathematics in Operations Research. Springer.

Krajewski, L., Malhotra, M., & Ritzman, L. (2016). *Operations Management: Processes and Supply Chains* (11th ed.). Pearson.

Krispin, R. (2019a). Retrieved 5 September 2020, from https://github.com/PacktPublishing/ Hands-On-Time-Series- Analysis-with- R /tree/master/ Chapter12

Krispin, R. (2019b). *Hands-on Time Series Analysis with R*. Packt.

Li, Z., Mahbobur Rahman, S. M., Vega, R., & Dong, B. (2016). A hierarchical approach using machine learning methods in solar photovoltaic energy production forecasting. *Energies*, *9*(1), 55. Advance online publication. doi:10.3390/en9010055

Mackenzie, A. (2015). The production of prediction: What does machine learning want? *European Journal of Cultural Studies*, *18*(5), 429–445. doi:10.1177/1367549415577384

Min, Q., Lu, Y., Liu, Z., Su, C., & Wang, B. (2019). Machine Learning based Digital Twin Framework for Production Optimization in Petrochemical Industry. *International Journal of Information Management*, *49*, 502–519. Advance online publication. doi:10.1016/j.ijinfomgt.2019.05.020

Nahmias, S., & Olsen, T. (2015). *Production and Operations Analysis* (7th ed.). Waveland Press.

Nguyen, T., Zhou, L., Spiegler, V., Ieromonachou, P., & Lin, Y. (2018). Big data analytics in supply chain management: A state-of-the-art literature review. *Computers & Operations Research*, *98*, 254–264. doi:10.1016/j.cor.2017.07.004

Omor. (2020). Retrieved 26 August 2020, from http://operations-management-research.essec.edu/home

Pfaff, B. (2008). *Analysis of Integrated and Cointegrated Time Series with R* (2nd ed.). Springer. doi:10.1007/978-0-387-75967-8

Roderick, O., Marko, N., Sanchez, D., & Aryasomajula, A. (2016). Data Analysis and Machine Learning Effort in Healthcare. In Internet of Things and Data Analytics Handbook (pp. 295–328). doi:10.1002/9781119173601.ch18

Shaw, M. J., Park, S., & Raman, N. (1992). Intelligent Scheduling with Machine Learning Capabilities: The Induction of Scheduling Knowledge. *IIE Transactions*, *24*(2), 156–168. Advance online publication. doi:10.1080/07408179208964213

Shumway, R., & Stoffer, D. (2017). *Time Series Analysis and Its Applications* (4th ed.). Springer. doi:10.1007/978-3-319-52452-8

Stock, J. H., & Watson, M. W. (2015). *Introduction to Econometrics* (3rd ed.). Pearson.

Sweenor, D., Hillion, S., Rope, D., Kannabiran, D., Hill, T., & O'Connell, M. (2020). *ML Ops: Operationalizing Data Science A Four-step Approach to Realizing the Value of Data Science through ML Operations | TIBCO Software*. Retrieved from https://www.tibco.com/resources/ ebook-online/ ml-ops-operationalizing- data-science-four-step-approach- realizing-value-data

Tayalı, H. A., & Tolun, S. (2018). Dimension reduction in mean-variance portfolio optimization. *Expert Systems with Applications*, *92*, 161–169. doi:10.1016/j.eswa.2017.09.009

Tetlock, P., & Gardner, D. (2015). *Superforecasting: The Art and Science of Prediction*. Crown.

Thieullent, A., Colas, M., Buvat, J., Kvj, S., & Bisht, A. (2016). *Going Big: Why Companies Need to Focus on Operational Analytics*. Academic Press.

Tolun, S., & Tayalı, H. A. (2016). Data Mining for Multicriteria Single Facility Location Problems. In N. Celebi (Ed.), *Intelligent Techniques for Data Analysis* (pp. 147–170). doi:10.4018/978-1-5225-0075-9.ch007

Tsay, R. (2010). *Analysis of Financial Time Series* (3rd ed.). Wiley. doi:10.1002/9780470644560

Tsay, R. (2013). *An Introduction to Analysis of Financial Data with R.* Retrieved from https://www.worldcat.org/title/ an-introduction-to-analysis-of-financial-data-with-r/oclc/ 904835289& referer=brief_results

Tsay, R. (2014). *Multivariate Time Series Analysis: With R and Financial Applications*. Wiley.

Zhao, L., & Huchzermeier, A. (2015). Operations-finance interface models: A literature review and framework. *European Journal of Operational Research*, *244*(3), 905–917. doi:10.1016/j.ejor.2015.02.015

ADDITIONAL READING

Amirian, P., van Loggerenberg, F., Lang, T., Thomas, A., Peeling, R., Basiri, A., & Goodman, S. N. (2017). Using big data analytics to extract disease surveillance information from point of care diagnostic machines. *Pervasive and Mobile Computing*, *42*, 470–486. doi:10.1016/j.pmcj.2017.06.013

Atkinson, S., O'Hara, S., & Sturgeon, A. (Eds.). (2014). *The Business Book: Big Ideas Simply Explained*. Dorling Kindersley.

Chiang, A. C., & Wainwright, K. (2005). *Fundamental Methods of Mathematical Economics* Retrieved from https://books.google.com.tr/books?id=QWOeQgAACAAJ&dq=chiang +wainwright&hl=tr&sa =X&ved=2ahUKEwjjobSV0Njr AhXQGuwKHbc7DeEQ 6AEwAHoECAIQAg

Druzdzel, M. J., & Flynn, R. R. (2011). Decision support systems. In *Understanding Information Retrieval Systems*. Management, Types, and Standards., doi:10.1201/b11499-37

Srinivasan, G. (2017). *Operations Research: Principles and Applications* (3rd ed.). PHI Learning.

Strang, G. (2019). *Linear Algebra and Learning from Data* -. Retrieved from https://books.google.com.tr/ books?id=L0Y_wQEACAAJ&dq=Strang, +G.+(2019).+Linear+algebra+a nd +learning+from+data.&hl= tr&sa=X&ved =2ahUKEwjAt 4u30NjrAhVSs KQKHQAbD5YQ6 AEwA H oECAEQAg

Taha, H. A. (2017). *Operations Research: An Introduction*. Retrieved from https://books.google.com.tr /books?id=HbpKjwEACAAJ&dq=taha+operations&hl=tr&sa=X&ved=2ah U KEwj61Pbmz9jr AhVQ-aQKHaDsD8UQ6AEw AHoECAQQAg

Thornton, P. (2014). *The Great Economists: Ten Economists Whose Thinking Changed the Way We Live*. Retrieved from https://www.google.com/books?hl=tr&lr=&id=2oXOAwAAQBAJ &oi=fnd&pg= PT3& dq=The+Great +Economist s+phil&ots =oZB5Fz1Tak& sig=fhGlAOQirYY5lYHX1KzlO6Lv CUE

Womack, J. P., & Jones, D. T. (2003). *Lean Thinking: Banish Waste and Create Wealth in Your Corporation*. Retrieved from https://books.google.com.tr/books?id=2eWHaAyiNrgC &printsec=frontcover &dq=jones+womack+lea n+ thinking&hl=tr&sa= X&ved=2ahUKEwiAt_eS0djrA hWPDewKHVDbDqkQ6A EwAHoE CAIQAg# v=onepage&q =joneswomackl eanthinking&f=false

KEY TERMS AND DEFINITIONS

Artificial Intelligence: Programming computers for performing complex tasks that can be done by human beings with intelligence.

Data Analysis: Examining data for to extract information with the help of a set of computational methods or techniques that range from basic descriptive statistical techniques to more sophisticated data mining.

Data Mining: A set of machine learning and statistical methods or techniques for drawing insight or extracting information from data or revealing patterns that are not implicitly available.

Data Science: An interdisciplinary field of study of data in relation to mathematics, statistics, operations research, data analysis, data mining, machine learning, computer science, engineering, visualization, data privacy, and big data.

Decision Analysis Models: Mathematical representations of quantified business processes for the analysis of decision alternatives for better decision-making.

Economic Forecast: A long-term forecast for planning the behaviour of the economic actors.

Economics Theory: The theory that investigates the interdependent relationships of people or organizations using the flow of money, goods, and services as well as various concepts such as interest rate, inflation, competition, growth, currency exchange, unemployment, social capital, and technological leaps.

Model: A mathematical representation of a real and complex system that formulates the relation between an input and an output.

Pattern Recognition: Discovering or detecting the explicit relation or repetitive structures in a dataset using data science.

Technological Forecast: A long-term forecast that examines the characteristics of advancements, policies, strengths, weaknesses, opportunities, or threats in relation to technology.

Chapter 5
A Study of Green and Risk-Resilient Supply Chain Strategy:
Analysis of the Best Innovative Practices of Fortune Global 500 Companies

Renuka Deshmukh
Massachusetts Institute of Technology, USA

ABSTRACT

With the rapid development of the economy, environmental problems have become increasingly prominent. Environmental pollution and degradation have become global problems. Environmental problems, such as global warming, ozone depletion, smog, and water pollution, have largely affected economic development and social progress for the next generations. With the increase in the number of people and the consumption of resource-based companies, coal, oil, natural gas, and other non-renewable energy sources are gradually decreasing or even being depleted. The use of these non-clean energy sources exacerbates the deterioration of the environment.

INTRODUCTION

With the rapid development of the economy, environmental problems have become increasingly prominent. Environmental pollution and degradation have become global problems. Environmental problems, such as global warming, ozone depletion, smog, and water pollution, have largely affected economic development and social

DOI: 10.4018/978-1-7998-5879-9.ch005

progress for the next generations. With the increase in the number of people and the consumption of resource-based companies, coal, oil, natural gas, and other non-renewable energy sources are gradually decreasing or even being depleted. The use of these non-clean energy sources exacerbates the deterioration of the environment. Businesses that do not take into consideration their social responsibility and do not contribute towards low carbon economy may have to forego the upcoming opportunities in carbon market (Eisntein & Walter, 2006). Thus, organizations have instigated to focus and lay emphasis on understanding the influence of their policymaking and management actions on the surroundings and to endorse green innovation (Cui, 2017; Safari et al., 2018). Several companies lay emphasis on the green design of products, few concentrate on raw materials and clean energy, and many other businesses are interested in the innovation of production methods. Nevertheless, for maximum organisations, green innovation practices are yet at a very primary stage of exploration. These firms immediately need pertinent theoretical research as a guiding document.

Green innovation has also developed as an emerging area academic research. Studies have revealed that green innovation presents the environmental inkling into the decision making and strategy formulation procedure to eradicate or condense the damage triggered to the atmosphere (Narendra Saran & Sparanjani, 2012). Further, firms with green innovation capability can utilize green resources and acquire the knack to retort to client requirements speedily and correctly so as to achieve upper edge in the competitive market. (Agarbhatt Lambort Morant et al., 2018). Many investigators pay examined the swaying aspects of green innovation, such as strategies framework and protocols (Stucki et al., 2018), quality management (D. Li et al., 2018), and the influence of green innovation on the financial and environmental performances of businesses (El-Kassar & Singh, 2019; Q. H. Li, 2014), green technology innovation (Liu et al., 2017), green design of products (Hashemi et al., 2015; W. Y. Li et al., 2016), and the disposal of waste (Y. S. Chen et al., 2006). Nevertheless, due to the diverse features of the industry and the firm itself, for instance type, size, nature, resource availability of firm etc. it is challenging to smear these research inferences to deliver reference models for green innovation for companies, particularly developing or startup firms, to follow and implement. If we can clutch the green innovation practices of selected businesses, particularly archetypal organisations, the companies discovering green innovation conduits can acquire valuable know-how to enhance the exploitation of resources, which has noteworthy practical connotation. In this research study, the researcher have attempted to identify and analyse the criteria of green innovation practices.

CONSEQUENCES OF CLIMATE CHANGE

The historical data on precipitation, heatwaves and streamflow shows the increasing trend in global warming (Dai, 2013). One of the significant consequences of climate change is global warming, cascading into droughts as well as floods. This is found to be profoundly influencing food supply chains in terms of food availability (Conway et al., 2015), food loss, and wastage (Devereux, 2007). Furthermore, the mining and logistics sectors will face a significant impact from rising (sea) water levels (Cazenave et al., 2014). As a consequence of climate change, sources of non-renewable sources (e.g. petroleum, coal, natural gas) and metal ores will significantly influence the manufacturing and transportation sectors. Climate change

The need of the hour for the corporate is to rethink and intensely take into consideration their supply-chain susceptibility and revelation to generate effective mitigation and business-sustainability continuity plans.

Consequences of Climate Change

The historical data on precipitation, heatwaves and streamflow shows the increasing trend in global warming (Dai, 2013). One of the significant consequences of climate change is global warming, cascading into droughts as well as floods. This is found to be profoundly influencing food supply chains in terms of food availability (Conway et al., 2015), food loss, and wastage (Devereux, 2007). Furthermore, the mining and logistics sectors will face a significant impact from rising (sea) water levels (Cazenave et al., 2014). As a consequence of climate change, sources of non-renewable sources (e.g. petroleum, coal, natural gas) and metal ores will significantly influence the manufacturing and transportation sectors. Climate change also driven by supply chain stakeholders involved in the global network. Jira and Toffel (2013) state that buying firms can influence suppliers by engaging them in climate change initiatives. However, their participation strongly depends on company size, profit of industry sector, and country location. A major barrier to climate change is the lack of knowledge about this growing issue (Ng et al., 2016). Nowadays investors and rating agencies demand climate change/risk disclosures from companies (Lash and Wellington, 2007; Wittneben and Kiyar, 2009). Sustainability-focused customer initiatives are needed for controlling the influence of climate change on global supply chains. For example, high levels of environmental pollution, energy consumption and GHG emissions produced by firms can be controlled by the market (customers) and regulatory (Governments) drivers

RESEARCH OBJECTIVES

1. To highlight the value-based dimensions of company's green innovation practices and social responsibility;
2. To study effect of green innovation activities on a companies' green performance which includes both environmental performance and competitive advantage of a firm.
3. To analyse the implications of climate change for supply chain management in terms of strategic and operational planning.
4. To analyse and evaluate the prevalence of stakeholder pressure on the level of green innovation practice as reported by the selected corporates.
5. To raise major implications and to offer suggestions for holistic implementation of green innovation policies and practices based on the results and discussions of the study.

HYPOTHESIS

H1: Green innovation has a positive effect on environmental performance of company

H2: Green innovation has a positive effect on competitive advantage of company

Research Methodology

This section mainly elaborates the procedures of using content analysis to study the green innovation practices of companies. As a commonly used analytical method in the research of social sciences, content analysis is a technique of gathering and organizing diverse data, involving coding information into various groups or categories based on selected criteria (Soldatenko & Backer, 2019).

First, we obtain the dimensions/themes of green innovation practices from the websites and literature (see Table 1). Second, we collect the related data of the top 500 global companies and obtain the criteria according to the dimensions. Then, cluster analysis is conducted to classify the companies. Finally, the analysis of green innovation practices for companies in different groups is conducted.

However, some secondary sources such as websites of selected corporates, sustainability reports, books, periodicals and reports were consulted for understanding the key concepts and reviewing relevant literature pertaining to the current field of study.

In order to gain an insight into the analysis of green innovation policies and practices the researcher designed an exploratory study based on the 'content analysis' on the websites of selected corporates.

The level of green innovative practices was measured and assessed under three categories, for the industries: (a) green innovative, (b) greener innovative, and (c) greenest innovative, levels.

Questionnaire is formed from three parts. First part includes descriptive information such as gender and division of respondents, size of the company according to employee quantity, sector of the company, ISO 14001ownership years and information about if the company has a reward regarding its environmental activities or not. According to survey results, %75 of respondents are male, %69 of respondents are working in sustainability, environment &safety, R&D or quality departments. %63 of companies are big sized company (251-2000 employees) and %28 of them are very big sized company (over 2000 employees). On the other hand, %69 of companies are belong to automotive, construction, chemical or energy industries. %72 of companies have ISO 14001 certificate more than 5 years. Also, %56 of companies has an environmental award. Second and third parts of questionnaire have items about green innovation and environmentally sensitive company performance, respectively. To measure green innovation, 13 item-scale adopted from Chen, Lai & Wen (2006) and Chiou, Chan, Lettice & Chung (2011) is used. Company performance scale is adopted from Conding & Habidin (2012); Lin, Tan & Geng (2012); Chang (2011); Chen, Lai & Wen (2006) and Chiou, Chan, Lettice & Chung (2011), which uses 15 items to measure two dimensions (environmental performance and competitive advantage) of company's green performance. Overall, questionnaire has 28 items in total with 5 likert-type scale in order to measure variables green innovation and company performance. Before correlation and regression analyses, validity and reliability analyses were performed. According to factor analyses result; green innovation scale had two sub- dimensions as green product innovation and green process innovation and after deleting some items scale was presented with 9 items. The Cronbach's alpha was also calculated for each variable. The Cronbachs's alpha of "green innovation" is 0.855, "environmental performance" is 0.882 and "competitive advantage" is 0.925. For each variable, value of Cronbach's alpha coefficient is greater than 0.7 and acceptable according to Hair et al. (1998). The Pearson correlation analysis was conducted in order to indicate relationships between variables. Table 1 shows the results of correlation analysis. According to analysis results, there is generally positive, statistically significant, medium or high correlation between green innovation and both environmental performance and competitive advantage. In detail, when there is high correlation between green process innovation and environmental performance, on the other hand, there is poor correlation between green product innovation and competitive advantage.

Statistical tools and techniques such as descriptive statistics (percentages, mean, and standard deviation), chi-square statistics, inter-correlations, Cramer's V and

multiple regression analysis were used for the purpose of analysing and interpreting the quantitative survey data.

LITERATURE REVIEW

Innovation and Green Innovation

One of the oldest definitions of innovation is made in 1939 by Schumpeter. According to this definition, innovation is not an invention or development, it is application of technical or organizational novelty (Larsen, 2005). Innovation is defined as realization new or highly improved product or process on organizational applications, a new marketing method or a new organizational method in Oslo Manual published by OECD (OECD, 2005). In any industry (Larsen, 2005); generation, development and adaptation of a new idea or behavior for a company (Damanpour, 1996), successful application of a product or process at the first time (Cumming, 1998) is defined as innovation. According to innovation area, OECD made an innovation grouping on four elements. These are classified as product innovation, process innovation, organizational innovation and marketing innovation (OECD, 2005). Green innovation facilities are subgroup of general innovation facilities and defined as development of environmental quality or optimum usage of natural resources (Rave, Goetzke & Larch, 2011).

In order to define innovation type which occurred to decrease negative effects to environment, different definitive words or concepts are mostly used within the literature such as; green, eco, environmental or sustainable (Schiederig, Tietze & Herstatt, 2011). Although, depending on applied innovation type, green innovation tends to come out when environmental pressures exist (Huber, 2008). Green innovation aims generally, decrease of pollution, energy productivity, decrease of waste, substitution of limited resources with sustainable resources and recycling (Kemp & Arundel, 1998). Green innovation facilities play a key role in company's environmental performance results and comprehensive environmental sustainability realization (Rave, Goetzke & Larch, 2011).

- Green innovation is categorized in three types according to its application method and potential effects (Ramus, 2002):
- Green innovation that decreases environmental effects of company (re-usage and recycling)
- Green innovation that solves environmental problems of company (decreasing usage of hazardous components)

- Green innovation that develops environmental friendly/effective products/ processes (less resource / energy using)

Green Product Innovation

Having a strategic priority today's business cycle green product innovation has been formed as a result of interaction between sustainability and innovation (Dangelico & Pujari, 2010). Either it comes out with some big improvements to current products or changes on materials, components and other characteristics which better the performance (Tübitak, n.d.). Some examples for green product innovation activities are such as; decrease of toxic components within products, decrease of emissions and energy consumption during product usage, increase of useful life of products, including of recycling schemes for products (Dangelico & Pujari, 2010) which can be a differentiation tool for marketing activities and can enable market share continuation (Rave, Goetzke & Larch, 2011). Green product innovation also means developing of products that have positive effects or less negative effects to the environment during their lifecycle (Durif, Bolvin & Julien, 2010).

Green Process Innovation

Green process innovations, which have direct relationship with company's internal productivity, are more difficult than green product innovations to recognize by customers. With green process innovation activities, companies aim to reduce environmental effects with a development on current production facilities or adding some new processes (Cheng, Yang & Sheu, 2014). Using different kinds of technologies on green process innovations, companies try to reach targets regarding pollution decrease, waste management, water and raw material retention and production efficiency (Shrivastava, 1995). Consequently, green process innovation interested in mostly energy saving, pollution prevention, waste recycling or hazardous materials prevention (Chen Lai & Wen, 2006). Generally, approaches of companies on environmental management are branching of two categories as; controlling and prevention approaches (Fernandez, Junquera & Ordiz, 2003; Azzone & Noci, 1998). Pollution control approach is defined as eliminating pollution factors after their existence using various technologies (Çevre ve Orman BakanlÕ÷Õ, n.d.). On the other hand, pollution prevention approach proposes to design and practice production systems of producers as creating no waste and minimizing environmental effects (Yüksel, 2003). There are also several strategies regarding environmental actions and applications. Pioneer companies see environmental protection as an opportunity resource rather than a problem that needs to be solved with minimum cost. Some companies do not get into action if they feel no pressure from outside (Del Brio

& Junquera, 2003). There are miscellaneous classifications in the literature for companies according to degree of their social responsibilities and environmental consciousness such as reactive, effective, pioneer companies (Küskü, 2001) or evangelist, proactive, consistent, reactive and passive companies (Azzone & Noci, 1998). Moreover, rather than classifying companies some authors split up their strategies on environmental management as; passive strategies that resistant to change, supposing environmental subjects as a cost matter and so missing some new opportunities, active strategies that show activity to agree with environmental regulations and laws and lastly proactive strategies that paying attention to targets regarding environment and developing themselves on this issue as using talents and responsibilities accompanying all divisions within a company, combining eco-efficiency and continuous development processes of company and total quality management (Borri & Boccaletti, 1995). 2.2. Environmentally Sensitive Company Performance Company performance, affected from several factors, is measured with different business outputs on various studies. These outputs can be either economical result such as profit margin, increase of income, new investments or some kinds of different kinds of characteristics which cannot be measured as certainly. Evaluating company performance as taking into account its sensitivity to environment and environmental management approach, we can call that performance as environmentally sensitive company performance. It has two dimensions; environmental performance and competitive advantage. In literature, there are some studies investigating about relationship of green innovation performance of companies with their environmental performance and competitive advantage. According to these studies, green product and process innovation performance of a company has a positive effect on competitive advantage (Chen, Lai & Wen, 2006; Chang, 2011). Moreover, green innovation has a positive relationship with green performance and environmental performance is an important dimension of green performance (Conding & Habidin, 2012). According to another study, which investigates green innovation within green supply chain management, making conscious of supplier's effects green innovation positively and also green innovation has an effect on environmental performance and competitive advantage (Chiou, Chan, Lettice & Chung, 2011). Consequently, green innovation effects environmentally sensitive company performance positively. (Cheng, Yang & Sheu, 2014; Lin, Tan & Geng, 2013).

Data Analysis

Table 1. Dimensions and Corresponding References of Green Innovation Practices

Dimensions	References
Green technology (D1)	Nieminen et al. (2007); Liu et al. (2017)
Materials (D2)	Chouinard and Brown (1997); Y. S. Chen et al. (2006); Hashemi et al. (2015)
Energy (D3)	Yi (2013); Yuan et al. (2017)
Water (D4)	Willard (2005)
Environmental management system (D5)	Winter and Lasch (2016)
Cooperation (D6)	J. Wang (2010)
Waste (D7)	Willard (2005); Y. S. Chen et al. (2006)
Product (D8)	Willard (2005); Hashemi et al. (2015); W. Y. Li et al. (2016)
Green finance (D9)	Bal et al. (2013)
Green office (D10)	Gou et al. (2012)
Supply chain (D11)	Laari et al. (2017); Aziz et al. (2016); Knez et al. (2011); Mina et al. (2014)
Green activities (D12)	Axon (2016); D. Li et al. (2017)

Company Clustering

In this section, we use the "explore" function of SPSS software to conduct Pearson correlation analysis of various companies in accordance with coding similarity and then select the 209 companies with strong correlation (correlation coefficient ≥.6;) to perform cluster analysis based on the criteria in Table 2. Because the number of clusters is generally less than the square root of the sample number (Vesanto & Alhoniemi, 2000), we take the integer part of 209 as the number of clusters. The companies are classified into 14 groups. See Table 3 for details. In Table 3, the first column is the 14 groups that were classified; the second column includes the names of each company in different groups; the third column contains the criteria of the green innovation practices corresponding to the companies in each group. Here, only the criteria with the highest frequency are listed as the representative criteria.

Table 2. The Dimensions and Criteria of Green Innovation Practices

Dimensions Criteria	Dimensions Criteria
Green technology (D1)	Clean production technology (C1) Resource saving technology (C2) Waste recycling technology (C3) Green information and communication technology (C4) Energy-saving technology (C5)
Materials (D2)	Develop and use clean materials (C6) Chemical control (C7) Reduce material use (C8)
Energy (D3)	Improve energy efficiency (C9) Use clean renewable energy (C10) Search for new energy (C11) Energy-saving reform (C12)
Water (D4)	Reduce water waste (C13) Reduce water pollution (C14) Improve water use efficiency (C15)
Environmental management system (D5)	Environmental strategy (C16) Environmental goals (C17) Green patents (C18) Monitoring and evaluation system (C19) Environmental regulation (C20) Provide training courses (C21) Green data center (C22)
Cooperation (D6)	Cooperate with suppliers (C23) Participate in green organization (C24) Cooperate with peers (C25) Cooperate with universities and research institutions (C26)
Waste (D7)	Waste recycling (C27) Waste disposal (C28)
Product (D8)	Product recovery (C29) Green design of products (C30)
Green finance (D9)	Green financial bonds (C31) Green-credit policy (C32)
Green office (D10)	Save paper (C33) Telecommuting (C34) Facilitate green transformation (C35)
Supply chain (D11)	Control producing area (C36) Green sales chain (C37) Green warehouse (C38) Transportation improvement (C39)
Green activities (D12)	Engage with communities (C40) Protect nature and species diversity (C41) Green innovation programs (C42) Environmental activities (C43)

Analysis of Green Innovation Practices

As shown in Table 3, the first group of companies is involved in the supply of raw materials, sales, transportation, communications, and finance industries, which are most concerned about cooperation with universities and research institutions, followed by the establishment of green data centers, combined with the community and improvement of the mode of transport. The second group mainly contains financial companies but also includes electronic information technology, infrastructure, and so on; this group pays more attention to cooperation with suppliers and the use of clean renewable energy (Le kim & Mark, 2018). In addition, the frequency of saving paper is also high, showing the companies in this group promote green offices. The companies in the third group are mainly the energy industry. The key criteria are green patents and green innovation projects, indicating that such companies tend

Table 3. Company Clustering and Corresponding Criteria of Green Innovation Practices

Group	Companies	Criteria
1	Continental AG; Lowes; Morgan Stanley; Noble Group; Sysco; United Technologies Corporation; Vodafone Group	Cooperate with universities and research institutions (C26) Green data center (C22) Engage with communities (C40) Transportation improvement (C39)
2	Allstate; China Electronics Corporation; China Aerospace Science and Technology Corporation; Compass Group; China Pacific Insurance; HSBC Holdings; JPMorgan Chase & Co; MITSUI & Co., Ltd.; Mitsubishi Chemical Holdings; NEC Corporation; Phoenix_Pharmahandel; Schneider Electric; Zurich Insurance Group	Cooperate with suppliers (C23) Save paper (C33) Use clean renewable energy (C10)
3	China Vanke Co., Ltd.; China Nonferrous Metal Mining (Group) Co., Ltd.; Rosneft Oil; Shenhua Group	Green patents (C18) Green innovation programs (C42)
4	China Merchants Bank; Industrial Bank; Samsung Electronics; Shanxi Yanchang Petroleum	Environmental activities (C43) Environmental goals (C17) Energy-saving technology (C5) Green-credit policy (C32)
5	Aviation Industry Corporation of China; China Metallurgical Corporation Group; China COSCO shipping group; State Grid; Zhejiang Materials Industry Group Corporation	Waste disposal (C28) Energy-saving reform (C12) Search for new energy (C11) Energy-saving technology (C5)
6	Allianz SE; Credit Suisse Group AG; Emerson Electric; General Motors Corporation; Magna International Inc.; National Australia Bank Ltd.; Sumitomo Mitsui Financial Group; Total	Improve energy efficiency (C9) Use clean renewable energy (C10) Environmental strategy (C16)
7	Deutsche Telekom AG; Idemitsu Kosan; Orange Group; Raytheon Company; Soft Bank; Suncor Energy; Scottish Southern Energy; Standard Chartered Bank; TJX Group; Unipol Group	Green information & communication technology (C4) Green data center (C22) Engage with communities (C40) Improve water use efficiency (C15)
8	Aegon; Aviva plc; Chubu Electric Power Company; CHS Group; EDF Group; Metro AG; Marubeni Corporation; Mitsubishi Corporation; Medipal Holdings; Sompo Japan Nipponkoa Holdings; SK Grouo; Time Warner Inc; Tokio Marine & Nichido Fire Insurance Company	Use clean renewable energy (C10)Protect nature and species diversity (C41) Environmental strategy (C16) Engage with communities (C40)
9	Airbus Group N.V.; Air France; Anthem Group; BHP Billiton Ltd.; BAE Systems plc; Bunge Limited; Comcast Corporation; Cigna Insurance Group; CVS Health Group; Danone; Eni energy company; Gazprom; Goldman Sachs; Holland Royal shell oil company; Halliburton Company; International Paper; Indian Oil Corporation; Inditex Group; Johnson&Johnson; Johnson Controls, Inc.; Louis Dreyfus; Lyondell Basell Industries; Mitsubishi Electric Corporation; Petronas; Pfizer,NYSE: PFE; Ray Pschorr company; Robert Bosch Group; Sodexo; Thyssenkrupp; Talanx Group; TIAA-CREF; Wesfarmers Limited; ZF Friedrichshafen AG	Reduce water waste (C13) Improve water use efficiency (C15) Waste disposal (C28) Reduce water pollution (C14)
10	Auchan; China Huadian Corporation; Datong Coal Mine Group Co., Ltd., Japan Post Holdings Co., Ltd.; Jiangxi Copper Corp; JX Holdings; Japan Mizuho Financial Group; MS&AD Insurance Group Holdings; Munich Re Group; Mitsubishi UFJ Financial Group, Inc.; Michelin; National Grid; Petroleos Mexicanos; Panasonic; Power Construction Corporation of China; SINOCHEM GROUP; Tata Motors; Vinci Group; Walgreens Boots Alliance	Protect nature and species diversity (C41) Waste recycling (C27)
11	China Railway Construction Corporation Co., ltd; China National Machinery Industry Corporation; China United Network Communications Limited; Ford Motor Company; HeSteel Group; Jizhong Energy Group; Shougang Group	Clean production technology (CI) Energy-saving technology (C5) Green innovation programs (C42) Resource saving technology (C2)
12	Hyundai Heavy Industries; Lufthansa; Microsoft Corporation; Pepsico; Sanpaolo IMI; Trafigura Beheer BV; Toshiba Corporation	Provide training courses (C21) Develop and use clean materials (C6) Chemical control (C7) Green design of products (C30)
13	Amgen; Alcoa; ACS; ABInbev; Aisin Seiki; Aetna; Arcelor Mittal; ANZ Bank; Asea Brown Boveri; Bouygues; Bayer; BP Amoco; Bharat Petroleum; Cardinal Health Group; CK Hutchison Holdings; CocaCola; Companhia Vale do Rio Doce; CRH Group; China Minmetals Corporation; Canon; Cisco Systems; Conoco Phillips; DuPont; Enel; EXOR Group; East Japan Railway Company; Enbridge Group; Fujitsu; Gilead Sciences Group; Glaxo Smith Kline; Groupe BPCE; Gas Natural Fenosa; Henri Nestle; Heineken Holding; Kroger; IBM Corporation; Kansai Electric Power; KOC; LG Electronics; Lockheed Martin; LG Display; Marathon Petroleum Corporation; Northrop Grumman; National Union Life and Limb Insurance Company; Nike; OAO Lukoil Holdings; OMV Group; Phillips 66 Group; Procter & Gamble; Rio Tinto Group; Roche Group; RWE Group; Royal Bank of Canada; Veolia Environnement Royal Dutch Philips Electronics Ltd.; Reliance Industries; Siemens; Saudi Basic Industry Corporation; Scotia bank; Sanofi; Sumitomo Electric Industries; Toronto-Dominion Bank; TUI Group; ITOCHU Corporation; TSMC; The Dai-ichi Life Insurance Company; Telstra; Unilever; United Continental Holdings; Wm Morrison Supermarkets; Wilmar International	Improve water use efficiency (C15)Reduce water waste (C13) Protect nature and species diversity (C41) Use clean renewable energy (C10) Reduce water pollution (C14) Reduce material use (C8)
14	Boeing; China National Chemical Corporation; Dow Chemical Company; General Electric Company; Hanwha Group; PKN Orlen; Zhejiang Geely Holdings	Green design of products (C30) Chemical control (C7) Green innovation programs (C42)

to start with the knowledge level in the process of green innovation. The fourth group, including Samsung Electronics, Yanchang Petroleum, and the two major banks, attaches importance to environmental protection activities, establishes environmental protection targets, and uses energy-saving technologies. In addition, a green credit policy is an important criterion for the banking sector (Calthor et al., 2019). Companies in the fifth group are all from China, involving equipment manufacturing, transportation, and power. The concerned criteria are waste disposal, energy conservation reform, new energy, and energy conservation technology development. These companies pay more attention to the energy problem. In the sixth group, the financial industry predominates; this group also includes automotive manufacturing and energy. The most concerned criteria of green innovation practices are the improvement of energy efficiency, use of clean and renewable energy, and the formulation of environmental protection strategies. The seventh group's companies include communications, finance, energy, and retail industries. The criteria of these companies are green information and communication technology, green data centers, engaging with communities, and improvement of water use efficiency. The eighth group involves financial insurance, electric power, energy and chemical industries, medicine and the media, and so on. This group focuses on the use of clean and renewable energy, protection of nature and species diversity, environmental protection strategies, and engagement with communities. The ninth group is involved in many industries, but the main one is the energy industry. The main criteria are to reduce water pollution and waste, improve water use efficiency, and dispose of waste (Shao et al., 2017). The tenth group is mainly the insurance industry and also includes energy, electricity, mining, and automobile machinery manufacturing industries. The common criteria of such companies are waste recycling and the protection of natural and biological diversity. The eleventh group is mainly engaged in steel automobile manufacturing and the construction industry. This group pays more attention to green technology, including clean production technology, energy-saving and emission-reduction technologies, and lowcarbon technologies (Masso & Vahter, 2008). There are numerous green innovation projects in such companies. The companies in the twelfth group are in different types of industries. The criteria include training courses, the use of cleaning materials, chemical control, and green product design. There are a large number of companies in the thirteenth group. They are divided into several types, including energy, finance, medicine, food, information technology, and manufacturing. The criteria in this group are to reduce water pollution and waste, improve water use efficiency, use clean renewable energy, reduce the use of raw materials, and protect nature and biodiversity. The fourteenth group is mainly petrochemical and machinery manufacturing, focusing on green product design, the control of chemicals, and green innovation projects.

In addition to intragroup analysis, an intergroup analysis is also needed. First, the thirteenth group contains 71 companies, accounting for one third of the total number of clusters, indicating that the corresponding criteria of this group are the common concern of most companies when performing green innovation. In addition, there are three criteria, including energy-saving technology, engaging with communities and green innovation programs, which also appear in three groups; the companies are highly concerned with these three criteria. At the same time, the frequency of criteria related to water resources and energy exceeded a value of 7 in all 14 groups, reflecting the importance of water resources and energy in green innovation practice (Gao et al., 2020). Second, there are some criteria that only appear in one group, which reflects the particular characteristics of the companies in this group. For example, the second group focuses on cooperation with suppliers and green offices, the companies in the third group have more green patents, the fourth group of companies focuses on carrying out a series of environmental activities and is good at setting goals, and the eleventh group is primarily concerned with green technology (Fujii & Managi, 2019). The above analysis shows that there are similar green innovation practices between different groups, and there are also differences according to their own actual situations. In summary, the research result reveals similarities and differences in the green innovation practices. Furthermore, to provide valuable reference for companies' decision-making of green innovation practices, we summarize six categories of industries with obvious characteristics in the above groups and propose corresponding measures, as shown in Table 4. From Table 4, for those companies exploring or intending to carry out green innovation, they can locate themselves into their own industry and make their own green innovation and development path by referring to the corresponding green innovation measures. For instance, companies in the energy industry can implement green innovation by actively developing green innovation programs, applying green patents and improving water use efficiency. The retail and material supply industry can carry out green innovation through energy-saving reform, improving the transportation mode, establishing a green data center, engaging with communities, and so on. In addition, the industry generally pays attention to water conservation and the protection of nature and species diversity and reflects the social responsibility of the companies and actively generates a good image of consciousness in the process of green innovation. In addition, some companies of an industry are distributed discretely, or the number in a group is small; they cannot present a certain trend, such as the communication industry, mineral industry, and entertainment industry, so we do not give a unified proposal for these types of companies, but we can search for similar business companies as references in the relevant industry.

Table 4. Green Innovation Measures for Companies

Category	Industry	Measures
1	Energy-related industries	Carry out green innovation programs, apply for green patents; conserve water, improve the utilization of water resources; address waste and focus on the protection of natural and biological diversity
2	Finance-related industries	Implement green offices, save paper; use clean renewable energy, and develop an environmental strategy; focus on waste recycling as well as the protection of nature and biodiversity
3	Diet and pharmaceutical industries	Cooperate with suppliers; conserve water and increase water use efficiency; use clean renewable energy and recycle waste materials; protect nature and biodiversity
4	Machinery manufacturing industries	Conserve water, increase water use efficiency; carry out green innovation programs and develop or introduce various green technologies; pay attention to the disposal of waste and protect the diversity of nature and biology
5	Electronic information and high-tech industries	Use clean renewable energy; conserve water and increase water use efficiency; cooperate with suppliers and implement green offices; protect the diversity of nature and biology
6	Retail and material supply industries	Engage with communities; establish a green data center; carry out energy saving reform; improve the transportation mode

Theoretical and Managerial Implications

First, we enrich the research on the criteria framework for green innovation practices. Such a criteria framework is basic and important for the study of influencing factors or evaluations. Researchers in the field of green innovation mostly focus on research on driving factors and influential mechanisms, among other factors, whereas the systematic and holistic criteria are lacking (H. J. Chen, 2012). In this study, we not only consider the common dimensions such as "Green technology," "Energy," and "Materials" but also certain distinctive dimensions such as "Cooperation" and "Green finance" to determine corresponding criteria. This new criteria system offers comprehensive insight for the green innovation practices of companies. Second, we enrich the methodology of green innovation. Specifically, we integrate the methods of literature research and content analysis. The dimensions of green innovation practices are taken from the existing literature. Based on these dimensions, the criteria are obtained from data of Fortune 500 companies by using content analysis. For instance, the corresponding criteria of the dimension "green technology" are energy-saving technology, clean production technology, resource conservation technology, waste recycling technology, and green information and communication technology. The corresponding criteria of the dimension "cooperation" are cooperation with suppliers, participation in green organizations, cooperation with peers, and cooperation with universities and research institutions. The data released by the

official websites of companies are scattered and numerous, so it is difficult to apply a homogeneous approach to utilize these data (Chan et al., 2016). Through the integration of literature research and content analysis, the research results of previous scholars can be included; in addition, valuable information contained in a large amount of company data can be mined, which greatly improves the credibility and reference value of the research. Finally, there are also important managerial implications according to the research results. By exploring the green innovation practices of companies in different industries, we propose suitable measures for green innovation. Other companies can refer to these measures to improve the efficiency of green innovation. According to the criteria of green innovation practices, companies with high correlation are clustered into 14 groups. Each group of companies places special attention on the aspect of green innovation. It can be seen that different green innovation practices of companies are based on their own different business characteristics and business modes. For example, in the first group, there are many companies in the retail and material supply industry, which are keen on energy conservation and improvement of transportation modes, as well as engagement with communities. The companies in the third group are mainly in the energy industry, which concerns green patents and green innovation programs. There are more companies in the financial sector in the eighth group. The use of clean renewable energy and the formulation of environmental strategies are the key strategies for these companies. The eleventh group contains mainly iron and steel industries and automobile manufacturing companies. Green innovation practices focus on green technologies, including clean production technology, energy-saving technology, and resource saving technology. At the end of this study, we summarize these groups as six industries according to industry characteristics, propose suitable green innovation measures for each industry, and then provide more direct reference to other companies. Specifically, the energy industry can actively carry out green innovation programs, apply for green patents, and focus on the disposal of waste. For the financial industry, the development of specific environmental strategies and green offices is necessary. The diet and pharmaceutical industry is recommended to work with suppliers to reduce the consumption of raw materials. The mechanical manufacturing industry should improve the importance of green technology, whereas some electronic information and high-tech industries should focus on the use of clean energy. The relevant companies in the retail and material supply industry can try to improve the mode of transportation by rationally optimizing the route and distributing transportation tools. Other companies can also look for industries with similar types and learn from the corresponding green innovation measures to improve the efficiency of green innovation.

Level of Green Innovation Practice

Finally, a greater portion of slightly more than 41 per cent reported to have been practising 'advanced' (greenest) level of green innovation activities.

Table 7 shows the data related to the green innovative practice based on the year of establishment of the organisations. Among those respondent industrial units

Table 5. Perceived Level of Green innovation Practice

Sr. No	Statements	Weights					Total	Mean	SD
		SDA(I)	D(2)	N(3)	A (4)	SA(5)			
1	Examining environmental information in business decision making	28 (8.2)	11 (3.2)	24 (7.0)	64 (18.8)	214 (62.8)	341 (100)	4.25	1.23
2	Impact of Environmental issues in personnel recruitment and training.	91 (26.7)	88 (25.8)	65 (19.1)	47 (13.8)	50 (14.6)	341 (100)	2.64	1.39
3	Impact of Environmental issues on advertisement and communication campaigns	101 (29.6)	84 (24.6)	65 (19.1)	44 (12.9)	47 (13.8)	341 (100)	2.57	1.39
4	Impact of Environmental issues in personal contacts// selling	95 (27.8)	88 (25.8)	77 (22.6)	65 (19.1)	16 (4.7)	341 (100)	2.47	1.21
5	Importance of environmental friendliness when planning the competitive emphasis for the price	11 (3.2)	16 (4.7)	43 (12.6)	87 (25.5)	184 (54.0)	341 (100)	4.22	1.05
6	Impact of Environmental issues on values and philosophy	61 07.9)	98 (28.7)	94 (27.6)	65 (19.1)	23 (6.7)	341 (100)	2.68	1.1
7	Considering environmental concerns in strategic planning	44 (12.9)	69 (20.2)	81 (23.8)	52 (15.2)	95 (27.9)	341 (100)	3.25	13
Overall responses (percentage)		431 (18.1)	454 (19.0)	449 (18.8)	424 (17.8)	629 (26.4)	2387 (100)	3.15	1.2

Source: Researchers data

Table 6. Level of Green Innovation Practices

Level Of Green Marketing Practice	Range of Scores	Number	Percentage
Green (1)	7-15	128	37.5
Greener(2)	16-25	73	21.4
Greenest(3)	26-35	140	41.1
Mean= 2.03		341	100.0

Source: Researchers data

Note -Figures in parentheses indicate percentages to the respective total

established prior to 1980, 47.6 per cent engaged only at the 'basic' level of green innovative activities, 44.5 per cent of the organisations that practised 'advanced' level of green innovative belonged to the units established between 1980-1990, 38.7 per cent were established between 1990-2000 and 38.9 per cent were established in the year 2000 onwards. This trend reveals that there is no significant association between the age of the organisation and level of green innovative practice (X2=5.197, p=0.519, Cramer's V=0.073). Therefore, level of green innovative practice is not associated with the age of the organisation

With regard to the relationship between ownership pattern of the organisation and the level of green innovative practice, nearly 52 per cent of the private sector organisations and 50 per cent of the multinational corporations (MNCs) engaged the advanced (greenest) level of green innovative practice. However, around 52 per cent of the public sector organisations reported that they implemented only 'basic' level of green innovative activities (Table 8). From this analysis it is clear that there is

Table 7. Year of Establishment (Age of the Organisation) and the Level of Green Innovative Practices

Year of establishment	Level of Green Innovative Practices			Total
	Green	Greener	Greenest	
Prior to 1980	10 (47.6)	05 (23.8)	06 (28.6)	21 (100.0)
1980-1990	59 (34.1)	37 (21.4)	77 (44.5)	173 (100.0)
1990-2000	54 (41-9)	25 (19.4)	50 (38.7)	129 (100.0)
2000 onwards	05 (27.8)	06 (33.3)	07 (38.9)	18 (100.0)
	128 (37.5)	73 (21.4)	140 (41.1)	341 (100.0)

Note -Figures in parentheses indicate percentages to the respective total

Table 8. Ownership pattern and Level of Green Innovative Practices

Year of establishment	Level of Green Innovative Practices			Total
	Green	Greener	Greenest	
Private	60 (30.4)	35 (17.8)	102 (51.8)	197 (100.0)
Public	63 (51.7)	32 (26.2)	27 (22.1)	122 (100.0)
MNC	05 (22.7)	06 (27.3)	11 (50.0)	22 (100.0)
	128 (37-5)	73(21-4)	140(4M)	341 (100-0)

Source: Researchers data

Note: Figures in parentheses indicate percentages to the respective total.

high degree of association between the green innovative practice and the ownership pattern of the organisation.

The relevant data and information in respect of industrial category and the level of green innovative practices are presented in table 9. Among those industrial units practising advanced level of green innovative, mention may be made of such industrial categories as steel (45.4%), chemicals (37.5%), food & beverages (34.6%), consumer durables (53.2%), and banking & finance (75%). On the other hand, some of the industrial sectors identifying with basic and intermediate levels of green innovative practice were mining, textiles and fertilizers. Finally, greater proportions of those organisations belonging to insurance (40%), marketing and distribution (39.1%), and education and consulting (41.7%) were engaged only in the basic level of green innovative practice. Further the results of ANOVA shows that the F value = 5.21. This value reveals a very highly significant relationship between industrial category and the level of green innovative practices (Fvalue = 5.21, p=0.0005).

As projected in Table-6.7 it is interesting to observe that the association between the ISO accreditation status of the organisation and the level of green marketing practices was highly significant. As such, a little over 50 per cent of the ISO accredited organisations engaged at the advanced level of green innovation practice. Not surprisingly, in contrast, 66 to 67 per cent of the organisations that are either in the process of obtaining ISO accreditation or without ISO certification implemented only 'basic' level of green innovation activities.

Regression analysis results show that green innovation explains %57,3 of change in environmental performance of a company and %31,1 of change in competitive advantage. The effect of green innovation on environmental performance is higher than competitive advantage. Both hypotheses are supported. On the other hand, we looked also green product and green process innovations' effects on both environmental performance and competitive advantages separately with multiple regression analysis. According to correlation analysis results, firstly green process innovation

Table 9. Industrial Category and the Level of Green Innovative Practices –ANOVA

Sn	Industrial Category	Level of Green Innovative Practices			Total	Mean	S.D	Mean (%)
		Green	Greener	Greenest				
1	Mining	03 (37.5)	03 (37.5)	02 (25.0)	08 (100.0)	1.88	0.78	62.5
2	Steel	04 (36.4)	02 (18.2)	05 (45.4)	11 (100.0)	2.09	0.90	69.7
3	Textiles	05 (35.7)	05 (35.7)	05 (35.7)	04 (28.6)	14 (100.0)	1.93	64.3
4	Chemicals	19 (47.5)	06 (15.0)	15 (37.5)	40 (100.0)	1.90	0.92	63.3
5	Food and beverages	24 (46.2)	10 (19.2)	18 (34.6)	52 (100.0)	1.88	0.89	62.8
6	Fertilizers	02 (14.2)	06 (42.9)	06 (42.9)	14 (100.0)	2.29	0.70	76.2
7	Consumer durables	32 (40.5)	05 (6.3)	42 (53.2)	79 (100.0)	2.13	0.96	70.9
8	Banking and finance	03 (9.4)	05 (15.6)	24 (75.0)	32 (100.0)	2.66	0.64	88.5
9	Insurance	04 (40.0)	03 (30.0)	03 (30.0)	10 (100.0)	1.90	0.83	63.3
10	Marketing & Distribution	27 (39.1)	25 (36.2)	17 (24.7)	69 (100.0)	1.86	0.79	61.8
11	Education & consulting	05 (41.7)	03 (25.0)	04 (33.3)	12 (100.0)	1.92	0.86	63.9
		128 (37.5)	73 (21.4)	140 (41.1)	341 (100.0)	1.88	0.78	62.5

Source: Researchers data

Note: (1) Figures in parentheses indicate percentages to the respective total.

Table 10. ISO Accreditation Status and Level of the Green Innovation Practices

ISO Status	Level of Green Innovative Practices			Total
	Green	Greener	Greenest	
ISO accredited	51 (22.6)	61 (27.0)	114 (50.4)	226 (100.0)
In the process of getting Certified	29 (65.9)	07 (15.9)	08 (18.2)	44 (100.0)
Non-ISO	48 (67.6)	05 (7.0)	18 (25.4)	71 (100.0)
	128 (37.5)	73(21.4)	140(41.1)	341 (100.0)

Table 11. Correlation coefficient matrix

Pearson Correlation Analysis	Environmental performance	Competitive advantage
Green innovation	.759*	.562*
Green product innovation	.589*	.424*
Green process innovation	.733*	.553*
* Correlation coefficient is significant at the 0.01 level		

and after both sub-dimensions were added to analysis. Green process innovation explains % 53,4 of environmental innovation and %30,1 of competitive advantage unaccompanied by green product innovation. Hence, green process innovation has much more importance than green product innovation on environmentally sensitive company performance sub-dimensions same as environmentally sensitive company performance.

Table 12. Regression analysis results

Dependent variables	Environmental performance	Competitive advantage
Independent variable: Green innovation		
R2	.575	.316
Adjusted R2	.573	.311
F	216,789	73,780
Sig	.000	.000

Lastly, we performed t-test and Anova analysis in order to find out any difference on variables according to; environmental reward ownership of company, respondents' department within the company, company's industry and duration of ISO14001 certificate of company. For environmental ownership situation, there is no difference on green innovation or environmental performance; however rewarded companies' competitive advantage average is higher than companies which have no reward about their environmental success. For respondents' department there is no significant difference on any variables. According to company's industry there is no significant difference on environmental performance or competitive advantage. But for green innovation variable there is a significant difference between automotive and energy sectors (Aveauto =4.2560 > Aveenergy = 3.6667). For ISO14001 certification duration, also there is significant difference for green innovation variable. Companies

which have ISO14001 certificate more than 10 years have higher average value than other groups.

ASSOCIATION OF FEW COMPANIES WITH CLEAN DEVELOPMENT MECHANISM (CDM) PROJECTS AND CARBON TRADING

Renewable Power Sources-Solar-Powered Corporations

The top corporations using solar power based on megawatts (MW) installed:

1. Target Corporation: 147.5 MW
2. Walmart: 145 MW
3. Prologis: 107.9 MW
4. Apple: 93.9 MW
5. Costco Wholesale: 50.7 MW
6. Kohl's: 50.2 MW
7. IKEA: 44.MW
8. Macy's: 38.9 MW
9. General Growth Properties: 30.2 MW
10. Hartz Mountain Industries: 22.7 MW

Green Risk Resilient Supply Chain

- Climate change risk propagation: It is critical for supply chains to understand the complex behaviour of risk and its cascading impact on the network (Bueno-Solano and Cedillo-Campos, 2014; Scheibe and Blackhurst, 2017; Ghadge et al., 2018). The longterm impact of climate change is found to be propagating from food to manufacturing, to logistics, due to intra-sector network dependencies. The study found climate change and supply chain operations mutually influence each other. The impact of global supply chains on climate change, beyond calculating GHG emissions, is an unexplored avenue. Holistic understanding of climate change and cascading risks is critical. Robust climate change models can be developed to quantify the impact and propose appropriate adaptation strategies.
- Sustainable practices for climate change mitigation: Several sustainable practices can be implemented to reduce the impact on social and environmental dimensions (Pagell and Shevchenko, 2014). Focused research on mitigating climate change by adopting sustainable practices is likely to reduce the

long-term impact of climate change on global supply chains. The impact of implementing sustainability practices on climate change is not explored in the literature. This interconnected link is expected to provide crucial insights into future mitigation strategies.

- Approaches for climate change scenarios: Comprehensive analytical/ empirical modelling approaches can be explored to develop climate change scenarios, such as a rise in sea level, cold waves, change in seasons or water scarcity in certain parts of the world. Four distinct future climate scenarios are proposed in the Climate Change 2014 report (IPCC, 2014), but they are based on expected GHG emitted in the years to come. Similarly, scenarios with the use of different renewable energy sources and their broader implications for global supply chains may be useful. Systems theory has the potential for developing simulation models for future climate change scenarios.
- Adaptation and supply chain re-design: Climate change is inevitable and today's supply chain managers need to adapt by re-designing their networks to build in resilience to unforeseen future disruptions. There is an urgent need to find ways to limit risks through substantial and sustained mitigation actions for climate change (Howard-Grenville et al., 2014). Furthermore, the findings indicate that developing innovative drivers for controlling climate change is crucial. Exploring opportunities resulting from climate change is an unexplored area. Melting of ice resulting in the opening of northern sea routes or improved road conditions in Canada may positively affect global supply chain networks. These opportunities would require re-designing of supply chains.
- Carbon supply chains management: Carbon capture utilization and storage/ sequestration (CCUS) is an integrated suite of technologies which can capture carbon dioxide from waste gases, and store carbon dioxide for long-term for use in industrial processes such as chemical production or enhanced oil recovery (Fanchi et al., 2016). Such initiatives (supported by Governments, policy makers) will help to mitigate climate change risk as well as reduce pressure on use of fossil fuels for energy. Hansen et al. (2015) attempted a network optimization for Carbon capture utilization and sequestration to minimize supply chain cost, while reducing stationary CO2 emissions. Designing and managing such unique supply chain networks for carbon capture, storage, transportation and usage will be an interesting future research area, we term this as 'Carbon Supply Chain Management'.
- It is observed that climate change has a significant effect on the demand and supply of goods, food, water, energy and agricultural products. Throughout the study, it was found that climate change and the supply chain are mutually influencing each other. 'Internal' sources are mainly driven by global supply

chain operations (production, transportation, overuse of resources) and are responsible for an increase in GHG emissions. Similarly, 'external' sources driven by climate change (e.g. extreme weather conditions, global warming) are negatively impacting supply chain operations in the form of natural disruptions.

CONCLUSION

With the rapid growth of the economy, the environment is deteriorating daily. Frequent environmental problems have sounded alarm bells for human society. As an important part of society, companies are exploring green innovation to improve their competitiveness and achieve green development. This research takes the world's top 500 companies as the research object and uses a content analysis method to extract data published by companies that reflect the practices of green innovation. The results indicate that the green innovation adopted by companies in different industries has different characteristics. Among them, the energy industry, the financial industry, the diet and pharmaceutical industry, machinery manufacturing industry, electronic information and high-tech industries, and retail and materials supply industry show obvious characteristics of the industry. The companies in each industry have their own measures and practices of green innovation. In addition, companies with green innovation pay more attention to the protection of water resources and the use of clean energy. The protection of nature and biodiversity is also a strong concern of companies. This information provides guidance for companies that are going to carry out green innovation or are in the green innovation exploration stage.

REFERENCES

Albort-Morant, G., Leal-Rodríguez, A. L., & De Marchi, V. (2018). Absorptive capacity and relationship learning mechanisms as complementary drivers of green innovation performance. *Journal of Knowledge Management*, *22*(2), 432–452. doi:10.1108/JKM-07-2017-0310

Axon, S. (2016). "The good life": Engaging the public with community-based carbon reduction strategies. *Environmental Science & Policy*, *66*, 82–92. doi:10.1016/j.envsci.2016.08.007

Aziz, T. N. A. T., Jaafar, H. S., & Tajuddin, R. M. (2016). Green supply chain: Awareness of logistics industry in Malaysia. *Procedia: Social and Behavioral Sciences*, *219*, 121–125. doi:10.1016/j.sbspro.2016.04.052

Bal, Y., Faure, M., & Liu, J. (2013). The role of China's banking sector in providing green finance. *Duke Environmental Law & Policy Forum*, *24*, 89–140.

Beise, M., & Rennings, K. (2005). Lead markets and regulation: A framework for analyzing the international diffusion of environmental innovations. *Ecological Economics*, *52*(1), 5–17. doi:10.1016/j.ecolecon.2004.06.007

Blättel-Mink, B. (1998). Innovation towards sustainable economy—The integration of economy and ecology in companies. *Sustainable Development*, *6*(2), 49–58. doi:10.1002/(SICI)1099-1719(199808)6:2<49::AID-SD84>3.0.CO;2-I

Camprubí, R., & Coromina, L. (2016). Content analysis in tourism research. *Tourism Management Perspectives*, *18*, 134–140. doi:10.1016/j.tmp.2016.03.002

Chan, H. K., Wang, X., Lacka, E., & Zhang, M. (2016). A mixedmethod approach to extracting the value of social media data. *Production and Operations Management*, *25*(3), 568–583. doi:10.1111/poms.12390

Chang, K., Zeng, Y., Wang, W., & Wu, X. (2019). The effects of credit policy and financial constraints on tangible and research & development investment: Firm-level evidence from China's renewable energy industry. *Energy Policy*, *130*, 438–447. doi:10.1016/j.enpol.2019.04.005

Chen, H. J. (2012). *Research on green driving mechanism and driving strength evaluation method of supply chain* [Doctoral thesis]. Jilin University.

Chen, Y. S., Lai, S. B., & Wen, C. T. (2006). The influence of green innovation performance on corporate advantage in Taiwan. *Journal of Business Ethics*, *67*(4), 331–339. doi:10.100710551-006-9025-5

Chouinard, Y., & Brown, M. S. (1997). Going organic: Converting Patagonia's cotton product line. *Journal of Industrial Ecology*, *1*(1), 117–129. doi:10.1162/jiec.1997.1.1.117

Costantini, V., Crespi, F., Marin, G., & Paglialunga, E. (2016). Eco-innovation, sustainable supply chains and environmental performance in European industries. *Journal of Cleaner Production*, *155*, 141–154.

Cui, L. (2017). Fuzzy approach to eco-innovation for enhancing business functions: A case study in China. *Industrial Management & Data Systems*, *117*(5), 967–987.

Cui, L., Chan, H. K., Zhou, Y., Dai, J., & Lim, J. J. (2019). Exploring critical factors of green business failure based on Grey-Decision Making Trial and Evaluation Laboratory (DEMATEL). *Journal of Business Research*, *98*, 450–461. doi:10.1016/j.jbusres.2018.03.031

Darnall, N., Henriques, I., & Sadorsky, P. (2010). Adopting proactive environmental strategy: The influence of stakeholders and firm size. *Journal of Management Studies*, *47*(6), 1072–1094. doi:10.1111/j.1467-6486.2009.00873.x

Duriau, V. J., Reger, R. K., & Pfarrer, M. D. (2007). A content analysis of the content analysis literature in organization studies: Research themes, data sources, and methodological refinements. *Organizational Research Methods*, *10*(1), 5–34. doi:10.1177/1094428106289252

El-Kassar, A. N., & Singh, S. K. (2019). Green innovation and organizational performance: The influence of big data and the moderating role of management commitment and HR practices. *Technological Forecasting and Social Change*, *144*, 483–498. doi:10.1016/j.techfore.2017.12.016

Elo, S., & Kyngäs, H. (2008). The qualitative content analysis process. *Journal of Advanced Nursing*, *62*(1), 107–115. doi:10.1111/j.1365-2648.2007.04569.x PMID:18352969

Esty, D. C., & Winston, A. S. (2006). *Green to gold: How smart companies use environmental strategy to innovate, create value, and build competitive advantage*. John Wiley.

Etzion, D. (2007). Research on organizations and the natural environment, 1992-present: A review. *Journal of Management*, *33*(4), 637–664. doi:10.1177/0149206307302553

Fujii, H., & Managi, S. (2019). Decomposition analysis of sustainable green technology inventions in China. *Technological Forecasting and Social Change*, *139*, 10–16. doi:10.1016/j.techfore.2018.11.013

Gao, C., Na, H., Song, K., Tian, F., Strawa, N., & Du, T. (2020). Technologies-based potential analysis on saving energy and water of China's iron and steel industry. *The Science of the Total Environment*, *699*, 134225. doi:10.1016/j.scitotenv.2019.134225 PMID:31677463

Gou, Z., Lau, S. Y., & Chen, F. (2012). Subjective and objective evaluation of the thermal environment in a three-star green office building in china. *Indoor and Built Environment*, *21*(3), 412–422. doi:10.1177/1420326X11419311

Gunasekaran, A., & Spalanzani, A. (2012). Sustainability of manufacturing and services: Investigations for research and applications. *International Journal of Production Economics*, *140*(1), 35–47. doi:10.1016/j.ijpe.2011.05.011

Hagen, L. (2018). Content analysis of e-petitions with topic modeling: How to train and evaluate LDA models? *Information Processing & Management*, *54*(6), 1292–1307. doi:10.1016/j.ipm.2018.05.006

Halila, F., & Rundquist, J. (2011). The development and market success of eco-innovations: A comparative study of eco-innovations and "other" innovations in Sweden. *European Journal of Innovation Management*, *14*(3), 278–302. doi:10.1108/14601061111148807

Hashemi, S. H., Karimi, A., & Tavana, M. (2015). An integrated green supplier selection approach with analytic network process and improved Grey relational analysis. *International Journal of Production Economics*, *159*, 178–191. doi:10.1016/j.ijpe.2014.09.027

Irena, V. (2015). Triple Helix Model of university–industry– government cooperation in the context of uncertainties. *Procedia: Social and Behavioral Sciences*, *213*, 1063–1067. doi:10.1016/j.sbspro.2015.11.526

Kemp, R., & Pearson, P. (2007). *Final report MEI project about measuring eco-innovation*. United Nations University–MERIT.

Kim, J., & Park, K. (2018). Effect of the Clean Development Mechanism on the deployment of renewable energy: Less developed vs. well-developed financial markets. *Energy Economics*, *75*, 1–13. doi:10.1016/j.eneco.2018.07.034

Knez, M., Bajor, P., & Seme, S. (2011). Green logistics—A solar warehouse concept. *Logistics & Sustainable Transport*, *2*(2), 1–8.

Kondracki, N. L., Wellman, N. S., & Amundson, D. R. (2002). Content analysis: Review of methods and their applications in nutrition education. *Journal of Nutrition Education and Behavior*, *34*(4), 224–230. doi:10.1016/S1499-4046(06)60097-3 PMID:12217266

Laari, S., Töyli, J., & Ojala, L. (2017). Supply chain perspective on competitive strategies and green supply chain management strategies. *Journal of Cleaner Production*, *141*, 1303–1315. doi:10.1016/j.jclepro.2016.09.114

Li, D., Zhao, Y., Zhang, L., Chen, X., & Cao, C. (2018). Impact of quality management on green innovation. *Journal of Cleaner Production*, *170*, 462–470. doi:10.1016/j.jclepro.2017.09.158

Li, D., Zheng, M., Cao, C., Chen, X., Ren, S., & Huang, M. (2017). The impact of legitimacy pressure and corporate profitability on green innovation: Evidence from China top 100. *Journal of Cleaner Production*, *141*, 41–49. doi:10.1016/j.jclepro.2016.08.123

Li, Q. H. (2014). *Green innovation of production enterprises: Influencing factors and performance* [Doctoral thesis]. Southwestern University of Finance and Economics.

Li, W. Y., Chow, P. S., Choi, T. M., & Chan, H. L. (2016). Supplier integration, green sustainability programs, and financial performance of fashion enterprises under global financial crisis. *Journal of Cleaner Production*, *135*, 57–70. doi:10.1016/j.jclepro.2016.06.048

Liang, J., Feng, C. J., & Song, P. (2016). A summary of large data correlation analysis. *Journal of Computational Science*, *1*, 1–18.

Liao, Z. (2018). Content analysis of China's environmental policy instruments on promoting firms' environmental innovation. *Environmental Science & Policy*, *88*, 46–51. doi:10.1016/j.envsci.2018.06.013

Liu, P., Zhou, Y., Zhou, D. K., & Xue, L. (2017). Energy performance contract models for the diffusion of green-manufacturing technologies in China: A stakeholder analysis from SMEs' perspective. *Energy Policy*, *106*, 59–67. doi:10.1016/j.enpol.2017.03.040

Masso, J., & Vahter, P. (2008). Technological innovation and productivity in late-transition Estonia: Econometric evidence from innovation surveys. *European Journal of Development Research*, *20*(2), 240–261. doi:10.1080/09578810802060751

Mele, C., & Russo-Spena, T. (2015). Eco-innovation practices. *Journal of Organizational Change Management*, *28*(1), 4–25. doi:10.1108/JOCM-08-2013-0146

Miah, S. J., Gammack, J., & Hasan, N. (2017). Extending the framework for mobile health information systems research: A content analysis. *Information Systems*, *69*, 1–24. doi:10.1016/j.is.2017.04.001

Mina, H., Mirabedini, S. N., Kian, H., & Ghaderi, S. F. (2014). A new two stage integrated approach for green supplier selection. Applied Mathematics in Engineering. *Management and Technology*, *1*, 1247–1126.

Moldavska, A., & Welo, T. (2017). The concept of sustainable manufacturing and its definitions: A content-analysis based literature review. *Journal of Cleaner Production*, *166*, 744–755. doi:10.1016/j.jclepro.2017.08.006

Nieminen, E., Linke, M., Tobler, M., & Beke, B. V. (2007). EU COST Action 628: Life cycle assessment (LCA) of textile products, eco-efficiency and definition of best available technology (BAT) of textile processing. *Journal of Cleaner Production*, *15*(13–14), 1259–1270. doi:10.1016/j.jclepro.2006.07.011

Ociepa-Kubicka, A., & Pachura, P. (2017). Eco-innovations in the functioning of companies. *Environmental Research*, *156*, 284–290. doi:10.1016/j.envres.2017.02.027 PMID:28395239

Safari, A., Salehzadeh, R., Panahi, R., & Abolghasemian, S. (2018). Multiple pathways linking environmental knowledge and awareness to employees' green behavior. Corporate Governance. *The International Journal of Business in Society*, *18*(1), 81–103.

Schiederig, T., Tietze, F., & Herstatt, C. (2012). Green innovation in technology and innovation management—An exploratory literature review. *R & D Management*, *42*(2), 180–192. doi:10.1111/j.1467-9310.2011.00672.x

Shao, W., Feng, J., Liu, J., Yang, G., Yang, Z., & Wang, J. (2017). Research on the status of water conservation in the thermal power industry in China. *Energy Procedia*, *105*, 3068–3074. doi:10.1016/j.egypro.2017.03.639

Chapter 6
Digital Preservation of Cultural Heritage:
Digital Innovative Approach Towards Sustainable Development of South African Rural Communities

Tlou Maggie Masenya
Durban University of Technology, South Africa

ABSTRACT

Given that cultural heritage resources are irreplaceable, their protection is critical. Digital preservation has become a popular method for safeguarding cultural heritage resources in recent years. The purpose of this chapter was to determine how digital preservation can be used as a strategy to promote access to cultural heritage for sustainable development of South African rural communities. Data collection was based on a critical review of literature in order to analyze policy and mechanisms being put in place for effective preservation of cultural heritage. Findings revealed that most of African rural communities do not have mechanisms for safeguarding their cultural heritage, and there is lack of technological tools for preservation of cultural heritage. Cultural heritage policy should also be implemented and better explained to the rural communities' authorities.

DOI: 10.4018/978-1-7998-5879-9.ch006

INTRODUCTION

Cultural heritage has in recent years become a key driver for sustainable and territory development. Falser (2011) describe cultural heritage as the legacy of physical artifacts and intangible attributes of a group society that is inherited from past generations. It includes artefacts, monuments, and groups of buildings and sites that have a diversity of values including symbolic, historic, artistic, aesthetic, or anthropological, scientific and social significance (UNESCO, 2009). Petti, Trillo and Makore (2020) further described cultural heritage as the element that shapes the so called five senses, namely: historic buildings and environment, create the senses of belonging somewhere, of social traditions and cultural identity of historic continuity and foster the senses of ownership and responsibility. As pointed out by Aparac-Jelušić (2017) cultural heritage can be instrumental in enhancing social inclusion, stimulating and supporting intercultural dialog, shaping the identity of a territory, improving the quality of the environment, and nourishing social cohesion, as well as sense of self and belonging, when properly managed.

Cultural heritage can also be valued in a wide variety of ways, from the aesthetic and emotional pleasure gained from experiencing heritage sites, to the value of those sites as generators of revenue, jobs and training opportunities, as noted by Axelsson (2013). Tonta (2016) also stated that cultural heritage has an indirect effect on economy, by stimulating tourism development (promoting cultural tourism), hospitality sectors and the emergence of new trades and activities as well as creating employment opportunities and providing income. Various economic benefits can thus be generated by cultural heritage and its preservation, and among these are job and household income creation, job training, city center revitalization, heritage tourism, increase in property values, small business incubation, compatibility with modernization and compatibility with evolution, product differentiation and import substitution (Petti, Trolli & Makore, 2019). However, as stated by Grazuleviciute-Vileniske (2006), cultural heritage is not just of value to the individuals who own it or live in historic properties, it can also have a value to well-being and quality of life of communities, can help mitigate the impacts of cultural globalization and can become an incentive for sustainable development. Therefore, in order to implement sustainable development strategies and to improve quality of life, it is essential to use the potential of cultural heritage, especially the possibilities embodied in abandoned historic buildings and territories (Grazuleviciute-Vileniske, 2006).

Fostering local distinctiveness and sustaining cultural heritage are therefore the keys of building sustainable communities, as stated by Koch (2018). For example, the government of the United Kingdom has recognized that cultural heritage and historic environment can play a significant role towards meeting the defined sustainability targets (Axelsson, 2013). As a result, the Deputy Prime Minister in United Kingdom

implemented the strategy for sustainable development, the Communities Plan, a long-term program of action for creating and maintaining sustainable communities in rural and urban areas (Power, 2004). The Community Plan lists a set of key requirements for sustainable communities that includes a sense of place, a safe and healthy local environment with well-designed public and green space, and a diverse vibrant and creative local culture encouraging pride in the community (Power, 2004).

However, cultural heritage can be divided into tangible and intangible. Tangible cultural heritage refers to physical artefacts produced, maintained and transmitted intergenerationally in a society and it includes artistic creations, built heritage such as buildings and monuments, and other physical or tangible products of human creativity that are invested with cultural significance in a society (UNESCO, 2003). UNESCO (2003b) also defines intangible cultural heritage as the practices, representations, expressions, knowledge, skills as well as the instruments, objects, artefacts and cultural spaces associated with communities, groups and, in some cases, individuals recognize as part of their cultural heritage. Intangible heritage is conceptualized into five categories focused on traditional social practices and processes, craftsmanship, rituals and arts (Amer, 2017). However, tangible and intangible heritage require different approaches for preservation and safeguarding, which has been one of the main motivation driving the conception and ratification of the UNESCO Convention for the safeguarding of the intangible cultural heritage (UNESCO, 2003). The Convention stipulates the interdependence between intangible cultural heritage, tangible cultural heritage and natural heritage, and acknowledges the role of intangible cultural heritage as a source of cultural diversity and a driver of sustainable development (UNESCO, 2003). The value and importance of cultural heritage, the definition of which expanded to include intangible and digital assets along with tangible ones, has long been recognized and efforts for its preservation have gained momentum throughout the world (UNESCO, 2003).

UNESCO (2003a) has also recognizes that resources of information and creative expression are increasingly produced, distributed, accessed and maintained in digital form, creating a new legacy called the digital heritage. The digital heritage consists of resources not only created digitally (born-digital) but also converted into digital form from existing analogue resources. In addition to cultural resources, digital heritage includes scientific, technical, educational, legal, medical, administrative and other kinds of resources which are on various formats such as texts, audio, still and moving images, graphics, software and web pages (UNESCO, 2003a). Many of these resources have lasting value and significance, and therefore constitute a heritage that should be protected and preserved for current and future generations (UNESCO, 2003a). As noted by Hosagrahar (2019) preserving cultural heritage provides environmental sustainability, cultural sustainability and economic sustainability. Cultural heritage value is thus a major reason behind the preservation

endeavors and the basis for its economic and social benefits. UNESCO's charter on the preservation of digital heritage also states that the purpose of preserving the digital heritage as to ensure that it remains accessible to the public and accordingly, access to digital heritage materials, especially those in the public, should be free of unreasonable restrictions (UNESCO, 2003). Therefore, preservation of cultural heritage and maintenance of historic environment play a significant role in many strategies of sustainable development. The outcome of the World Summit on the Information Society (WSIS) further stresses that:

We recognize that Information and Communications Technologies(ICTs) are also increasingly a means to support the diversity of cultural expression and the fast growing cultural and creative industries, and we affirm that comprehensive, practical digital strategies are needed for the preservation of cultural heritage and access to recorded information in the digital environment in all its forms(UNESCO, 2003).

In January 2010 the African Union head of state and government adopted a declaration that calls on the African countries to prioritize ICTs as a vehicle for driving Africa's development agenda. The increased use of ICT infrastructure was therefore viewed as the prerequisite for the African countries to develop the ICT sector and to also achieve sustainable development (South African Department of Arts & Culture, 2019). In this regard, numbers of countries, cities and communities have decided to develop measures for reaching the goals of sustainable development, and there are also increasing number of studies investigating the development of harmonized data in order to successfully achieve the Sustainable Development Goals (SDGs) (Koch, 2018). There are also established discourse on the documentation of cultural heritage and the development of heritage databases in implementing sustainable development for urban and rural areas, as noted by Shah (2016). This chapter has therefore focused on the digital preservation of cultural heritage for sustainable development of rural communities and what cultural heritage institutions should do in promoting and preserving cultural heritage, in order to support these communities in accessing, recovering and re-use their heritage for sustainable development.

RATIONALE FOR THE STUDY

Cultural heritage often remains an irreplaceable resource and the loss or the abandon of heritage is a risk that cannot be underestimated (UNESCO, 2003). However, with the move from an analogue object-based memory to a digital-based memory, librarians, archivists, governments and cultural heritage owners or communities are

facing new challenges in ensuring that our collective cultural heritage will not be lost (UNESCO, 2016). Therefore, according to Brungs and Wyber (2016), if cultural heritage institutions, governments, technology industry, individuals and all related stakeholders do not act now, we will lose our cultural heritage and our times will be a new dark age in history. The Sendai Framework for Disaster Risk Reduction 2015-2030 also stated that it is urgent and critical to anticipate plans to reduce disaster risk in order to more effectively protect persons, communities and countries, their livelihoods, health, cultural heritage, socioeconomic assets and ecosystems, and thus strengthen their resilience (United Nations, 2015). Digital preservation can be used as a strategy to enhance access and safeguarding cultural heritage for the development of societies and helps to build resilient communities. Enhancing access to cultural heritage thus allows for identity building, reconciliation, creativity, innovation, and many other activities that make societies stronger, richer and more peaceful (Brungs & Wyber,2016). However, despite the efforts that have been put in place in documenting and preserving cultural heritage, most of rural communities in Africa are still confronted with challenges such as poor governance, lack of supportive legislation, standards and procedures to regulate the storage, retrieval and preservation of cultural heritage resources and poor collaboration efforts and partnerships (Kanyengo, 2006; Ngulube, 2012 ; Sigauke & Nengomasha, 2011).

Barillet, Joffroy and Longuet (2006) concur that rural communities that have fully integrated the importance of documenting and preserving cultural heritage in their projects are facing a number of difficulties including financial problems and problems dealing with human competencies and skills. Although most of African rural communities recognized the importance of documenting and preserving their cultural heritage resources, they still do not have cultural heritage institutions such as museums, archives and libraries, and only few have established a proper inventory of their natural and cultural heritage (Barillet, Joffroy & Longuet, 2006). Many rural communities do not have mechanisms for safeguarding their heritage while very few are aware of the World Heritage Convention, National Heritage Repository and South African Heritage Resources Information System (SAHRIS) aimed at harmonizing data for the achievement of the SDGs. There is therefore, a paucity of studies that have explored the preservation of cultural heritage for sustainable development of rural communities in Africa, particularly in South Africa.

Digital preservation and valorization of cultural heritage has become a powerful instrument in the economic and territorial development of a community while also contributes to strengthening the local populations' pride, dignity and feeling of belonging, not to mention the job creation and revenue-making opportunities it offers them (Brungs & Wyber, 2016). However, according to Brungs and Wyber (2016) a challenge lies in the fact that cultural heritage institutions have the primary roles of preserving and providing access to cultural heritage, yet, the rural communities

require proper handling of their cultural heritage due to their deep connection to the community's spiritual beliefs, cultural identity, worldviews and indigenous laws. This chapter thus investigated digital preservation of cultural heritage for sustainable development of rural communities, a process that is poorly understood. It contributes to the limited knowledge base on digital preservation practices in Africa, particularly in South Africa where little attention has been paid to safeguarding cultural heritage. The following objectives were formulated to address the research problem:

- to examine the current state of safeguarding cultural heritage towards sustainable development of rural communities;
- to determine how digital preservation can be used as a strategy to promote and safeguard cultural heritage for sustainable development;
- to determine the role of cultural heritage institutions in promoting and preserving cultural heritage; and
- to assess the impact of policy on the promotion and preservation of cultural heritage.

RESEARCH METHODOLOGY

This qualitative study used literature review to investigate the promotion and preservation of cultural heritage towards sustainable development of South African rural communities. This methodology was used to apply and increase knowledge in a particular area of research thereby showing proficiency in reviewing, synthesizing and critically analyzing the relevant research literature. Secondary sources, including books, journals and research reports on initiatives published by governmental and international agencies available in official web sites as well as policy documents and articles on previous studies reporting on digital preservation of cultural heritage, were reviewed to address the research objectives.

AN OVERVIEW OF LITERATURE REVIEW

It has been accorded in literature review that cultural heritage play a significant role in sustainable cultural, social and economic development of communities. As stated by Petti, Trillo and Makore, (2019) protection and maintenance of cultural heritage thus play a crucial role for sustainability of rural communities, because all the cultural assets, theater, music, visual arts, crafts, local customs and traditions are inherently connected with and enhanced by the physical context within which they were created and evolved for centuries. However, cultural heritage is under constant

threat of destruction, such as neglect, destruction in war, conflict or natural disaster (IFLA, 2017), and as a result, significant cultural heritage worldwide have suffered a variety of fates. In addition to destruction, looting and dispersal, illegal trading, inadequate housing and funding have also played a part and many cultural heritage materials were looted and destroyed in various countries such as Libya, Egypt, Syria, Yemen and Bosnia (Moustafa, 2017). For example, Iraq lost many of its cultural heritage materials such as books, journals, newspapers and manuscripts during the war, and 60% of the library's historical documents were lost and 25% of its books were looted and damaged (Moustafa, 2017). Another example is the cultural heritage that was lost in Balkan countries in Europe in 1990s, due to conflicts. In 1992, The National and University Library in Sarajevo was also set on fire and more than million books and manuscripts were destroyed, and only 10% of the whole library collection was saved (Tonta, 2016). The archival documents belonging to the period of 1878-1918 were also damaged when The Archives of Bosnia Herzegovina was set on fire at the beginning of 2014 (Tonta, 2016). All these cultural heritage attacks prove the importance of safeguarding cultural heritage assets and these events have stirred the urgent need to explore imminent risks to cultural heritage. The preventive actions are therefore of utmost importance for the protection of cultural heritage resources. This constitute cultural heritage that should be protected and preserved for current and future generations, and also underscore the need for documentation and preservation of cultural heritage resources as well as the development of accurate databases in protecting cultural heritage from threats. Documenting and preserving cultural heritage has therefore been regarded as a way of appearing to recover and protect cultural heritage while at the same time enhancing access to this heritage and the potential for its exploitation (UNESCO, 2003).

The importance of preserving cultural heritage has also been recognized and regulated both nationally and internationally. Considerable efforts have been made over the past few years to document, protect and preserve cultural heritage for posterity and for the benefit of cultural heritage owners and their communities. Many of the initiatives were aimed at creating collaborative efforts in preservation and protection of cultural heritage materials, providing the necessary infrastructure and strengthening capacity for safeguarding cultural heritage in African countries. For example, organizations like the United Nations recognized not only how people interact with their cultural sites or rural territories, but also the fundamental need to preserve cultural heritage through international conventions (United Nations, 2015). Intergovernmental organization such as United Nations Educational, Scientific and Cultural Organization (UNESCO) adopted a Charter on the Preservation of the Digital Heritage in 2003 with the aim of intensifying projects for the safeguarding of documentary heritage resources (South African Department of Arts & Culture, 2010). This eventually led to a formal acknowledgment of the deeply rooted

interdependence between the intangible and the tangible heritage through the 2003 Convention for the Safeguarding of the Intangible Cultural Heritage (UNESCO, 2003). The Convention emphasizes the crucial role of intangible cultural heritage as a mainspring of cultural diversity and a guarantee of sustainable development (UNESCO, 2003).

UNESCO's Memory of the World Programme was also developed with its mission to facilitate preservation by the most appropriate techniques, of the world's documentary heritage, to assist universal access to documentary heritage and to increase awareness worldwide of the existence and significance of documentary heritage (UNESCO, 2019), while the vision of the programme states that the world's documentary heritage belongs to all should be fully preserved, protected and be permanently accessible to all without hindrance. The United Nations 2030 Agenda for Sustainable Development Goal (SDG) (2015) is another example which calls on governments to strengthen efforts to protect and safeguard the world's cultural heritage as well as to ensure public access to information and protect fundamental freedoms, in accordance with national legislation and international agreements. Digital Imaging of South Africa (DISA) project, hosted by the University of KwaZulu-Natal, Alan Paton library and funded by the Andrew W. Mellon Foundation, was another initiative aimed at building on-line high quality information resource containing materials of heritage importance and interest to scholars and students and to make it visible and accessible globally. In 2009, National Research Foundation (NRF) was commissioned by government to host national heritage resources of all institutions whether governmental or non-governmental under one web-based portal known as National Heritage Repository, funded by the Carnegie Corporation of New York. The National Heritage Repository has helped in incorporating heritage resources of various kinds like photographs, history papers, and others in one portal. In 2010, the Department of Arts and Culture (DAC) in South Africa also promulgated the National Policy on Digitization of Heritage Resources (DAC, 2010). Preservation of cultural heritage is thus considered as a key condition for innovative activities in our digital era, and as a result, cultural heritage institutions are using digitization to acquire, capture, preserve and disseminate cultural heritage, and this supports easy accessibility of this heritage.

The documentation and preservation of cultural heritage has therefore become a popular method for preservation and protection of cultural heritage of value. Preserving cultural heritage is a way of assisting rural communities to work towards the recovery of their collective memory and identity, and for sustainable development of these rural communities. However, cultural heritage can still be lost and not be recovered if it is not properly documented, recorded and preserved. Therefore, proper procedures need to be implemented in the preservation of cultural heritage in rural communities in Africa, particularly in South Africa. The interest in

preserving cultural heritage also requires measures that enable rural communities to retain control over their remaining cultural, intellectual and natural wealth for their continual sustainability and self-development. The policy and strategies guiding in the implementation and ensuring continuous and sustainable development with a focus on long-term objectives thus become necessary.

Cultural Heritage and Sustainable Development

United Nations (UN) adopted the Sustainable Development Goals(SDGs) in 2015, resulted in a comprehensive set of 17 goals and 169 targets aimed at reducing poverty and advancing health and wellbeing for all by 2030 (Agenda 2030) (United Nations, 2016). The SDGs aimed at addressing many of the shortfalls of the Millennium Development Goals (MDGs), that committed governments and international agencies to reduce the number of people living in poverty or lacking access to essential services and infrastructure while the SDGs commit these actors to poverty eradication and universal access to these services and infrastructure(SDGs, 2015). World Commission on Environment and Development defines sustainable development as the development that meets the needs of present generation without compromising the abilities of future generations to meet their own needs (United Nations, 2016). The notion of sustainability involves rethinking development to integrate environmental, economic, social and cultural goals (Mensah, 2019). Therefore, to be sustainable, development must foster protection and rehabilitation of ecological systems, improve economic efficiency and enhance the well-being and cultural diversity of the population (Chiabrando, et al., 2018).

Several initiatives and projects have been introduced to build evidence-based indicators that will help to build a multidimensional, coherent and strong narrative on culture and development (Petti, Trillo & Makore, 2019). UNESCO 2030 Agenda for Sustainable Development Indicators initiative is one of these projects. The indicator is concerned with developing a global picture of financial actions to safeguard cultural and natural heritage made by organizations in the private sector and public authorities at local and national levels (SDGs, 2015). This project deals with the integration of culture in the implementation of the 2030 SDGs Agenda (Hosagrahar, 2019), and its aims to establish a methodology and conceptual framework for countries and cities to assess the contribution of culture to the SDGs as part of the existing implementation mechanisms of the 2030 Agenda at the national or local level. A common approach to the protection and safeguarding of European heritage was also explored with the aim to feed into the SDGs goal and indicator: Target number11.4: Strengthening efforts to protect and safeguard the world's cultural and natural heritage (Petti, Trillo & Makore, 2019).

Digital Preservation as a Strategy to Enhance Access to Cultural Heritage

Digital technologies have presented cultural heritage institutions with an array of new possibilities for the creative interpretation and presentation of these heritage. Today vast amount of libraries, museums and archives have already started to digitize their heritage materials and place them on the web. The amount of digital heritage materials generated through digitization of analogue materials or content being born digitally has thus increased during the past decade. Heritage resources whether cultural, educational, scientific or other kind of information thus require management, preservation and maintenance to be retained, as many of these resources have lasting value and significance (UNESCO, 2003). Ram (2015) pointed out that digital heritage materials of all regions, countries and communities should be preserved and made accessible, creating over time a balanced and equitable representation of all peoples, nations cultures and languages. As a result, the cultural heritage community has embraced digitization as a means to preserve and safe-guard their cultural heritage materials from occurrences of natural disaster (McDowell, 2007). Digital preservation is understood as an act of responsible custody aimed at preventing the deterioration of cultural heritage materials and restoring their usefulness and information value (Conway, 2010). Nowadays preservation of cultural heritage has to be considered not only as a means for preserving physical fabric and sustaining cultural values, but as an incentive for enhancing cultural diversity, sense of place and sustainable economic development (Grazuleviciute-Vileniske, 2006). UNESCO's charter on the preservation of digital heritage states the purpose of preserving the digital heritage as to ensure that it remains accessible to the public and access to digital heritage materials, especially those in the public, should be free of unreasonable restrictions (UNESCO, 2003). UNESCO has the responsibility to perform the following functions, as noted by Ram (2015):

- take the principles set forth in its charter into account in the functioning of its programmes and promote their implementation within the United nation system and by intergovernmental and international non-governmental organizations concerned with the preservation of the digital heritage;
- serve as a reference point and forum where member states, intergovernmental and international non-governmental organizations, civil society and the private sector may join together in elaborating objectives, policies and projects in favor of the preservation of the digital heritage;
- foster cooperation, awareness raising and capacity-building and establish standard ethical, legal and technical guidelines as a companion sourcebook to this charter;

- determine on the basis of the experience gained over the next coming years in implementing the present charter and the guidelines, the need for further standard-setting instruments for the promotion and preservation of digital heritage

Despite the uncertain terrain, many initiatives have started in recent years to address the need to combat digital amnesia and to preserve digital cultural heritage for the future. For example, the Department of Manuscripts and Archives at the University of Cape Town (UCT) preserved several interesting collections housed in university archives and special collections including photographs of the San people between 1910 and the late 1920s (Dunlop & Hart, 2005). This collection is possibly the most unique and one of the most important of UCT's special collections and it attracts researchers from all over the world, and has also been listed as being a heritage of international importance on UNESCO's Memory of the World register (Dunlop & Hart, 2005). Another initiative contributing to digital preservation endeavor is the Syrian Heritage Archive Project, initiated in November 2013 as a cooperation between the Museum of Islamic Art in Berlin and the Orient Department of the German Archaeological Institute, (DAI, 2013). International teams worldwide are putting great efforts into saving the cultural heritage in Syria, by systematically documenting the various data and collections, building online archives after the war has destroyed a large portion of the country`s outstanding heritage and still poses a serious threat to the cultural legacy that remains (Nmeir, 2018). The project began to digitize the archives of both the Museum of Islamic Art and the German Archaeological Institute, which comprise extensive analogue materials such as photos, documents, plans and maps (DAI, 2013).

Over the last three years, the UNESCO PERSIST project has also started to address many of the challenges encountered by cultural institutions when dealing with the long-term preservation of digital heritage by looking at content and best practice, policy and technology (UNESCO, 2012). The aim of the project was to support the belief that good management of trustworthy digital information is fundamental to sustainable development by developing and implementing a global digital roadmap under the auspices of the Memory of the World Programme, to encourage all relevant stakeholders, in particular cultural heritage institutions, governments and the industry, to invest in trustworthy digital infrastructure and digital preservation (UNESCO/UBC Vancouver Declaration, 2012). On the other hand, International Federation of Libraries Association (IFLA) has been working closely with UNESCO and other digital preservation initiatives such as the International Council of Museums (ICOM), International Council on Monuments and Sites (ICOMOS) and International Council on Archives (ICA) in order to ensure that the library voice is heard and recognized as an important partner in the preservation of digital cultural

heritage (IFLA, 2018). IFLA also created Preservation and Conservation (PAC) Centre for digital preservation and digital sustainability at the National Library of Poland which became operational in late 2016, to support this work further (Brungs & Wyber, 2016).

The SEAD project, funded by the Swedish Research Council and Council for Research Infrastructures was also initiated, and aimed at facilitating the online storage, extraction, analysis and visualization of data on past climates, environments and human impact by providing online tools to aid international researchers in these tasks and by providing access to data that are currently not accessible online (Buckland et al., 2011). The Archaeology Data Service (ADS) was also established in 1996, as the mandated place of deposit for archaeological research data for a number of research councils and heritage organizations and makes all its holdings freely available for download or online research (ADS, 1996). Value-based approaches have been adopted in European countries for an increasing range of categories of cultural heritage, including archaeological and historic objects, sites, historic buildings, urban and rural landscapes (Burra Charter, 2020).

UNESCO's Convention for the Safeguarding of the Intangible Cultural Heritage also gives recommendations for signatories to develop a database of national tangible and intangible cultural heritage (UNESCO, 2003). As stated by UNESCO (2003) countries such as Italy, France and England lead in the availability of data pertaining to cultural heritage and this is largely because these countries own a noteworthy number of world cultural heritage sites listed by UNESCO under the Convention concerning the protection of the world cultural and natural heritage as ratified in 1972. For example, as noted by Petti, Trillo and Makore (2019) Italy has a comprehensive database catalogue called SIGECweb which contains over 2,700,000 records of archaeological, architectural, historical heritage and intangible assets. According to Petti, Trillo and Makore (2019) the National Heritage List for England (NHLE) is the only official up to date spatial database of all nationally protected historic buildings and sites led by Historic England, the UK Government-funded agency for heritage in England. Other countries such as Portugal, the Netherlands, Ukraine, Lithuania and Poland have also developed databases using the UNESCO framework as a significant catalyst. Myers (2016) described six characteristics for effective heritage database and management systems, as part of a funded project by the Getty Conservation Institute:

- records should have accurate information (such as location and significance or designation status), in order to make decisions and manage risk affecting heritage sites;

- to safeguard all heritage at risk within a particular area, there should be wide-ranging information about the geographic area, as gaps in coverage could significantly increase the risk on heritage;
- databases need to have up-to-date and current information;
- authoritativeness; databases and inventory systems should be a definitive system of record for that context;
- controlled accessibility which refers to information from that database that needs to be accessible, such as including data export functionality and expanded search tools; and
- security of information from corruption or intentional damage.

THE ROLE OF CULTURAL HERITAGE INSTITUTIONS IN PROMOTING AND PRESERVING CULTURAL HERITAGE

Delivering cultural heritage resources has become an imperative associated with the core mission of libraries (Deegan & Tanner, 2006b), and therefore, providing the community with sustainable access to its heritage helps to foster creativity, build resilient societies and further development. Cultural heritage institutions such as libraries, archives, museums and art galleries have always been at the forefront of efforts to fight against various threats by safeguarding, preserving and providing access to documentary cultural heritage. These institutions can thus assist in publicizing the value and importance of cultural heritage to both non-indigenous and indigenous people, raising awareness on the protection of cultural heritage against exploitation and encouraging the recognition of intellectual property laws to ensure the proper protection (IFLA, 2018).

International organizations, national policy making bodies and professionals from various disciplines especially from cultural heritage institutions have also put tremendous efforts into preserving and making cultural heritage resources publicly available. In 2015 the IFLA stressed its support for the UNESCO Vancouver Declaration of the libraries' role of providing access and safeguarding of heritage resources (UNESCO Memory of the World Programme, 2015). It was thus indicated as an opportunity by IFLA to draw attention to the involvement of libraries in heritage from the oldest manuscripts to the newest born-digital materials, when the year of 2018 was declared the Year of Cultural Heritage in Europe (IFLA, 2018). According to IFLA (2018), making cultural heritage widely known might help increasing awareness and the chances for libraries to receive the support (both legally and financially) they require to continue undertaking their work in this field effectively. Although cultural heritage institutions (libraries, archives and museums) have a common mission which is to make their cultural heritage resources

accessible to intended users, however, libraries have a long history of collecting, storing, organizing, preserving and providing access to cultural heritage materials. Increasing number of libraries thus started to digitize their unique holdings, including photographs, postcards, books, manuscripts, maps, and analog audio and video recordings, in order to enhance access to cultural heritage resources. Digitization not only contributes to the conservation and preservation of heritage resources through high quality images, but it also provides improved access by the citizen to these resources (Boock & Vondracek, 2006).

During the last couple of decades, national libraries worldwide have also become active in digitizing their holdings and promoting them on their websites in different ways. The role of the national libraries as the guardian of the national cultural heritage has therefore long been recognized. Findings of a research conducted by Šalamon-Cindori (2017) on fifty (50) European national library indicate that almost 94 percent have either digital holdings or a digital library and about half (58 percent) of these libraries create virtual exhibitions, although there are significant differences in quality and functionality among them. Cultural heritage institutions can therefore act as repositories of knowledge to ensure that it is accessible and usable in enhancing sustainable development in a country. Durst and Wilhelm (2012) acknowledged that information centres and libraries have played a major role in South Africa's national life and in the fight for democratic freedom through political and cultural impacts. Cultural heritage institutions in South Africa should therefore recognize their influence as socio cultural agents and actively work with rural communities in protecting and preserving cultural heritage resources.

Cultural heritage institutions have been committing increasing amounts of time and money for safeguarding the heritage resources in their collections (UNESCO, 2003b), and are engaging in the acquisition and preservation of these heritage materials for sustainable development. For example, when armed groups occupied Northern Mali and Timbuktu in 2013, librarians and volunteers smuggled the manuscripts to safeguard them during the occupation, and since then, the manuscripts have been kept in the capital and are undergoing restoration and digitization work (Kottoor, 2013). Libraries from across Japan also came together to help rebuild lost infrastructures, safeguarded and preserved damaged materials after the Earthquake in 2011 (IFLA, 2018). Another example is the initiative started by Kanye Public Library in Botswana to capture, record and document cultural events such as cultural day celebrations and provide access to this collection of videos and photos (Setshwane & Oats, 2015). Libraries are therefore key partners for any effort to ensure preservation and access to human kind's cultural heritage for future generations (IFLA, 2018), and it is therefore crucial to involve libraries in all discussions and actions around the preservation and safeguarding of cultural heritage, especially in the context of the 2030 Agenda.

Although cultural heritage institutions make information resources that was previously available only to a limited group of users accessible to all, however, these institutions are faced with digital preservation challenges. There are some differences among these institutions regarding challenges they face. As noted by Tonta (2008), digital preservation poses more challenges for museums than it does for libraries and archives. First of all, museums collect 2D and 3D objects of which is challenging since it requires more storage space, special software and high bandwidth to view, while libraries preserve primarily the printed and graphic materials (Tonta, 2008). Secondly, heritage materials preserved by museums are unique, while library materials usually have more copies kept in different libraries (Tonta, 2008). Cultural heritage institutions should continue building consultation networks with various stakeholders in order to improve best practices. However, in order to execute this more efficiently, there is a need for a collaborative and coordinated approach of cultural heritage management among government authorities, rural communities, researchers and cultural heritage institutions. By working together would also enable the establishment of a database that will provide access to different types of users governed by different access rights to ensure that community engagement programmes are carried out.

The UN 2030 Agenda also mentioned the need for universal literacy in its preamble, which underlines clearly the need to not only preserve and give access to cultural heritage but also to ensure that people have the skills to use digital heritage (United Nations, 2015). To achieve this, people need multiple literacy skills to use digital technologies which enable access to digital cultural heritage. As also noted by Raju (2014) the skills of information professionals have to be as relevant to the electronic milieu created by technological changes as to that of print. Information professionals, librarians and archivists need to have developed a set of important skills and competences in order to perform their roles successfully. The development of these skills would further assist librarians and information professionals to take part in large scale, international cultural heritage projects and most importantly work closely and collaboratively with researchers from other disciplines. Vassilakaki and Moniarou-Papaconstantinou (2015) identified key roles that librarians need to adopt nowadays and these roles include: information professionals, Information Technology (IT) specialists, embedded librarians, information consultants, knowledge managers and subject librarians.

THE IMPACT OF SOUTH AFRICAN HERITAGE RESOURCE AGENCY ON PROMOTION AND PROTECTION OF CULTURAL HERITAGE

In South Africa, the legislation contained in the Promotion of Access to Information Act (PAIA), No. 2 of 2000 and the National Environmental Management Act (NEMA) No. 107 of 1998 require that the public has access to the bulk of the types of records held at South African Heritage Resource Agency (SAHRA) (Department of Arts and Culture) (DAC, 1998). SAHRA is responsible for the identification and management of the national estate of the country, as well as the co-ordination of the management of heritage resources at provincial and local level (DAC, 1998). Section 39 of the National Heritage Resources Act (NHRA) (1999) also stipulates that a record of all conservation-worthy heritage resources is to be maintained in the form of a database, which is to be publicly accessible and populated in the format prescribed by SAHRA. The purpose of the NHRA is to protect those heritage resources of South Africa which are of cultural significance or other special value for the present community and for future generations because they are considered part of the national estate and fall within the sphere of operations of the heritage resources authorities (NHRA, 1999). Several years of research determined that the best way to achieve this goal was through the development of an online, integrated heritage management system, designed using Free and Open Source Software (FOSS) (Smuts, Mlungwana & Wiltshire, 2016).

As mandated by the NHRA, the South African Heritage Resources Information System (SAHRIS), a digital heritage management system, which integrates the processes of recording moveable (objects) and immoveable (sites) heritage resources with their management, was also developed (SAHRA,2011). SAHRIS has four main functions, namely: it serves as an integrated heritage management system, as a national sites repository, as a national collections repository and as a centralized platform for reporting and tracking heritage crime (SAHRA, 2011). The coordination of sites created on SAHRIS are mapped using the system built in GIS functionality, as are the locations of heritage objects within repositories such as museums and galleries. In the process of developing SAHRIS, it became necessary to choose a suitable licensing system for the content to ensure that it was disseminated legally and as openly as possible (SAHRA, 2011). SAHRA (2011) also chose to license all of the media content on SAHRIS using a share alike license called the creative commons that allows users to freely share information they find on SAHRIS, provided that they cite the author and do not sell the data. SAHRIS thus makes it easy for applicants and heritage authorities to interact through the submission of applications via a four-page online wizard that allows users to fill out all relevant details about their project through a quick and- easily followed process (SAHRA, 2011).

THE IMPLICATIONS OF POLICY ON DIGITAL PRESERVATION OF CULTURAL HERITAGE FOR SUSTAINABLE DEVELOPMENT OF RURAL COMMUNITIES

This chapter was based on how cultural heritage can be protected towards the achievement of the sustainable development of South African rural communities and how can digital preservation be used as a strategy to enhance access to cultural heritage. The advancement of digital technologies enables cultural heritage to be easily and freely available to the general public and this facilitates easy copying and transmission of digital information. As noted by Richards, et al. (2013) for a digital archive to be considered credible, and thereby attain trusted digital repository status, it must be able to demonstrate well-documented preservation policies and processes as well as having a robust long-term sustainability plan. International and national initiatives, strategies and policy for the protection of cultural heritage that gave an insight into what work has been happening around the world in the quest of protecting cultural heritage, were reviewed in this chapter. Most of the initiatives and policy have centered on understanding the value of cultural heritage, and the preservation and protection of these heritage at national and local levels. The review of these policies and initiatives helped in understanding whether digital preservation of cultural heritage can be a viable strategy in achieving sustainable development goal.

A number of countries have embarked on developing digital research infrastructures and data archives in an attempt to preserve and promote more integrated access to cultural heritage. Although South Africa has been slow in embracing the opportunities offered by the digitization of cultural heritage resources, however, there are numerous discrete digitization and preservation projects completed or underway at present. As compared to other countries, South Africa emerged as the only country that has instituted the web-based portal of the national heritage resources known as National Heritage Repository, hosted by National Research Foundation (NRF). In addition, in 2010 the Department of Arts and Culture (DAC) promulgated the country's national policy on digitization of heritage resources that serves as a guiding framework for institutional policies. However, much of the cultural heritage materials in South Africa, with the exception of material which is currently in the public domain, remains subject to relevant copyright laws. In many cases, cultural heritage institution is the owner of copyright while on the other hand, copyright is owned by the individuals or entities which created the particular work or material (Andrzejewski, 2010). The majority of developed countries have laws governing the preservation of cultural heritage, and these laws make provision for the establishment of national institutions with responsibility for implementing measures that serve to ensure the protection of the cultural heritage.

The national government developed national heritage policies, the strategies for implementation and cultural heritage preservation regulations. These laws sometimes work as decentralized service structures, making it easier to manage cultural heritage within rural communities and are therefore tools which if utilized properly allow for an effective protection of the cultural heritage. In most countries, archaeological data is still not accessible because the traditional approach to research also protects the intellectual property rights of researcher (Richards et al., 2013). Therefore, most of cultural heritage in developed countries is legally protected while in developing countries it is not, and this leaves much of cultural heritage open to bio-piracy and other forms of misappropriation. A sui generis protection can thus be the preferred as more appropriate method for effectively protecting cultural heritage in developing countries, particularly in South Africa. It is therefore suggested that a sui generis approach (the approach that has been favored by international organizations in protecting and promoting cultural heritage and indigenous knowledge) be adopted. By adopting sui generis approach in South Africa means it will avail its databases to the international community so that when there is a patent application in any part of the world the databases can be searched for the existence of the information on which the patent is based. Sui generis implies that adding information to the database automatically constitutes establishing a legal claim over it. Sui generis approach is thus recommended in order to provide a holistic protection for cultural heritage and for effective protection, preservation and promotion of cultural heritage in South Africa.

The sustainability of cultural heritage and its management is strongly dependent on the national and local government, the participation and support from local communities. Although government remains in charge of protecting the National Cultural Heritage, effective protection and preservation of the cultural heritage cannot be accomplished without the establishment of operative partnerships at a local level. National and local capacity development is thus needed to ensure the sustainability of national and local processes. Rural authorities thus have a greater role to play in the protection and management of cultural heritage, and as a result, cultural and heritage policies should depend much upon local governments' dynamism and on the way that culture is valued and perceived by local decision makers (UNESCO, 2003). However, the current Sustainable Development Goal (SDG) 11.4 indicator: strengthening efforts to protect and safeguard the world's cultural and natural heritage is inadequate in representing the challenges and opportunities of cultural heritage within the context of sustainable development (SDG, 2015).

Access to cultural heritage information and information sharing is generally perceived as important, and therefore, according to SDG (2015) there is a crucial requirement for standardized methods for valuing and preserving cultural heritage in order to enhance access to cultural heritage across cities and countries. The

harmonization of these processes using similar standardized methods can allow for the comparison of data among countries towards the achievement of the SDGs. In order to enable people to preserve and access their cultural heritage, cultural heritage institutions and relevant stakeholders need to work together to overcome obstacles, such as copyright and intellectual property issues, ever-changing digital technology, and the sheer mass of digital content available. Therefore, to preserve cultural heritage for current and future generations, action is needed now from all actors including policy makers, practitioners, content and technology creators. Cultural heritage institutions cannot only be responsible for digital preservation, the industry and governments will also need to be actively involved in ensuring that our digital cultural memory will be accessible for future generations.

CONCLUSION AND RECOMMENDATIONS

This chapter reviewed initiatives, strategies and policy frameworks in order to understand the protection of cultural heritage for sustainable development of South Africa rural communities. Today, organizations from different sectors and professionals from various disciplines at different levels (local, national, regional, international) have put tremendous effort into preserving and making cultural heritage resources publicly available. Cultural heritage is making a growing contribution to rural communities globally, although a significant limitation is the availability and accessibility of data which varies from country to country. In this regard, databases of local tangible and intangible cultural heritage are critical tools for the management of these cultural resources. A comprehensive, publicly accessible database on cultural heritage for each member state would provide an essential resource to support the SDG achievement of the goals. These databases allow for the compilation of cultural heritage in one place, but more importantly, they reflect the classification and valorization used by the member state. The databases are the underpinning for establishing mechanisms for protection, and are key components of cultural management plans and critical in order to protect and preserve what is found in a specific area.

Cultural heritage, local knowledge systems, sociocultural practices and values must therefore be documented and analyzed as a means to achieve a comprehensive understanding of rural realities. The involvement of the public in developing the intangible inventories reflects the increasing focus on identifying, recognizing and valuing the local community as a key factor in the process of sustainable heritage management. Local communities and government must ensure that heritage assets are managed in a sustainable manner in order to ensure that the benefits they provide are realized. The national policy can serve as a guiding framework for the institutional

digitization projects. A collaborative approach in the development of national policies is thus recommended for digitization and preservation projects. Cultural heritage institutions in South Africa need to develop their capacities in terms of safeguarding cultural heritage and partnering with rural communities. Governments also need to consult with rural communities when developing regulatory laws to safeguard cultural heritage, for these laws not to be rendered irrelevant and resulting in significant damage. Public data repositories and the related standardization are also the best solution for long-term preservation.

REFERENCES

Amer, M. (2017). Egyptian Intangible Heritage between Preservation Management and Sustainable Development Pattern: Analysis of the Popular Craft of Manufacturing Mats. *Egyptian Textile Museum e-Bulletin*, *1*, 226-242.

Axelsson, R., Angelstam, P., Degerman, E., Teitelbaum, S., Andersson, K., Elbakidze, M., & Drotz, M. K. (2013). Social and cultural sustainability: Criteria, indicators, verifier variables for measurement and maps for visualization to support planning. *Ambi*, *42*(2), 215–228. doi:10.100713280-012-0376-0 PMID:23475657

Barillet, C., Joffroy, T., & Longuet, I. (2006). A guide for African local governments: Cultural heritage and local development. CRATerre-ENSAG, 112.

Brungs, J., & Wyber, S. (2016). Preserving our digital culture for the future: Overcoming obstacles through collaboration. International Federation of Library Associations and Institutions (IFLA). *Global Information Society Watch*, 36-40.

Burra Charter. (2020). *The Burra Charter: The Australia ICOMOS Charter for Places of Cultural Significance.* Available online: http://openarchive.icomos.org/2145/

Chiabrando, F., Colucci, E., Lingua, A., Matrone, F., Noardo, F., & Spanò, A. (2018). A European Interoperable Database (Eid) to Increase Resilience of Cultural Heritage. ISPRS-. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *XLII-3*(W4), 151–158. doi:10.5194/isprs-archives-XLII-3-W4-151-2018

Dewi, S. T., & Susetyo-Salim, T. A. (2017). Challenges and Opportunities in the Protection and the Preservation Indigenous Knowledge of "Rabab Music Art" Pariaman. *Social Sciences*, *12*(2), 262–265.

Dunlop, J., & Hart, L. (2005). *Digitization projects at the University of Cape Town Libraries.* Available: www.innovation.ukzn.ac.za/InnovationPdfs/No30pp32-42Dunlop&Hart.pdf

Durst, S., & Wilhelm, S. (2012). Knowledge management and succession planning in SMEs. *Journal of Knowledge Management*, *16*(4), 637–649. doi:10.1108/13673271211246194

Frey, B. (1997). The Evaluation of Cultural Heritage: Some Critical Issues. In M. H. A. I. Rizzo (Ed.), *Economic Perspectives on Cultural Heritage* (pp. 31–49). Palgrave MacMillan. doi:10.1007/978-1-349-25824-6_3

Grazuleviciute-Vileniske, I. (2006). Cultural heritage in the context of sustainable development. *Environmental Research, Engineering and Management*, *3*(37), 74–79.

Hitchcock, M., King, V., & Parnwell, M. (2010). *Heritage Tourism in Southeast Asia*. NIAS Press.

Hosagrahar, J. (2019). UNESCO Thematic Indicators for Culture in the 2030 Agenda for Sustainable Development. In *Analytical Report of the Consultation with the Member States*. UNESCO World Heritage Centre.

IFLA. (2018). *IFLA - Global Vision Report Summary*. https://www.ifla.org/node/11905

Jigyasu, R. (2014). The Intangible Dimension of Urban Heritage. In F. Bandarin & R. v. Oers (Eds.), *Reconnecting the City: The Historic Urban Landscape Approach and the Future of Urban Heritage*. Wiley-Blackwell. doi:10.1002/9781118383940.ch5

Kanyengo, C. W. (2009). Managing digital information resources in Africa: Preserving the integrity of scholarship. *The International Information & Library Review*, *41*(1), 34–43. doi:10.1080/10572317.2009.10762795

Koch, F., & Krellenberg, K. (2018). How to Contextualize SDG 11? Looking at Indicators for Sustainable Urban Development in Germany. *ISPRS International Journal of Geo-Information*, *7*(12), 464. doi:10.3390/ijgi7120464

Kottoor, N. (2013). How Timbuktu's manuscripts were smuggled to safety. *BBC World Service Magazine.*

Liburd, J. J. (2007). Sustainable Tourism, Cultural Practice and Competence Development for Hotels and Inns in Denmark. *Tourism Recreation Research*, *32*(1), 41–48. doi:10.1080/02508281.2007.11081522

Lipp, T. (2013). Materializing the Immaterial. On the Paradox of Medializing Intangible Cultural Heritage. In M.-T. Albert, R. Bernecker, & B. Rudolf (Eds.), *Understanding Heritage: Perspectives in Heritage Studies*. UNESCO Digital Library. doi:10.1515/9783110308389.135

Mensah, J. (2019). Sustainable development: Meaning, history, principles, pillars, and implications for human action: Literature review. *Journal of Cogent Social Sciences*, *5*(1), 1–21. doi:10.1080/23311886.2019.1653531

Myers, D. (2016). Heritage inventories: Promoting effectiveness as a vital tool for sustainable heritage management. *Journal of Cultural Heritage Management and Sustainable Development*, *6*(2), 102–112. doi:10.1108/JCHMSD-02-2016-0009

Nengomasha, C. T. (2009). Managing public sector records in Namibia: A propose model. *Information Development*, *25*(2), 112–126. doi:10.1177/0266666909104712

Ngulube, P. (2012). "Ghosts in our machines": Preserving public digital information for the sustenance of electronic government in sub-Saharan Africa. *Mousaion: South African Journal of Information Studies*, *30*(2), 127–135.

Nmeir, E. (2018). The Syrian heritage archive project in Berlin: Protecting and Interpreting Cultural Heritage in the Age of Digital Empowerment. India Habitat Centre.

Nocca, F. (2017). The Role of Cultural Heritage in Sustainable Development: Multidimensional Indicators as Decision-Making Tool. *Sustainability*, *9*(10), 1882. doi:10.3390u9101882

Petti, L., Trillo, C., & Makore, B. C. N. (2019). Towards a Shared Understanding of the Concept of Heritage in the European Context. *Heritage*, *2*(3), 2531–2544. doi:10.3390/heritage2030155

Power, A. (2004). Sustainable communities and sustainable development: A review of the sustainable communities plan. The Sustainable Development Commission.

Raju, J. (2014). Knowledge and skills for the digital era academic library. *Journal of Academic Librarianship*, *40*(2), 163–170. doi:10.1016/j.acalib.2014.02.007

Ruthven, I., & Chowdhury, G. G. (2015). *Cultural heritage information: access and management*. Facet Publishing.

Seifert, C., Bailer, W., Orgel, T., Gantner, L., Kern, R., Ziak, H., Petit, A., Schlötterer, J., Zwicklbauer, S., & Granitzer, M. (2017). Ubiquitous Access to Digital Cultural Heritage. *Journal on Computing and Cultural Heritage*, *10*(1), 1–27. doi:10.1145/3012284

Shah, K. (2016). Creation of cultural heritage inventories: Case of the historic city of Ahmadabad. *Journal of Cultural Heritage Management and Sustainable Development*, *6*(2), 166–194. doi:10.1108/JCHMSD-02-2016-0011

Smuts, K., Mlungwana, N., & Wiltshire, N. (2016). SAHRIS: South Africa's integrated, web-based heritage management system. *Journal of Cultural Heritage Management and Sustainable Development*, *6*(2), 138–152. doi:10.1108/JCHMSD-01-2016-0002

Stephenson, J. (2008). The Cultural Values Model: An integrated approach to values in landscapes. *Landscape and Urban Planning*, *84*(2), 127–139. doi:10.1016/j.landurbplan.2007.07.003

Sustainable Development Goals (SDGs) 2015-2030. (2015). United Nations.

UNESCO. (1972). Convention Concerning the Protection of the World Cultural and Natural Heritage. United Nations Educational Scientific and Cultural Organization (UNESCO).

UNESCO. (2003). *Convention for the safeguarding of the intangible cultural heritage*. UNESCO.

UNESCO Institute for Statistics. (2009). *UNESCO Framework for Cultural Statistics*. UNESCO Institute for Statistics.

United Nations. (2015). The Sendai Framework for Disaster Risk Reduction 2015-2030. *The Third UN World Conference in Sendai*.

United Nations. (2016). *Sustainable Development Goals.* Available online: https://www.un.org/ Sustainable development/sustainable-development-goals/

Uršic, M. (2011). The Diminished Importance of Cultural Sustainability in Spatial Planning: The Case of Slovenia. *Cult. Local Gov.*, *3*, 101–116. doi:10.18192/clg-cgl.v3i1.189

Vassilakaki, E., & Moniarou-Papaconstantinou, V. (2015). A Systematic Literature Review Informing Library and Information Professionals' Emerging Roles. *New Library World*, *116*(1/2), 37–66. doi:10.1108/NLW-05-2014-0060

Chapter 7
Low-Cost Home Automation System for Physical Disability and Limited Mobility People: A Case Study on Needy Brazilian Communities

José Irineu Ferreira Júnior
https://orcid.org/0000-0001-5468-8275
Federal Institute of Alagoas, Brazil

Paulo César do Nascimento Cunha
Federal Institute of Alagoas, Brazil

Vitor Gabriel Nunes Soares
Federal Institute of Alagoas, Brazil

Álvaro Sobrinho
https://orcid.org/0000-0002-1753-1890
Federal University of the Agreste of Pernambuco, Brazil

ABSTRACT

The general Latin American population with a physical disability or limited mobility has faced the daily basis challenge of having autonomy in home activities, with low-income or almost no-income. Needy Brazilian communities are examples of poor populations suffering from the lack of autonomy at home, aggravated by scarce financial resources. The authors developed a low-cost home automation system, aiming to assist people who live in Palmeira dos Indios city and Arapiraca city, needy communities located in the Northeast of Brazil. The system is composed of

DOI: 10.4018/978-1-7998-5879-9.ch007

hardware and software components. The hardware comprises of microcontrollers used to actuate over electrical devices at home, while an Android application provides a simple graphical user interface (GUI) to control the devices using touch and voice commands by Bluetooth communication. They evaluated the system by implementing a home model and providing the home for four physical disability persons and one limited mobility person. They considered the system`s effectiveness, the system`s usability, and users` perceptions during the evaluation.

INTRODUCTION

The first attempts to apply control automation systems occurred in the United States of America, aiming to assist industrial processes. Since these first attempts, the scope of automation has been increased to cover different contexts, such as home activities (Vacher, Portet, Fleury & Noury 2011). In Latin America, home automation systems have evolved from simple three-way light switches in 1930, video home system in 1976, Internet connectivity and home theater in 1994, and light switches by remote control in 2000, to the integration of wireless devices in 2010 (Mourão, 2012). Nowadays, home automation systems have evolved to multifunctional mobile platforms (Liao, Wang, Tsao, Wang, Jhang, Chu, Tsao, Tsai, Chen, Chuang & Ger, 2019).

Developers of home automation systems use technology to provide some common tasks automatically, such as executing commands (e.g., turning lights on and off, opening and closing doors, irrigating the garden), increasing interior security, monitoring the home remotely, and bringing more convenience and autonomy. Some benefits include (Muratori & Dal Bo, 2017) valuation of the property, since it is an additional comfort for future residents; more security, by integrating alarm systems with home automation systems; and the reduction of energy consumption, e.g., by automatically switching off of lamps and household appliances.

Home automation systems are used not only to provide convenience for users but may also improve the quality of life of physical disability and limited mobility people (Morais, Sobrinho, Oliveira, Silva & Macedo, 2019). The automation can be implemented using, e.g., mobile technologies, sensors, and actuators, to enable these people to conduct daily activities that were before impossible or extremely difficult (Noury, Barralon, Vuillerme & Fleury, 2012).

Our proposed research provides a low-cost home automation system composed of an Android app and hardware controllers to actuate electrical devices. One of

the main objectives is to evaluate the benefits and challenges of using the home automation system in needy Brazilian communities. Therefore, we implemented a model (small home) to conduct a case study on two needy Brazilian communities: Palmeira dos Índios city and Arapiraca city.

Related Works

As an attempt to improve the quality of life of physical disability and limited mobility people, some mobile applications (apps) are available in the market to assist users to conduct home activities. For example, OpenHab (OpenHab, 2020) is a Java application (app) that combines different smart home systems and technologies to assist users. IFTTT (Ifttt, 2020) is an app (Android and IOS) used to integrate devices into a home environment. eWeLink (eWeLink) enables home automation by providing features of remote control.

In addition, Morais, Sobrinho, Oliveira, Silva & Macedo (2019) designed a home automation app using Android and integrated it with Arduino to assist limited mobility people to conduct simple home activities such as light switches. Only a prototype is presented to evaluate the design of the system. Similarly, Liao, Wang, Tsao, Wang, Jhang, Chu, Tsao, Tsai, Chen, Chuang & Ger (2019) present a low-cost system for smart home control and environmental monitoring. In this case, the authors implemented a prototype and conducted evaluations using a model home to validate the quality attributes of the system. Manda, Kushal & Ramasubramanian (2018) provide a cost-effective home automation system using the NXP LPC11U24 microcontroller unit and the global system for mobile communication technology. Kronbauer, Gomes & Campos (2018) developed a platform (universal remote control) to assist limited mobility people to conduct interactions with electronic devices at home. The authors evaluated the platform by conducting usability tests.

Up to this date, we were not able to identify studies focusing on home automation systems used by needy communities in the northeast of Brazil: Palmeira dos Indios city and Arapiraca city.

Problem Formulation

Physical disability and limited mobility people, such as wheelchair users and the elderly, face challenges in conducting simple activities at home, usually requiring the assistance of third parties that may be not always available. Challenges can be related to safety (e.g., fall hazards, and trips due to the absence of light) and practicality (e.g., easy-of-use remote control). Considering easy-of-use, the quality attribute usability is a key factor for the success of home automation systems for limited mobility people (Kronbauer, Gomes & Campos, 2018). For example, some

researches have provided mechanisms to describe usability problems of apps for the elderly and to make the apps easily available (García-Peñalvo, Conde-González & Matellá, 2014).

In addition, the high costs for implementing home automation systems is a critical challenge, mainly in needy Latin American populations. For example, the Brazilian Association of Home and Building Automation states that the costs to automate a home using the most recent technologies is from approximately 455,75 United States dollars (USD) up to approximately 4557,47 USD, depending on the type of automation conducted (Braziliense, 2015). The Brazilian industry provides systems to control home devices by remote controls (e.g., smartphones). However, when considering physical disability and limited mobility people, there is a reduced number of attempts to provide low-cost systems (Paulus, Piloti Antoniazzi & Antunes, 2017).

This article is organized as follows. Section 2 presents the main terms and definitions related to this study. Section 3 describes the home automation system developed. Section 4 presents the test environment designed, while Section 5 describes the evaluation results using the test environment. Section 6 concludes the study.

Main Terms and Definitions

In the Brazilian legislation, people with motor limitations are classified with a physical disability or limited mobility. According to the federal decree 5,296/04 (Brasil, 2004), physical disability is the complete or partial change of one or more segments of the human body, resulting in the impairment of physical function. In the same decree, the term limited mobility is related to a person who has an effective reduction in mobility, flexibility, motor coordination, and perception (permanently or temporarily). Examples of limited mobility people include, for example, elderly people, pregnant women, obese people, and wheelchair users.

Accessibility for people with disabilities is strongly impacted when the environment does not have any necessary adaptation. It is necessary for the usage of resources that provide safe conditions of mobility and comfort, such as specialized materials, adapted equipment, adequacy of furniture, and adequacy of architectural structures. In Brazil, the technical assistance committee, instituted by Ordinance of number 142 of November 16 (Humanos, 2006), defines *assistive technology* as an interdisciplinary area of knowledge, which encompasses products, resources, methodologies, strategies, practices and services, aiming to promote autonomy, independence, quality of life and social inclusion, by providing a set of functionalities.

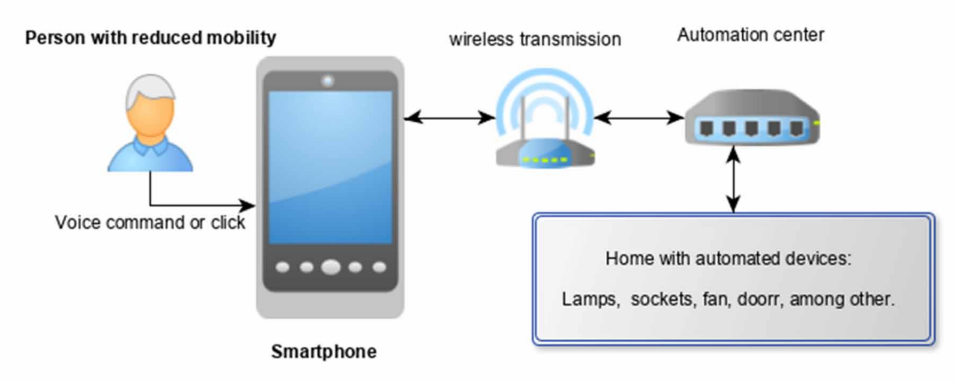
Therefore, the universal design is a term first created in the 70s by the American Ronald Mace, a wheelchair architect. According to the definition of the Center for Universal Design (North Carolina State University, USA), the purpose of universal design (also known as inclusive design) is to generate accessible environments,

products, services, programs, and technologies (Mace, Hardie & Place, 1991). The main objective is to support the largest number possible of people, without the need for adaptation or specialized design.

AUTOMATION SYSTEM

We designed the system by considering the universal design concept. The system is composed of an Android mobile app and an automation center (controller). The mobile app enables physical disability and limited mobility people to remotely access home devices using smartphones or tablets. The automation center comprises the microcontroller Atemega328P to enable home automation. Figure 1 illustrates an overview of the home automation system components. The automation center communicates with the mobile app using the HC-06 Bluetooth module (10 meters average range). A physical disability or limited mobility person sends a voice command or presses a button using the mobile app to access home devices such as lamps and fans. The automation center controls the environment and returns the status of devices to the mobile app.

Figure 1. Overview of the home automation system components

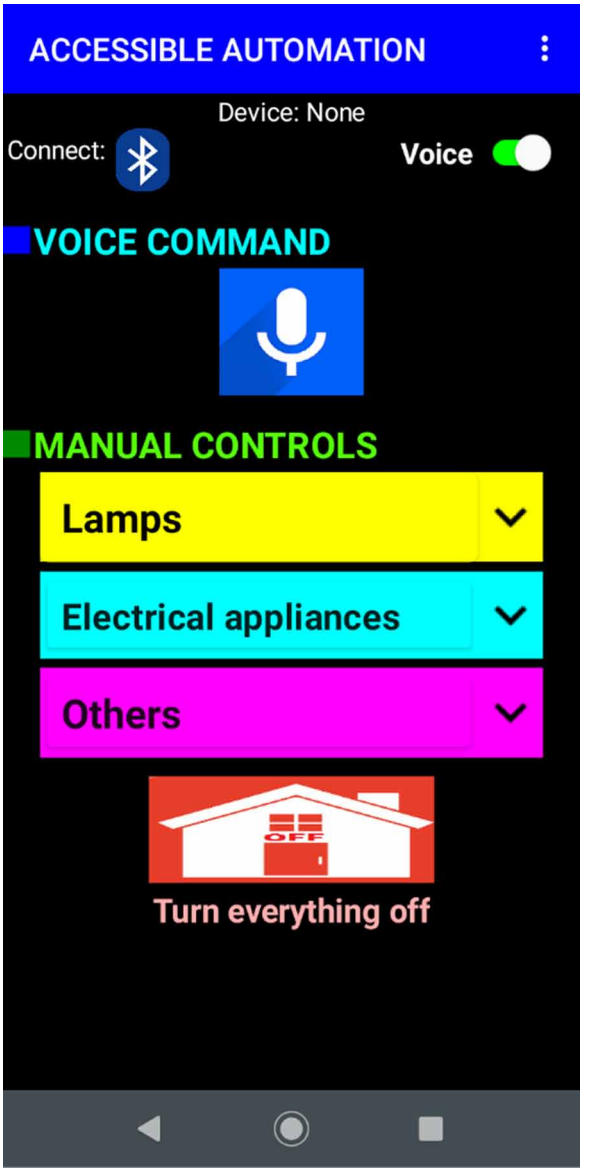


Mobile App

We developed the app (named *Accessible Automation*) using the MIT App Inventor 2, which includes the TinyDB database. We describe the features of the app along with graphical user interfaces (GUI). An overview of the app is presented in Figure 2, showing a sample of GUI.

Firstly, a physical disability or limited mobility person is able to connect the *Accessible Automation* app with the automation center by enabling and selecting the Bluetooth network available (Figure 2). There are three classes of devices: lamps, electrical appliances (e.g., fans), and other (e.g., doors). The app enables users to

Figure 2a. Sample of GUI of the Accessible Automation app. (a) Main GUI, showing the Bluetooth connection and classes of devices controlled



provide inputs using touch and voice commands. When using voice commands, users need to press the button named *Voice Command* and speak the words *Turn on* or *Turn off*, followed by the name of the device. When using touch commands, the users only need to press a specific button related to the device under control. In

Figure 2b. Sample of lamps controlled

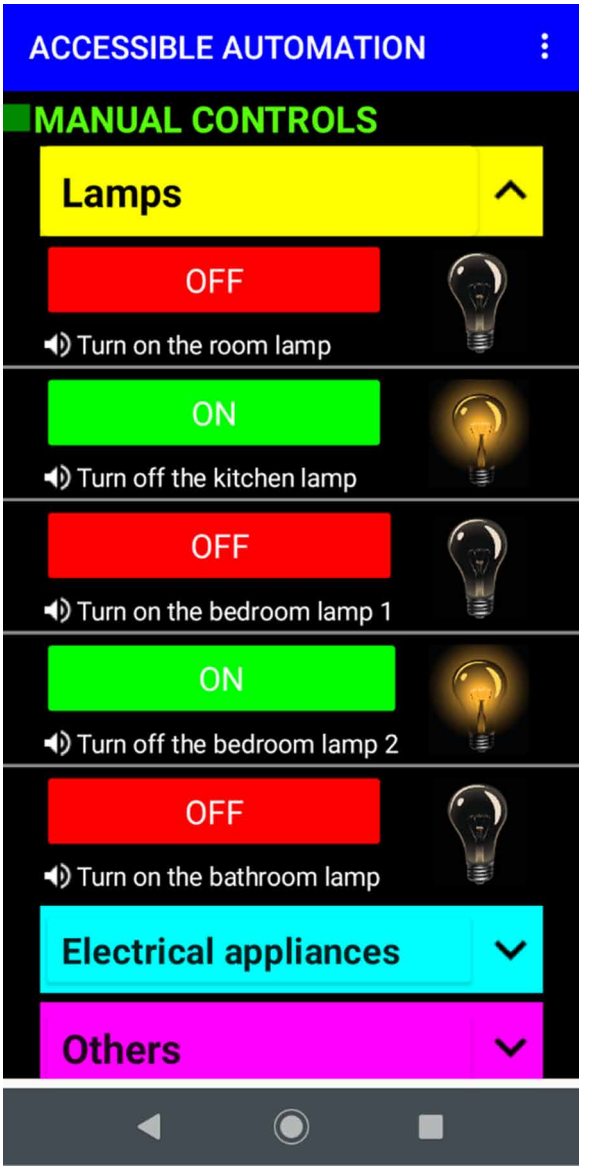
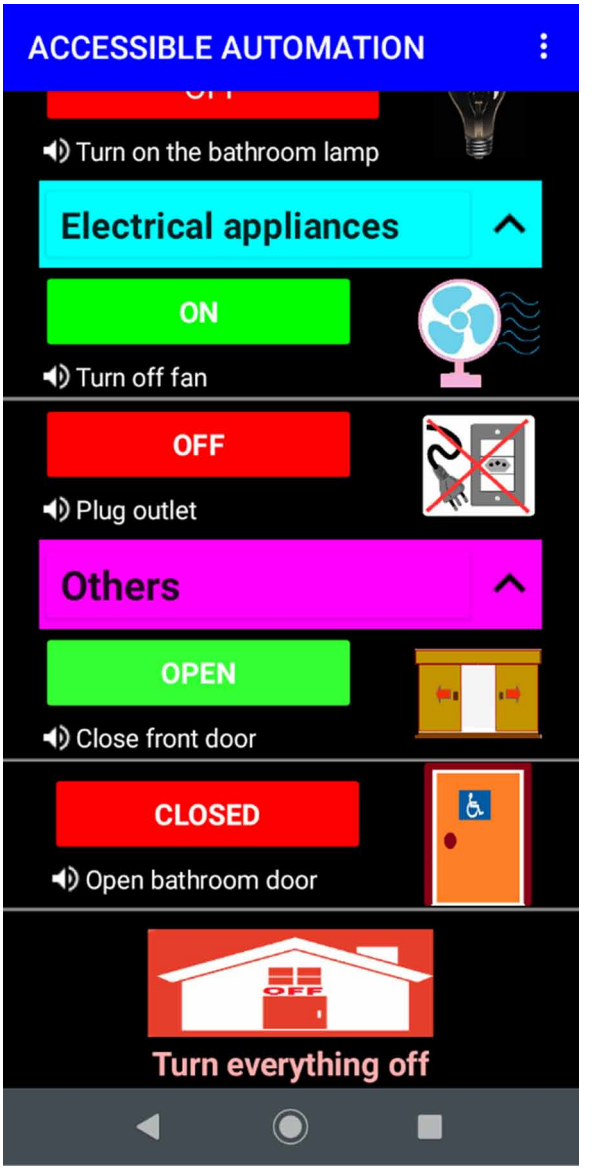


Figure 2c. Sample of general electrical devices controlled



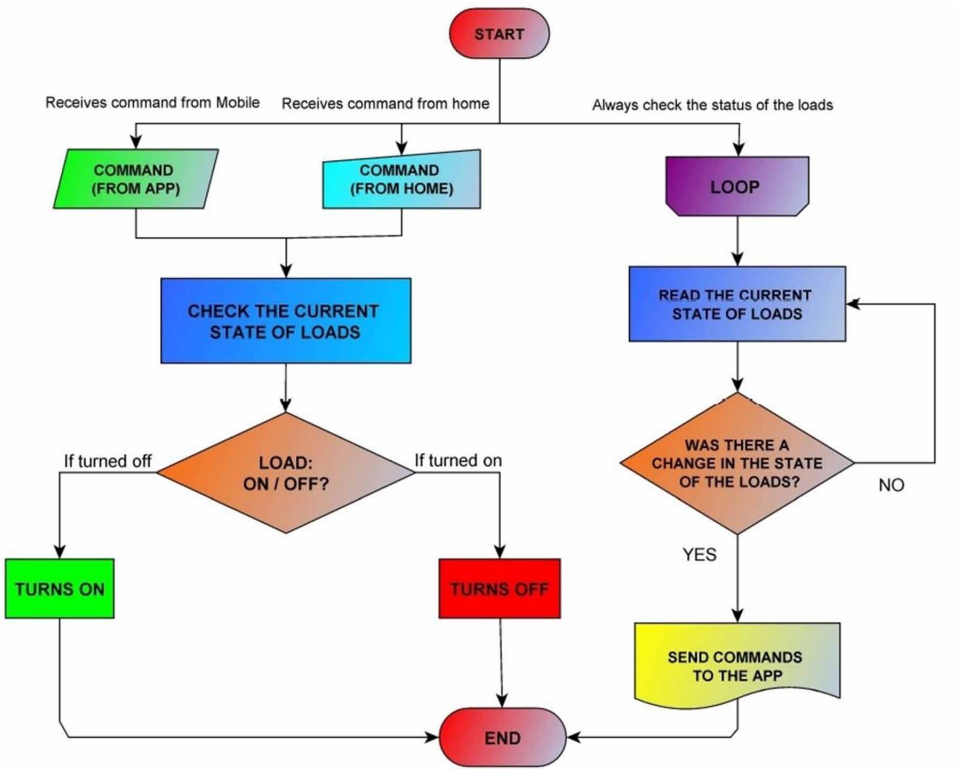
both cases, the GUI presents information showing the current status of the device controlled.

We designed the GUI aiming to improve the users` experience as easy as possible. For example, buttons contain specific colors (i.e., red for turned off and green for turned on) along with the status of the devices illustrated.

Automation Center

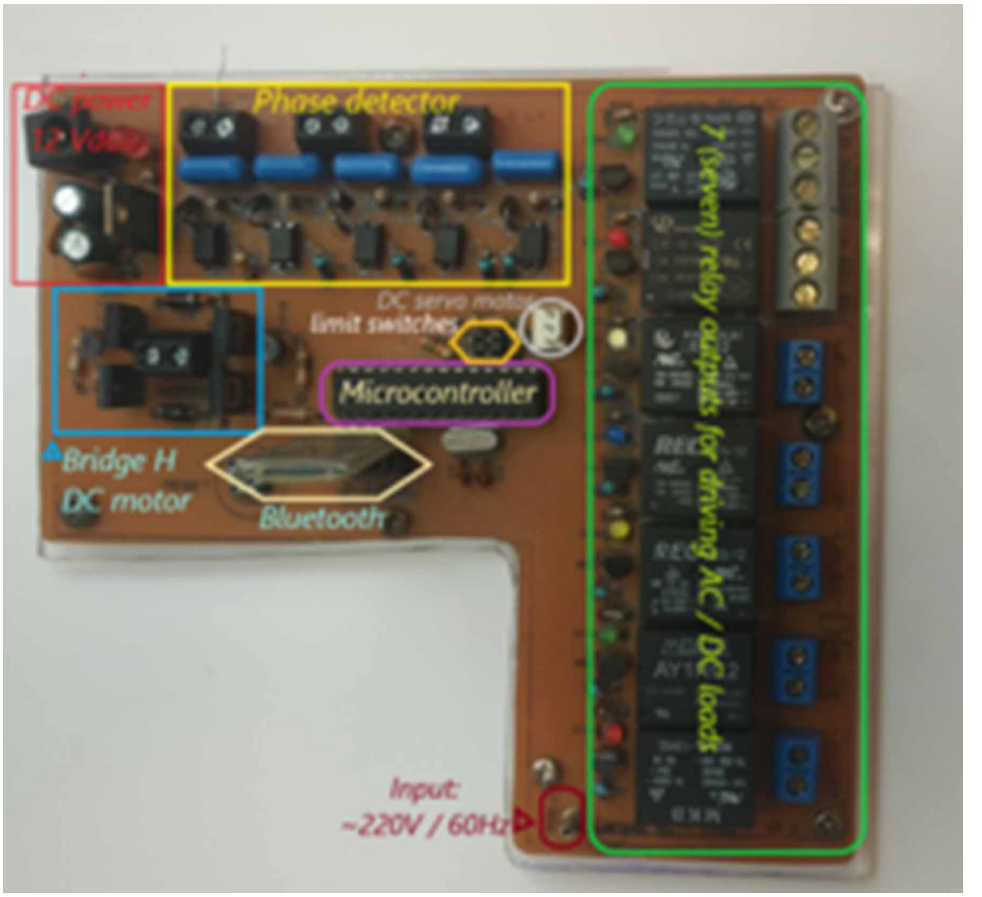
We developed the automation center to control devices, considering sensors and actuators. A microcontroller enables communication with the mobile app using Bluetooth. The automation center receives requests from physical disability or limited mobility people by the mobile app or physical switches. We used the Arduino environment to configure the microcontroller following the flow described in Figure 3.

Figure 3. Overview of the control flow of the automation center



The Proteus ISIS/ARES software (Rodriguez, Martínez, Barcenas & Rangel, 2018) enabled the design and simulation of the automation center, including the printed circuit board (PCB) (Appendix A). Figure 4 presents the control board of the automation center designed based on Proteus. We designed the board comprising up to 9 loads, being 7 220V/10A relay outputs and 2 DC outputs. The board is powered by a 12 Vdc source, through the jack connector, while the loads can be supplied by

Figure 4. Control board of the automation center

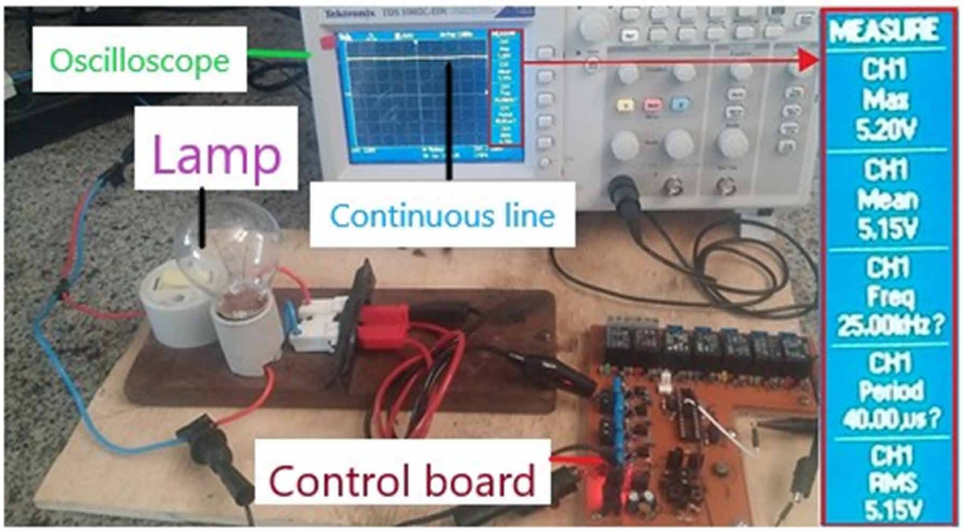


alternating or continuous voltage, depending on the need. There is a phase detector circuit responsible for detecting the loading/unloading of up to 5 loads (e.g., lamps).

We conducted performance tests to analyze the automation center designed. Figure 5 illustrates a sample of the test scenario using the phase detector circuit. On the one hand, Figure 5a shows the oscilloscope results when the load (i.e., lamp) is off, presenting a mean continuous tension of 5.15V. On the other hand, Figure 5b shows the activation of the load (i.e. lamp on), when the phase detector circuit sends a square wave with a frequency of 60 Hz to the microcontroller, presenting an average voltage of 2.64V and effective value of 3.64V. The Atmega328p microcontroller reads the analog input and converts it to the digital domain using an analog-to-digital converter (with a 10 bits resolution).

In addition, considering project costs, the total cost of the control board presented in Figure 4 was R$ 193,46 Brazilian real (approximately 43 USD), considering device

Figure 5a. Performance test scenario of the automation center



components such as resistors, capacitors, integrated circuits, and transistors. When considering a brief web search, it is possible to find automation systems composed of Bluetooth and the Atmega328p microcontroller, by at least R$ 426,00 Brazilian real (approximately 95 USD).

Figure 5b.

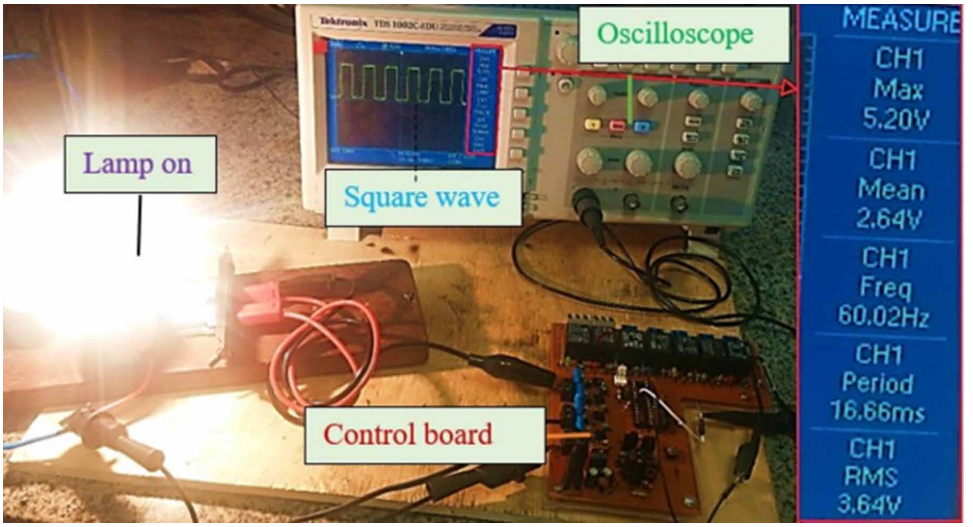


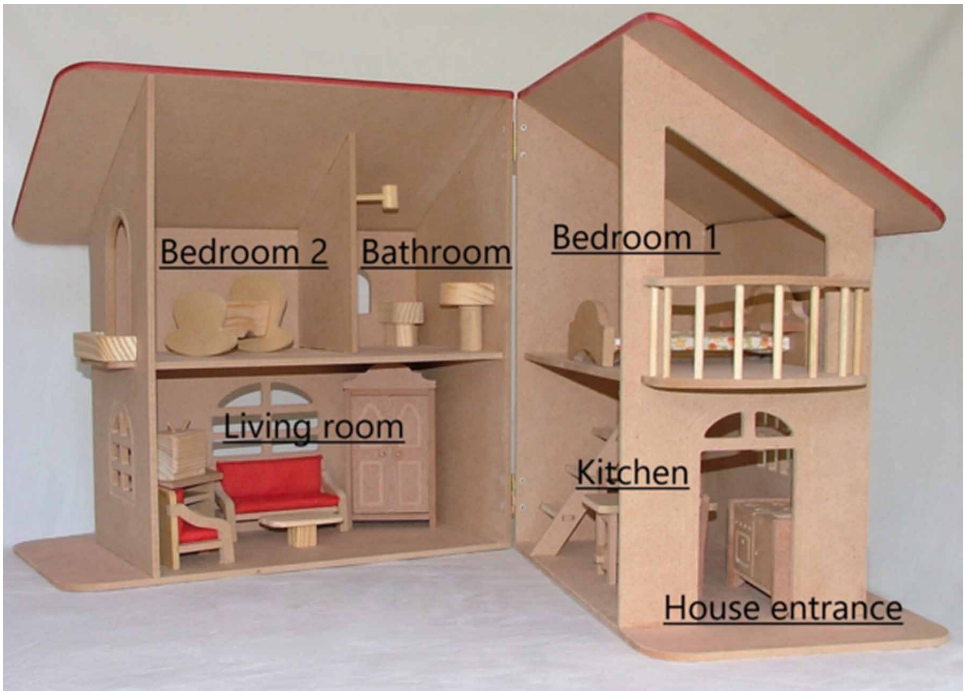
Table 1. Load frame of the small home

Circuit	Description	Schema	Voltage	Total power
1	Lighting	F+N	220V	500VA
2	Power plug	F+N+T	220V	100VA
3	Fan + motors	+Vcc+GND	12V/5V	2VA

Test Environment

We implemented a model home (small home) as a test environment of the proposed home automation system based on an initial design using the AutoCAD software. We also designed an electrical project based on the NBR4510:2004 standard, to be compatible with the real needs of a home, including loads such as lamps and sockets. Physical actuation is conducted by switches. The load frame is described in Table 1.

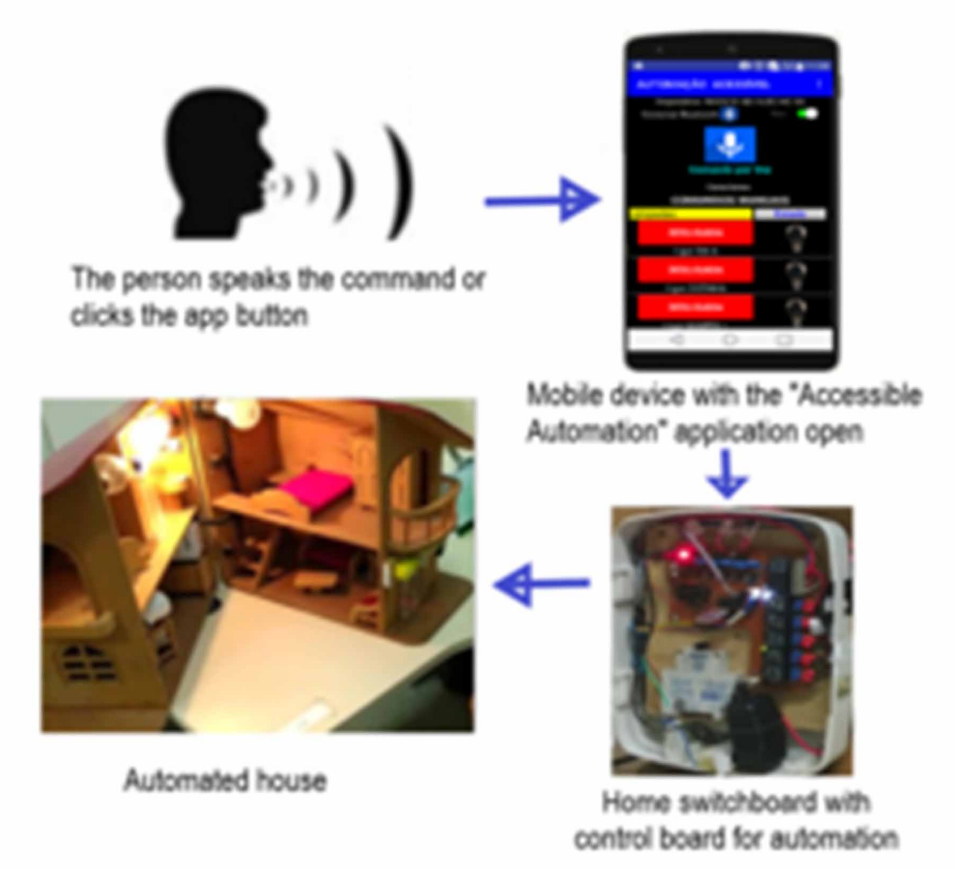
Figure 6. Small home designed to conduct the evaluation of the home automation system



The small home is furnished and divided into rooms, similar to real homes (Figure 6). The home is composed of lamps, sockets, switches, and doors. The electrical project enabled the integration of the home with the automation center.

The test scenario used in the evaluation is presented in Figure 7. As already highlighted, a physical disability or limited mobility person uses the *Accessible Automation* app by touch or voice commands to initiate the interactions between the app, automation center, and the house. Four physical disability persons and one limited mobility person (wheelchair person) used the home automation system considering the test scenario to evaluate system`s effectiveness, the system's usability, and users' perceptions.

Figure 7. Evaluation scenario of the home automation system



Evaluation Results

In August 2019, we evaluated the automation system, using the small home, by providing it for the usage of a limited mobility person (wheelchair person) with spinal cord injury in the lumbar region.

We explained the automation system for the subject, including main functionalities, and project costs. We defined a controlled environment and recorded audio and video of the person when using the system. In addition, we applied a semi-structured interview with the subject to evaluate usability and perception, guided by the topics described in Table 2. The questions only guided the researchers to conduct a discussion about the system.

Table 2. Questionings that guided the semi-structured interview

Circuit	Question
1	What is your opinion about automating a home environment for people who live in needy communities?
2	Do you believe that this type of technology would benefit you at home in daily tasks?
3	What is your perception about the home automation system, including the app?
4	Is the App easy to understand and handle?
5	Are the location of the buttons and images intuitive?

We transcribed the recorded interview to document it and perform analysis. During the testing session, the subject demonstrated to be interested in the functionalities of the automation system, and in the costs needed to implement it. For example, the subject stated:

"Great. It ends up providing more freedom and autonomy!".

Therefore, the subject reported the importance of making such technologies available in needy communities, benefiting poor people with a physical disability or limited mobility, aiming to increase autonomy at home. That is:

"Of course. As I said, it would make it easier to get around the house".

When asked about specific benefits and improvements of the home automation system for people who live in needy communities, the subject stated:

"I believe that the improvements are individual, as each person with limited mobility has specific needs".

The statement may indicate the need for adaptable automating systems, depending on the profile of the users. However, this type of feature will probably increase project costs (a critical problem for needy communities).

In addition, still in August 2019, we presented the home automation system for representatives (i.e., the association`s head, a woman, and two men) of the Association of Physically and Mentally Disabled of Arapiraca (Arapiraca, 2019) (a needy community), Brazil. All representatives have some type of physical disability. We used the same protocol described at the beginning of this section. One of the subjects that represent the association stated that:

"…the system can benefit physically disabled people because it assists the their basic needs".

This statement is in accordance with the person with limited mobility interviewed, indicating the need for more personalized features. Considering costs, the representatives of the association agreed that the low-cost solution can benefit poor people who live in needy communities, given the widespread use of mobile devices. We also requested the representatives to handle the home automation system to discuss the usability of the app. A subject stated that:

"…the interface is friendly! The voice command of the app is interesting to interact with users".

However, the subjects advised some adaptations in the app`s layout; e.g., one of the subjected stated that:

"…to prevent problems for people without arms, the commands should be presented on a single screen, without using the scroll bar".

We considered all the suggestions of the subjects by improving the GUI of the mobile app (named *Accessible Automation*) presented in Section IIIA. We finish developing the home automation system in December 2019.

CONCLUSION

We designed and implemented a home automation system focused on needy Brazilian communities. The system is composed of an Android app and an automation center. We evaluated the automation system by designing and implementing a home model (small home), and by providing the system to four physical disability persons and one limited mobility person (wheelchair user).

The home automation system presented low project costs when compared to systems available in the Brazilian market. Cost is a critical problem for people who live in Latin American needy communities because of the low-income situations suffered by these populations. The evaluation results showed that the simplicity of the GUI of the mobile app was helpful, considering also the low-literacy of most of the targeted population.

However, there are some limitations to validity. For example, during the evaluation, a small number of subjects was interviewed. We faced this limitation by interviewing subjects that are known representatives of the Association of Physically and Mentally Disabled of Arapiraca, composed of persons who live in needy communities. Moreover, we only considered a small set of devices that may compose a real home. We faced this limitation by selecting the most used devices.

We envision some future work. Firstly, it is necessary to modify the GUI to further improve the home automation app, complying even more with the suggestions of improvements identified during the evaluation. In addition, we envision to improve the home automation system considering the user`s profile to adapt the system for the specific needs of users at running time. We also envision to improve the home automation system using the modules ESP8266 or ESP32, considering a network mesh topology and a limit switch. With this system, there will be no need for a control center to centralize all commands, aiming to save wires to make the installation costs as minimal as possible.

ACKNOWLEDGMENT

The authors would like to thank all the professors of the Federal Institute of Education, Science and Technology of Alagoas, Brazil, who directly or indirectly contributed to the development and evaluation of the solution proposed in this research.

REFERENCES

Brasil. (2004). *Decreto 5.296 de 2 de dezembro de 2004*. Available from http://www.planalto.gov.br/ccivil_03/_ato2004-2006/2004/decreto/d5296.htm

Braziliense, C. (2015). *Saiba qual é o custo-benefício de ter um lar inteligente*. Available in https://www.correiobraziliense.com.br/app/noticia/tecnologia/2015/08/20/interna_tecnologia,495363/saiba-qual-e-o-custo-beneficio-de-ter-um-lar-inteligente.shtml

Secretaria Especial dos Direitos Humanos. (2006). *Portaria 142, de 16 de Novembro de 2006*. Author.

eWeLink. (2020). *Features*. Available in https://www.ewelink.cc/en/intro/

García-Peñalvo, F. J., Conde-González, M., & Matellán, V. (2014). Mobile Apps for Older Users – The Development of a Mobile Apps Repository for Older People. In *International Conference on Learning and Collaboration Technologies*. 10.1007/978-3-319-07485-6_12

Ifttt. (2020). *Every thing works better together*. Available in https://ifttt.com/

Kronbauer, A., Gomes, F., & Campos, J. (2018). Specification of a Universal Remote Control for Interaction in Residential Environments. *IEEE Latin America Transactions.*, *16*(11), 2680–2688. doi:10.1109/TLA.2018.8795108

Liao, L.-D., Chuang, C.-C., Ger, T.-R., Wang, Y., Tsao, Y.-C., Wang, I.-J., Jhang, D.-F., Chu, T.-S., Tsao, C.-H., Tsai, C.-N., & Chen, S.-F. (2019). Design and Validation of a Multifunctional Android-Based Smart Home Control and Monitoring System. *Design and Validation of a Multifunctional Android-Based Smart Home Control and Monitoring System.*, *7*, 163313–163322. doi:10.1109/ACCESS.2019.2950684

Mace, R. L., Hardie, G. J., & Place, J. P. (1991). *Accessible Environments: Toward Universal Design*. Van Nostrand Reinhold.

Manda, V. L. K. B., Kushal, V., & Ramasubramanian, N. (2018). An Elegant Home Automation System Using GSM and ARM-Based Architecture. *IEEE Potentials*, *37*(5), 43–48. doi:10.1109/MPOT.2016.2515644

Morais, B. S. G., Sobrinho, A., Oliveira, H., Silva, L. C. & Macedo, R. L. (2019). *Design of a Home Automation App to Assist Elderly and Limited Mobility People The IoT and the Next Revolutions Automating the World*. IGI Global. . doi:10.4018/978-1-5225-9246-4.ch005

Mourão, L. (2012). *Automação residencial: sem fio, controlada por celular e mais barata*. Available in https://casa.abril.com.br/construcao/automacao-residencial-sem-fio-controlada-por-celular-e-mais-barata/

Muratori, J. R., & Dal Bo, P. H. (2017). *Home automation: concepts and applications. 2*. Educere.

Noury, N., Barralon, P., Vuillerme, N., & Fleury, A. (2012). Fusion of Multiple Sensors Sources in a Smart Home to Detect Scenarios of Activities in Ambient Assisted Living. *International Journal of E-Health and Medical Communications*, *3*(3), 29–44. doi:10.4018/jehmc.2012070103

OpenHab. (2020). *Documentation*. Available in https://www.openhab.org/docs/

Paulus, G. B., Piloti, J. S., Antoniazzi, R. L., & Antunes, E. F. (2017). Residential Automation System: Accessibility in Domestic Control. XXII Jornada de Pesquisa, (13).

Rodriguez, R. A., Martínez, A., Barcenas, E., & Rangel, A. J. (2018). Electronic Emulator Circuit to the Muscle Movement in Response to a Stimulus. *IEEE Latin America Transactions.*, *16*(4), 1030–1035. doi:10.1109/TLA.2018.8362133

Vacher, M., Portet, F., Fleury, A., & Noury, N. (2011). Development of Audio Sensing Technology for Ambient Assisted Living: Applications and Challenges. *International Journal of E-Health and Medical Communications*, *2*(1), 35–54. doi:10.4018/jehmc.2011010103

APPENDIX

The development of the PCB was conducted by defining an electrical scheme of the automation center with the Proteus ISIS software (Figure 8). The Proteus ARES was used to design the bottom copper and top silk of the PCB (Figure 9 and Figure 10). We conducted the following procedures for the physical construction of the PCB:

- Circuit printing on a 120g photo sheet with a laser printer;
- Delimitation of the size of the phenolite copper plate to accommodate the printed circuit on the sheet;
- Cleaning the copper surface of the plate using a steel wool to remove dirt and oil residues;
- Overlapping of the sheet with the circuit on the copper face of phenolite;
- Usage of a 1000W iron to heat the paper placed on the plate on the copper part. After ironing for a few minutes (10 minutes was enough for this PCB), the ink was transferred to the plate;
- The cooling was done, wetting in water;
- The wet paper was removed using the fingers of the hand It was necessary to rub until all the paper comes out, leaving only the tracks covered by the ink on the plate;
- A fountain pen was used to correct some faults on the track, when they occurred;
- The plate was immersed in the iron perchloride to corrode the copper in the parts where they were uncovered (without paint);
- After a few minutes, the PCB was ready. All the tracks preserved and the parts without paint were without copper because it was corroded by acid;
- To put the name of the components on the face of the plate, the previous steps were done, with the difference of not using iron perchloride anymore;
- It was necessary to remove the paint only from the islands where the components are welded. Once this was done, the islands in the circuit were drilled with a manual or mini drill;
- Finally, the components were soldered to the plate; and
- Tests were conducted to verify the functioning of the PCB.

Figure 8. Electrical scheme of the automation center of the home automation system, developed on the Proteus ISIS Software

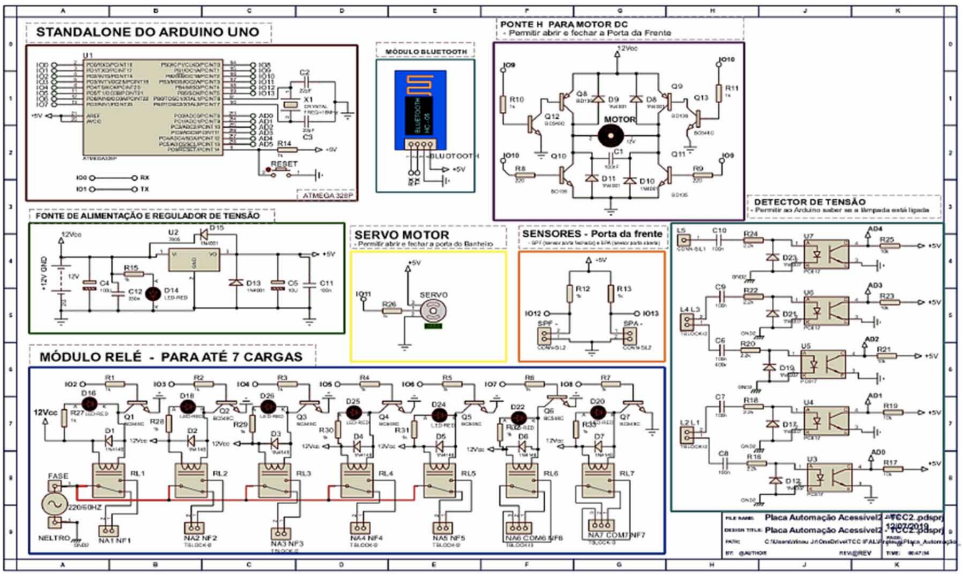


Figure 9. PCB of the automation center of the home automation system, developed on the Proteus ARES Software (bottom copper in original size)

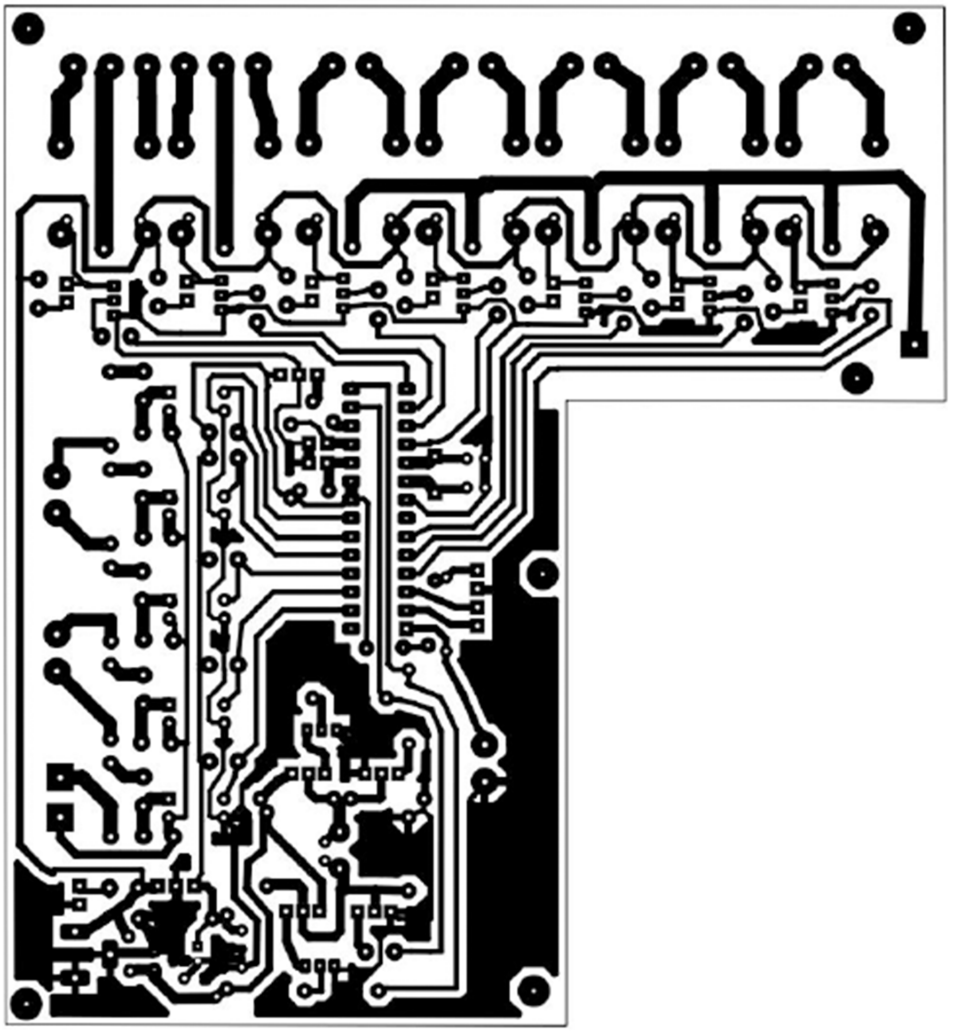
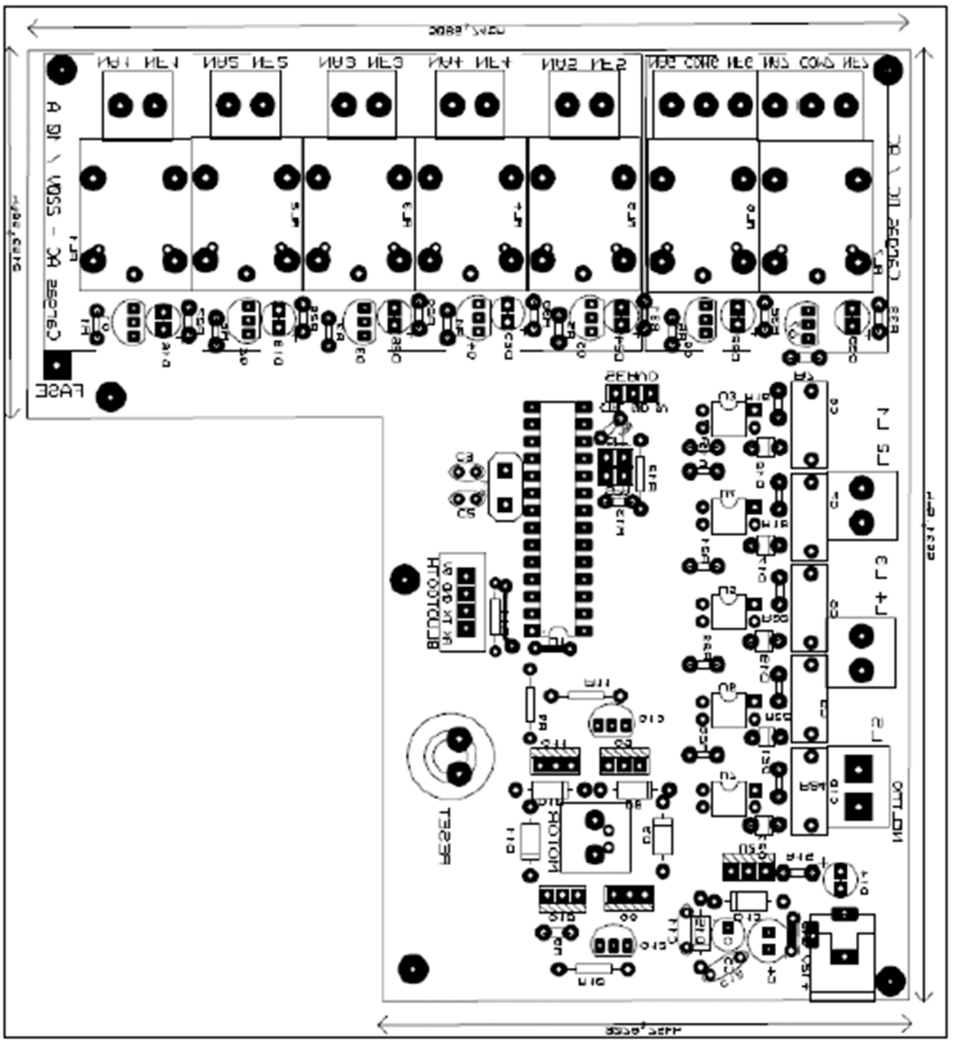


Figure 10. PCB of the automation center of the home automation system, developed on the Proteus ARES Software (top silk in original size)



Chapter 8
Supply Chain Sustainability in Food and Beverage Industry

Anusha Thakur
https://orcid.org/0000-0001-8761-2250
University of Petroleum and Energy Studies, India

ABSTRACT

Green supply chain management (GSCM) is defined as the delivery of various products and services from the different manufacturers, suppliers, and end customers through the information flow in terms of environment. Moreover, unlike the conventional supply chain processes, green supply chain process is engaged in the implementation of various environment friendly ideas as well as strategies in it. GSCM includes different ways to amend the negative environmental impacts along with the improvement in efficiency, increased profitability and costs. In today's scenario, the consumers are shifting their preferences from unsustainable products to sustainable food products, thereby opting green for the same. This chapter emphasizes the necessities of the green supply chain processes as well as the strategies adopted by the firms, particularly in India in the food and beverage industry. The chapter focuses on the trends, impacts, challenges, and opportunities of GSCM.

INTRODUCTION

Expansions in global economy have led to an increase in energy level and material consumption, thereby impacting the environment in various ways. These include ozone layer depletion, biodiversity losses, depletion of air, water, pollution, and minerals, along with the changing climatic conditions (Programme, 2012) (Bank, 2012). It is increasingly becoming significant for the organizations to balance the

DOI: 10.4018/978-1-7998-5879-9.ch008

economic as well as environmental factors in their business operations (Shultz, 1999). Furthermore, with the changing environmental regulations, which have affected the manufacturing activities, the need to emphasize more towards the advancement of strategies related to the Environmental Management, particularly, for the supply chain segment is expected to witness significant growth (Beamon, 1999).

Supply Chain Management (SCM) can be defined as the management of flow of various goods and services, which includes procurement, production, and distribution of various raw materials to the end-users. This process helps maximize the customer value, and reduce the operating costs thereby gaining a competitive edge in the market. **Green Supply Chain Management** (GSCM) includes the amalgamation of environmental concepts or ideas into the Supply Chain of the business processes. Being one of the latest innovations, this process creates a direct relation of Supply Chain with the environment (Azeved, 2011). Few features of the Green Supply Chain include waste reduction, product recycling, asset efficiency, and life cycle costing. This concept deals with the practice of improving as well as monitoring the various environment related performances in the supply chain processes. With the increasing adoption of the sustainable supply chain processes, the environmental impact is expected to be reduced, along with the reduction in costs for the producers and suppliers, reduction in the ownership costs for the consumers as well as reducing the resource consumption in the different segments. Additionally, GSCM is also engaged in improving asset utilization, and increasing innovations in products and services with major emphasis on reduction in cost and waste. Along with the reduction in waste as well as harmful emissions, the effect of introducing this process is expected to impact the business segment both intangibly as well as tangibly. Hence, sustainability in the supply chain process deals with the incorporation of various technological advancements, wherein the social integrity as well as the environmental benefits is well maintained.

The table mentioned below illustrates the differences between Green Supply Chain Management and Supply Chain Management on the basis of few characteristics:

Table 1. Difference between the Green Supply Chain Management and Supply Chain Management

Characteristics	SCM	GSCM
Values from System	Financial	Economic and environmental
Environmental Impact	Higher Impacts	Lower Impacts
Speed and Flexibility	High	Low
Selection of Supplier	SCM focuses on cost	GSCM focuses on ecological aspects

Source: (Bhattacharjee, 2015)

In today's scenario, the organizations are expected to witness various global impacts on their business environments. Hence, in order to overcome these impacts and challenges, the companies emphasize on various ways to achieve sustainability and cleaner environment. Various initiatives are being taken by the organizations to include the "Green Concepts and Principles" in their business operations such as: usage of eco-friendly raw materials, usage of recycled materials for the packaging of the products, and also reducing the usage of petroleum power. With the adoption of GSCM process, the organizations can differentiate among themselves from their competitors, thereby posing a competitive advantage over the same.

The ethical as well as responsible procurement is expected to pose as a challenge for the food and beverage industry segment, owing to the fact that the agricultural products rely on the environmentally damaging technologies as well as the low-cost of labor inputs, for higher volumes of production (Lin, 2007). Such factors are expected to impact the different social as well as environmental aspects, thereby impacting the supply of the food products and its capacity for longer time duration and also threatening the reputation of different food and beverage organizations for the short-term period. Hence, shifting preferences from various operational activities to strategic activities in the supply chain processes of the organizations, can preferably be seen or observed over the given time period.

LITERATURE REVIEW:

Many firms in Asia Pacific, which are an important source of various components, raw materials, and finished products, are expected to witness pressure from the consumers to shift to sustainable products and services. The procurement process in the food and beverage industry is expected to be challenging on account of the factors such as environmentally damaging means of practice adopted to increase volume of the products, along with the low cost of labor inputs. Further, these factors also pose to be a challenge for the food supply chains in the long term. Hence, the various food & beverage companies are shifting their preferences and changing their strategies towards eco-friendly processes. For instance, in today's scenario, the purchase segment of the food industry focuses primarily on the environment friendly materials and methods for the packaging of food products, since packaging and distribution of the same plays a vital role in the industry. Hence, along with reducing the negative environmental impact of the product, the companies also need to focus on the greening of internal operations of the firm.

Green Supply Chain Management (GSCM) is defined as the combination of environmental thinking with the conventional supply chain technique such as sourcing and selection of materials, product designing, manufacturing processes coupled with

delivery of the final products to the consumers (Srivastava, Green Supply Chain Management: A State of the art literature review). GSCM is expected to witness surging demand owing to the growing environmental concerns or problems which includes increasing wastes, declining raw material sources along with the rising level of pollution. GSCM mandates the incorporation of environmental ideas at every stage of the supply chain processes (Infosys). The motive of the Green Supply Chain processes is expected to vary from reactive monitoring of the environment related programs to further proactive practices which includes the R's (Re-Use, Recycle, Reclaim, Remanufacture) of environmental management, varies (Toke, 2010). Few **concepts** associated with the GSCM process is illustrated below:

Green Purchasing: Procurement of products and services with lesser impact on the environment as well as health of the individuals, in comparison to the other products. Green purchasing, also known as the Environmentally Preferable Purchasing (EPP), is engaged in balancing the environmental as well as the financial risks of the organizations, adopting the process. Furthermore, the process of green purchasing is anticipated to offer benefits such as environment related efficiencies, stronger and better relationships with the suppliers, risk management, as well as enhancements in the environment related performances.

Green Manufacturing: The process of green manufacturing leads to reduced occupational and environmental safety expenses, production efficiency gains as well as reduced costs of the raw materials. This also includes the renewal of production processes and the inclusion of environment based technological operations, wherein the pollution and waste can be minimized, with less usage of natural resources. Hence, this concept can be better defined as the strategy adopted by the different organizations, to thereby focus on maximizing the profitability along with efficiency and productivity, with the implementation of the various eco-friendly techniques in the business segments.

Green Distribution: Growing environmental awareness among the consumers as well as the manufacturers is expected to drive the organizations towards the adoption of various environment friendly practices by the organizations in their respective business segments. This concept refers to the methods or ways of logistics and packaging of the goods and services with lesser impact on the environment.

Reverse Logistics: This includes all the operations for the reuse of different materials as well as products. The process comprises of planning as well as implementation of effective & efficient inbound flow and storage of the goods along with the relevant information for proper disposal. According to this concept, the goods are moved from their destinations in order to capture proper disposal or its value.

WHY GO GREEN? "BENEFITS, DRIVERS AND CHALLENGES OF SUSTAINABLE SUPPLY CHAIN PROCESS"

Benefits of Green Supply Chain Management

Growing trend towards the adoption of sustainability in the supply chain processes offers benefits such as reduction in the operating costs; ease the risks involved in the businesses, as well as growth in the adaptability. Additionally, with the implementation of this concept encourage proper alignment with the different customers as well as suppliers, thereby increasing the probability of the same as the most preferred vendors in the supply chain processes. Further, the greener processes of supply chain enhances or optimizes the transportation routes, thereby offering energy efficient, as well as different ways to minimize the costs involved in transportation of the different products from one segment to the other.

Implementation of GSCM can be beneficial to the different organizations in various ways. These include:

- **Lower Risk:** The greener products & services help the organizations to reduce the risks, which are expected to lead to financial losses. There are many evidences where the companies have been focusing on the sale of their products in terms of quantity, by means of illegal ways, thereby affecting the image of the company and the brand. These risks are expected to be reduced by implementing and adhering to the environmental practices.
- **Increase in Revenue:** There is an increase in competition among the companies to reduce the energy and material consumption which have impacts on the environment. The industries primarily invest in the renewable energy, and energy efficiency, thereby satisfying the customers as well as meeting the stakeholder demands.
- **Indirect Yield:** With the implementation of the environmental practices and techniques, the waste products get reduced.

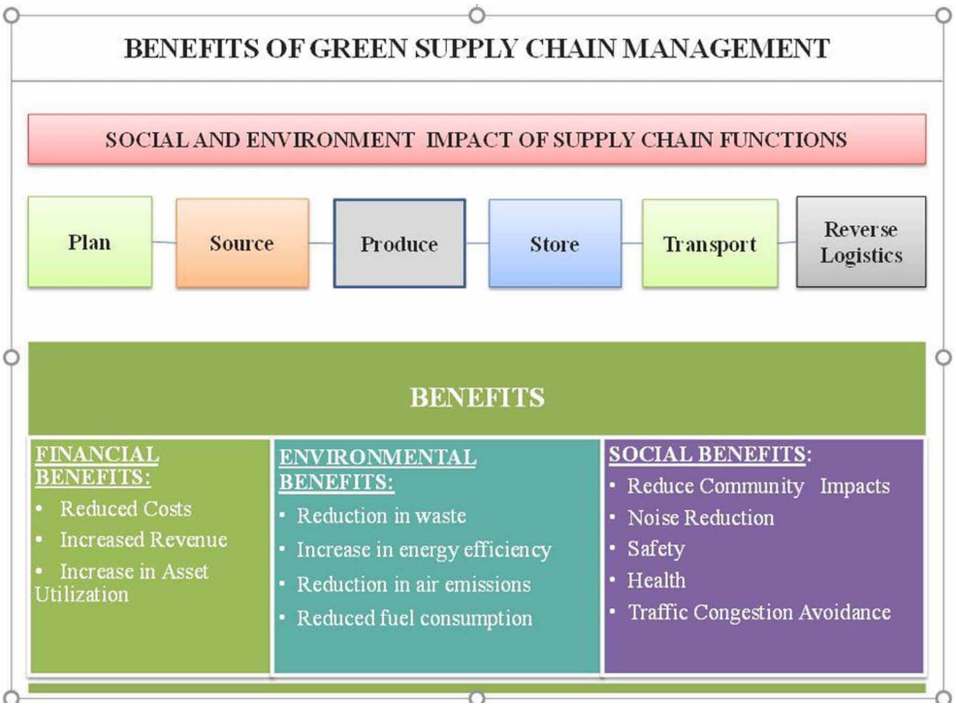
Hence, opting of the greener technology or the processes of supply chain by the different organizations is expected to favorably impact the return on investments for their business segments.

A few benefits of the GSCM processes are illustrated in the figure below:

Drivers of Green Supply Chain Management

There are several factors which are expected to initiate the implementation of the environmental management techniques in the supply chain methods. This is

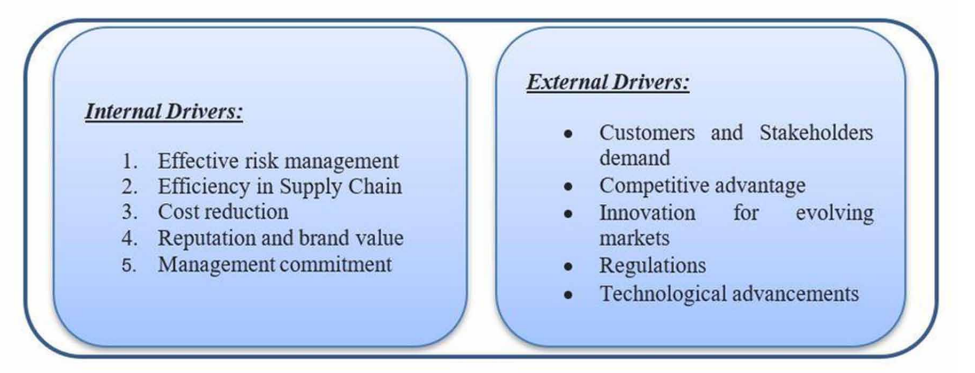
Figure 1.
Source: Secondary Sources



expected to be encouraged by the firm's stakeholder's requests and persuaded by the organizational needs in order to have full compliance with the environmental regulations or sometimes being promoted by the internal strategies of the organizations. This further enables the different companies to gain competitive edge over their competitors in the market, thereby maximizing their productivity and profitability. However, the two key aspects which boost the adoption of GSCM practice include:

- **External Factors:** The external factors include the different government regulations as well as the pressures from the stakeholders. Further, external factors are linked to the different social pressures which are posed by the different communities and groups for the adoption of such practices.
    - **Customers and Stakeholders Demand:** In today's scenario, the consumers are becoming aware for the usability of eco-friendly products. Moreover, the consumers nowadays are keener towards knowing whether the companies are adopting the environmental ways of production or not. Hence, the changing consumer demands are anticipated to play a substantial role in impacting the demand for sustainability in the supply

Figure 2.
Source: *(KPMG, Capitalising on green governance in retail supply chain, February 2017)*



chain process. Understanding of various environmental issues and increasing awareness among the consumers leads to surging demand among the companies for the adoption of sustainable practices which leads to cleaner environment.

- **Innovations for evolving Markets:** Sustainable products are also expected to act as a differentiating factor, thereby adding to the sales of the company. Suppliers are anticipated to provide inputs on the developing environmental friendly products and services, thereby boosting the product innovations. The companies are either focusing on the development of newer advanced products or introduce new features in the existing products.
- **Technological advancement:** This is one of the factors favorably impacting the market growth for sustainability. Various advancements in the renewable technology are expected to increase the investments by the big retail companies in the cleaner energy segment.

- **Internal Factors:** Includes a set of business led strategic motives. These include advancements in profitability, productivity, and performance.
  - **Management Commitment:** In many organizations, the drive for the adoption of sustainable practices comes from the top management of the company. These provide vital roles in the integration of supply chain in the organization's operational process, which thereby creates a friendly culture in the firm.
  - **Effective Risk Management:** The retailers are engaged in adopting the green supply chain management processes, for minimizing the industry disruption from different social as well as environmental risks. Effective

management of environmental and social risks helps the organizations to minimize the operational delays.

- **Efficiency in Supply Chain:** For the implementation of sustainable initiatives in the supply chain processes, clear understanding of the cost, environmental as well as social impact is very much essential. This would help in the attainment of better management as well as channeling of resources. Increase in knowledge and awareness is also expected to act as an effective way or method for quality enhancement and thereby leads to minimal pollution and waste.

The above mentioned factor enables the firms to adopt these kinds of standards and initiatives, and become certified in compliance with the same.

Challenges in Green Supply Chain Management Process

With the implementation of sustainable supply chain process, certain challenges can be expected. These challenges can be described as:

- Practicing of the green marketing is expected to be costly at the initial stages. The Green Supply Chain Management includes greener technology, green products or services and expenses included in the Research & Development division as well.
- Well-equipped technology along with the lack of technological expertise in order to compliment the businesses with Green Practices might also pose to be a challenging factor.
- The customers are expected not to believe in the efficacy of the green strategies implemented by the different firms or organizations. Hence, it becomes very important for the firms to individuals regarding the greener initiatives by the introduction and adoption of the different environment related labeling schemes. These schemes are very famous in the regions such as Europe and Asia Pacific, particularly Japan, and are engaged in offering eco-friendly status to the various products.
- Lack of awareness amongst the supply chain firms for the benefits of green products. Hence, the lag in the supplier as well as consumer support exists. Additionally, in India, the presence of inadequate groups and organizations to encourage the companies to implement sustainable measures in the right manner
- At the initial stages, the profitability is expected to be less, owing to the fact that the recyclable products and the use of greener technology are more costly.

- One of the most important aspects of GSCM includes the integration of recycling of the products. However, integration of the waste as raw materials and then further using it in the manufacturing segments is expected to be the challenging factor for implementation of GSCM.

RESEARCH METHODOLOGY

This study includes varied information collected through the different secondary sources such as journals, research papers, articles, trade reports and company annual reports. Various innovations across the different industries, as well as businesses were particularly considered. Additionally, the study was based on the different strategies, initiatives and measures taken towards the Green Supply Chain Management processes by the different organizations or firms in the Asia Pacific region.

RESEARCH QUESTIONS

- What are the different issues affecting the adoption of Green Supply Chain Management in India?
- What are the different challenges or hurdles which the companies are facing to implement the GSCM practices?
- Different initiatives and measures adopted by the Indian companies in terms of sustainability or with respect to the GSCM.

Significance of the Study

This study aims to provide in-depth analysis of the Green Supply Chain Management practices. Further, this study emphasizes on various topics such as:-

- To understand the different factors which favorably impacts the operation of Green Supply Chain Management in the various application segments particularly, the food & beverage industry.
- Challenges related to the implementation of sustainable supply chain processes by the different organizations, in the Asia Pacific region, particularly in India.

Scope of the Study

- This study provides emphasis on various trends of Green Supply Chain Management practices in the regions of Asia Pacific, particularly, in India along with the benefits offered by the same.

ANALYSIS: "Asia Pacific Region"

The food & beverage industry is continuously gaining traction in terms of newer advancements such as concept of sustainable production as well as green supply chain processes. This can be attributed to the factors such as increasing demand for product output as well as healthy organic products, coupled with the changing consumer preferences and lifestyles. In today's scenario, the supply chain pattern is witnessing significant change towards efficiency as well as cost effectiveness.

Key market players are engaged in making investments for the different ways or methods to achieve sustainability in the supply chain processes. For instance, the Asian companies are primarily emphasizing on factors such as eco-friendly ways of packaging and management of the same. This can be illustrated as:

- Reduction in plastic packaging:

Increasing awareness among consumers for sustainability along with China announcing the ban on imports of plastic waste products are anticipated to favorably impact the shift towards greener supply chain. Further, as per the aforementioned trends, several brands or players are increasing their commitments and goals towards the implementation of the same, particularly in the Asia Pacific region. For instance, players such as PepsiCo, as per one of its key strategies - "Performance with purpose goal-2025" is focusing much on the greener methods of packaging which includes designing the packaging in a way which can be reusable, or recycled, or compostable among different other products. Further, with the introduction of "Performance with the Purpose" strategy, PepsiCo is engaged in reducing the greenhouse gas emissions across its supply chain segment by nearly 20 per cent by the year 2030. Additionally, PepsiCo also announced the launch of pilot in "India" which includes the first compostable packaging for varied snack products such as Kurkure and Lays. This newer method of packaging is basically bio-based, wherein it is particularly, made from the plant-based materials as well as 100 per cent compostable. Further, the packets used for the packaging of the same, can be disposed with the regular food taste and can is expected to easily get decomposed at the different industrial composting locations.

Furthermore, PepsiCo has also announced the launch of the "Sustainable Farming Program" in India, thereby offering significant say in the agricultural sector. Additionally, this program also offers a roadmap to the company for further

improvements or advancements in their farms or the regions. Further, the company is involved with the growers of all farm sizes and varieties, and in providing various environment friendly farming techniques or practices, thereby enhancing the capabilities of the growers and mitigating the risks involved. The company is engaged in procuring several agricultural ingredients from various farmers across the world, both indirectly as well as directly. As per the reports, the company is largely dependent on the farmers across the different regions for the procurement of products such as potatoes for the Lays Chips, oranges for the Tropicana juices, along with the oats for the Quaker products.

Hence,

- PepsiCo is engaged in the sourcing of its products via the adoption of various sustainable practices.
- The Supply Chain process of the company includes engagement with the various farmers for the supply of agricultural raw materials or resources
- As per the company's reports, nearly 24 per cent of the directly sourced agricultural raw material products can be classified as a part of sustainable source.
- The company is engaged in adopting of the supply chain processes wherein, the harmful emissions can be reduced, thereby reaching the point of sustainability.
    - Investments in R&D for ensuring sustainability:

Growing advancements for research and development in the green manufacturing segment through various ways of energy as well as water reduction techniques, waste reductions/treatment coupled with the reuse of eco-friendly materials are expected to lead to different leaner production methods. However, few major challenges in the green manufacturing processes includes reduction in pollution and waste products, and improving the design of the equipment, to further enhance the efficiency and productivity in the manufacturing processes. Additionally, reduction of environmental effect on processing ways is expected to reduce the energy usage along with the decrease in overall costs, thereby offering the manufacturers return on their investments.

ANALYSIS: "Scenario In INDIA"

In India, the businesses are recognizing the sustainability benefits as well as organizational transparency. The companies are now realizing the need to measure the sustainable performance along with the evolving regulations around the social as well as environmental parameters. The different strategies as well as technologies

being implemented in the supply chain processes by the different players help them gaining competitive edge over the other competitors.

Implementation of GSCM Technique by Companies Such as: "Coca Cola, Hindustan Unilever Limited"

Coca Cola

In the year 2007, Coca Cola Enterprises announced few strategic Corporate Responsibility and Sustainability (CRS) in key segments. These included sustainable recycling/packaging, conservation of energy, diversified culture, and varied product portfolios. Further, the company emphasizes on the establishment of cost-effective analysis processes in order to prioritize its various investments.

One of the key strategies of Coca Cola includes reduction of the carbon footprint by nearly 15 per cent by the year 2020, considering the base year for calculations as 2007. Additionally, this can be further explained as the reduction in the impact of packaging, i.e. maximizing the usage of recyclable, reusable as well as renewable resources. For the reduction of carbon footprint, Coca Cola included certain procedure wherein, the company was engaged in measuring firstly their carbon print and then calculating the carbon footprint of the first certified product of the different beverages and further also increased their fleet by approximately 120 trucks. Further, for the establishment of sustainable water related operations, the company announced the reduction of usage of water ratio to approximately 1.7 Litres, and saving nearly 301 Million Litres with the help of various initiatives, thereby increasing the efficiency.

Furthermore, in January 2018, Coca-Cola announced the plan to recycle the beverage bottles at a global level by 2030. The company is engaged in focusing towards the making all its packaging 100 per cent recyclable across the world by reducing the amount of plastic content in the bottles. For instance, for the reduction of environmental impact on the packaging processes, Coca Cola reduced the usage of nearly 31,000 metric tons of packaging materials, thereby reaching share of over 90 per cent in terms of recycling of the waste products and also recycled nearly 1,25,000 metric tons of the packaging material used.

Additionally, by 2030 the company has targeted to make the bottles with an average of nearly 50 per cent recycled content. However, it has not provided the content of recycled content in its packaging currently. Further, the company has also emphasized that one of the challenges for the mentioned target is achieving it in the developing countries, since; the developing countries have nearly 25 per cent of any form of formal waste collection.

Hindustan Unilever Limited

Nutrition segment: India Food and Refreshment Portfolio

- **Nutritional Standards:** The Company is constantly working on nutritional standards for improvement in the quality of products across the dietary standards recognized across the world. According to the 2017 statistics, 39 per cent of the Food segment had met the highest nutritional standards globally. However, In India, only 47 per cent of the total food & beverage segment had met the nutritional standards.

Table 2. Ways to reduce the environmental impact

Ways to reduce environmental footprint	Solutions taken
Reducing CO2 emissions in Manufacturing	• In the year 2017, as per the study conducted, CO2 emissions were reduced in terms of per tonne by approximately 54 per cent in comparison to the previous years. • This has been achieved through the rising usage of solid biomass and liquid biofuels for renewable electricity and process heating through the solar photovoltaic installations and solar power purchase agreements.
Reduction in Greenhouse Gas Emissions from Transport	• In the year 2017, the CO2 emission was reduced nearly by 17 per cent. The strategy of "Load More Travel Less" along with the rising usage of the alternative fuels as well as increased efficiency of processes helped in reduction of the CO2 emissions. • The company had introduced CNG trucks in some regions
Reduction in the Greenhouse Gas Emissions from refrigeration	• Usage of eco-friendly freezer cabinets which includes hydrocarbon refrigerants as an alternative to the Hydro fluorocarbon refrigerants. In 2017, the company rolled out nearly 2500 units of eco-friendly mobile vending models comprising of the latest HC technology.

Source: (Unilever Sustainable Living Plan: India Progress 2017)

The Different Sustainability Initiatives Taken by Unilever in India Include

- **Reduction of Waste During Manufacturing:** According to the company's reports, the total waste products produced from the factories was reduced by nearly 54 per cent in 2017, keeping the base year as 2008. The company was engaged in maintaining the "zero non-hazardous waste" option from the different locations. Additionally, these waste products was further recycled via various eco-friendly methods.

- **Reduction in Packaging:** With the innovations in various packaging methods, the usage of plastic was reduced in 2017. The company was engaged in substituting the different commodity polymers with the different performance based polymers, thereby changing the packaging patterns and optimizing the packaging designs as well. The aforementioned factor is expected to reduce the consumption of plastics for the different product or application segment. Hence, in 2017, Unilever had announced the reduction of waste products, generated as a result of the usage of polymers by nearly 1700 tonnes. Furthermore, as per the reports, the company also offered reduction of approximately 95 tonnes of glass in the food segment with the help of various material optimization techniques.
- **Recyclable, Compostable or Reusable Plastic Packaging:** Unilever is engaged in offering 100 per cent compostable, recyclable, as well as reusable plastic packaging products by the forecast year 2025. The company has reduced nearly one-third of their packaging based on plastics since the base year 2010.

The Unilever Sustainable Living Plan (USLP) is committed to ensure 100 per cent of the reusable and recyclable plastic packaging by 2025. The company also announced the reduction of nearly 1,300 tonnes of paper across different groups or segments and approximately 95 tonnes of glass in the food segment through various material usage optimizations.

The Different Sustainable Sourcing Initiatives Taken by Unilever Include

- **Sustainable Sourcing of the Different Raw Materials:** Unilever is considered to be as one of the leading buyers of products such as tomatoes, and black tea produced across the different regions of the world. The company focuses majorly on the sustainable ways of procuring the agricultural raw materials. Factors, such as, where does the company procure these products from, and with whom do these companies work with is expected to have intense impact on the procurement of various global raw materials as well as resources.
- **Sustainable Tea:** According to the study conducted by the Hindustan Sustainable Living Plan: 2017, nearly 285 tea estates are rainforest alliance certified and 423 tea estates in India are trust tea verified. Additionally, nearly 52 per cent of the tea is sourced from the different sustainable sources in the country and the country aims to reach the target of approximately 90-100 per

cent by the year 2020. Also, approximately 40,000 smallholders and 5,00,000 plantation workers are verified under the trust tea code.

- **Sustainable Vegetables and Fruits:** Unilever had announced the procurement status of tomatoes for its well-known brand "Kissan" for the product segment Kissan ketchup, as 100 per cent from the sustainable sources, in the year 2017. In 2012, the company announced the private-public partnership between the Government of Maharashtra and HUL, for the sustainable sourcing of the tomatoes. The company is engaged in various strategies such as offering the buy-back guarantee to the farmers for every production of the product. Furthermore, the company is also involved in providing different types of awareness as well as expertise, in the sustainable agricultural practices for the cultivation of tomatoes, such as the different irrigational practices, different techniques related to agriculture, coupled with the implementation and usage of the correct type of seeds being used.

SUGGESTIONS

The adoption of various greener techniques impacts the sustainability as well as stability, in every possible socio-environmental way, thereby proving it beneficial for the longer run of the business. For the successful implementation of sustainable supply chain processes, the companies need to focus on stronger relationships of the trading partners, and also emphasize on the effective coordination of every step involved in the supply chain process, right from the procurement of the raw materials to the final delivery of the products to the end-users.

Use of eco-friendly packaging material: The organizations should focus on the usage of environment friendly products. The usage of biodegradable material for the packaging reduces the harmful effect on the environment.

Adoption of green and clean technologies: The low cost of manufacturing products is expected to create a hub of cleaner technology products. Additionally, the manufacturers should also focus on the awareness for technologies related to the GSCM practices and must be given sufficient technical training to gain expertise in that segment.

Reverse logistics: The materials after consumption should be effectively recycled, re-used, re-distribution, and management. Reduction of pollution during the transportation proves to be one of the vital aspects of reverse logistics.

CONCLUSION

In today's scenario, factors such as climatic changes along with global warming is expected to impact businesses in the longer term and also impact the sustainable economic progress of the same. Hence, to tackle such problems, the companies are increasingly, focusing on the adoption of green supply chain management techniques in their business segments, thereby achieving efficiency, cost-effectiveness, as well as profitability in the same. Furthermore, the key players with time have realized the importance of these sustainable practices, and are hence, implementing the same to increase their credibility among the different stakeholders, thereby proving in their respective business segments for longer duration or a longer run.

These kind of environmental friendly activities or processes are expected to have positive impacts on the financial performance of the organization. This sustainable process helps in the reduction of energy consumption, costs reduction, as well as for the reduction of the waste products. Further, this approach is also expected to lead to internal cost savings as well.

Green Supply Chain Management is an important issue, which if implemented in the right manner is expected to gain traction over the forecast period. Currently, the current operations in various organizations in India and across the world, is expected to negatively impact the environment, thereby reducing the profits. The growing environmental concerns are expected to promote the adoption and implementation of the environment friendly practices in every stage of the supply chain process. Hence, in today's scenario, the companies are emphasizing on investing heavily on the sustainable sourcing and procurement, green manufacturing and product packaging, with a focus on reduction of carbon footprints in the supply chain process. The organizations are putting a lot of efforts on the sustainable processes to achieve cleaner and greener environment. However, the country's legislative policies and frameworks which support the sustainable efforts should be specific. Additionally, lack of proper technological knowledge and expertise is also expected to pose as challenge in the implementation of GSCM practices in India. This paper focuses on encouraging the different new market players to adopt sustainable techniques of supply chain for their different business or application segments.

REFERENCES

Azeved, S. C. (2011). The Influence of Green Practices on Supply Chain Performance: A Case Study Approach. *Transporation Research. Part E*, *47*(6), 850–871. doi:10.1016/j.tre.2011.05.017

Bank, W. (2012). *Towards a Green, Clean and Resilient World for all*. Academic Press.

Beamon, B. (1999). Designing the Green Supply Chain. *Logistics Information Management*, *12*(4), 332–342. doi:10.1108/09576059910284159

Bhattacharjee, K. (2015). Green Supply Chain Management - Challenges and Opportunities. *Asian Journal of Technology & Management Research, 5*(1).

Infosys. (n.d.). *Green Supply Chain Management*. Academic Press.

Jackson, a. R. (1998). Where's the profit in industrial ecology. *Journal of Industrial Ecology, 2*(1), 3–5.

KPMG. (February 2017). *Capitalising on green governance in retail supply chain.* KPMG.

Lin, J. (2007). *Sustainable Supply Chains in the Food and Beverage Industry*. Academic Press.

P, R. (2007). Greening of the supply chain: an empirical study for SMES in the Philippine context. *Journal of Asia Business Studies, 1*(2).

Programme, U. N. (2012). *Global Environment Outlook: Environment for the future we want*. Author.

Srivastava, S. (2007). Green supply-chain management: A state-of-the-art literature review. *International Journal of Management Reviews*, *9*(1), 53–80. doi:10.1111/j.1468-2370.2007.00202.x

Srivastava, S. (2007, March). Green Supply Chain Management: A State of the art literature review. *International Journal of Management Reviews*, *9*(1), 53–80. doi:10.1111/j.1468-2370.2007.00202.x

Toke, L. K. (2010). Green Supply Chain Management; Critical Research and Practices. *International Conference on Industrial Engineering and Operations Management*. *Unilever Sustainable Living Plan: India Progress 2017.*

Chapter 9
Transition for Transformation for Sustainable Automation

Stephen Bushell
Bushell Investment Group, UK

ABSTRACT

Transformation and specifically digital transformation have been at the heart and soul of all enterprises. The focus of enterprises when it comes to transformation has been on digital transformation and in some cases organisational transformation. However, very rarely transformation has focused on both digital and organisational transformation, and very rarely for the purposes for transition for transformation. Transformation on its own will only provide improvement and enhancement to the current processes and systems and will not introduce new and innovate methods and approaches to the enterprises knowledge and capabilities. This chapter aims to emphasis the characteristics of transition for transformation from a business perspective in light of 21st century challenges and emphasizes the importance of transparency and collaboration.

INTRODUCTION

Mining Knowledge and Capability

Digital Transformation? Really? Let's begin positively where most innovation projects fail, let's not get people on the back foot and scaremonger with bullying tactics, lets apply common logic and decency and ensure realistic psychological reassurance is administered.

DOI: 10.4018/978-1-7998-5879-9.ch009

After all it is unproductive to start the process by highlighting the unnecessary label of transformation, after all who wants to be told they need to be transformed.

Surely the best practice approach should be evolutionary, transformation by default creating an intuitive and innovative transitional roadmap and a desire by all to deliver excellence supported by productive quality data – in. By adopting this mantra, eliminating ego and protection of domain data we stimulate only a desire to achieve collaboratively and create a dynamic sharing economy (Smaczny, 2001).

Once established we automagically create quality solutions and then the whole facets of the business become digital by default. If we are forced to deliver just any and all data, then we only end up automating a data mess that was is already recorded in the system for data sake and remains unproductive meaningless and unstructured and held hostage by the nay Sayers. I suppose a good analogy of this is having all the best ingredients, but not knowing how to create the actual meal or bake the perfect cake!

CEO, Directors, Management and full team buy-in and collaboration in all departments across the business is essential. This collaborative cross-pollination of data and process is possibly the most important first steps in uncovering; "The Art of The Possible. With an uncontaminated and open mindedness acceptance of what can be.

(OHT) Organic Human Transition

Nurturing a mindset by default to accept and embrace cutting edge invention allaying any threat and fear of losing job security.

After all, "it is human nature that one strives for survival as every human needs a sense of purpose to remain sane and useful to survive!" Accepting technology as an enabler and as a valuable assistant will accelerate this mission. Furthermore, it will aid you to develop concise innovation pathways that become meaningful and productive that will truly drive innovation and productivity through sustainable automation for business and personal(human) growth.

"Successful and sustainable automation can only be achieved when a person truly believes and embraces the vision and mission".

Sequentially and with openness, the trust now established across the enterprise, especially from the "people people "will create a pathway that will seamlessly enable a natural, human transitional acceptance (NHTA) and a desire and willingness to embrace new ways of working. Furthermore, it will embed a more proactive and fearless approach, instilling confidence for an open-minded understanding of cutting-edge tech, tools and better quicker faster ways of working. New skills will be

developed, and the training and upskilling will create vital new learning pathways that will continuously evolve accurately and organically in harmony throughout the business visualised in 3d rapidly implemented by state-of-the-art software and digital tools in perpetual motion.

The evolving business roles that would surface will become the future of new job creation assisting the business. In addition, this discovery workflow will uncover new and creative roles that would naturally assist the innovation process and function required to empower and deliver the inventive transformative slick way the business would maintain global competitiveness. Ultimately this exciting new collaboration and cross-pollination of skills and data-sharing will deliver meaningful transformation in the day-to-day business that will be embraced and will empower the business with a global leading edge (Chesbrough and Rosenbloom, 2002).

Real time data collaboration across multiple departments with a dynamic reports' engine will save on duplication of effort and create new skills in harmony. Finally, the business economy becomes futureproofed by developing a centralised data dashboard with secure roles-based access and aggregated global cross -platform collaborative solutions and automated systems for scale and growth in real- time (Chesbrough, 2010).

It is fundamental that there is a clear career pathway and a guaranteed future period of Job security presented in the beginning of the project vision. In addition, it is furthermore vital to endorse the importance of human collaboration and employee inclusion in achieving this required yet exciting new business transformational invention. Now we can dispel the myth of not having secure employment by helping to enable automating their current business function and eliminating any negative sense of doubt. This honest, transparent inclusive approach will instil the necessary confidence and voluntary cooperative willingness to embrace, adopt and adapt meaningful business tools and create better solutions implementing sustainable automation. Let us also not forget the importance of unleashing the new skills that will emerge throughout the transitional and transformational evolvement.

Adopting this collaborative and cross departmental attitude and openness in sharing data, it will empower essential invention and innovating better skills and tools for faster human adoption & transition for evolutionary transformation by default and with a 3d 360-degree view *(see figure 1). Clearly,* by incentivising and re-enforcing job stability you will destroy the human pushback and eliminate the challenging mindset of "not invented here syndrome" and furthermore over protecting their domain knowledge and shared expertise.

After all Charles Darwin once said "It's not the strongest of the species that survives, nor the most intelligent that survives. It is the one that is the most adaptable to change" -including the leadership…. We experience so often the expression; "do as I do but not as I" say which appears to bode well with most **Machiavellian**

style leadership and even more so, having heard someone senior in the business transformation once say "let's lead the witness" or leading the witness can most definitely sew the seed of concern and create unnecessary doubt. Success is not achieved by leading someone into the abyss or being hoodwinked into a false sense of security The art is to share the vision and stimulate ownership and involvement and most importantly to make it known that it is just as much virgin territory for everyone and that its ok to make mistakes along the way. By being open, transparent and demonstrating true partnership, it will most certainly encourage and stimulate new ideas and pathways for success.

This is about taking effectively what is in between the ears and inventing better ways of working such as innovating new business models, tools and methods and then processing the information with a best practice /best value approach, which underpins and opens the gateway for success. Whilst energising the transition through invention for the human and accompanied by visionary new skills, tools and capabilities, this process naturally delivers sustainable automation (Kearns, Chesbrough and Rosenbloom, 2002). and then "The inventive **possible** becomes an innovative **art** of requirements". In addition, new skills capabilities and relevant meaningful and a necessary pallet of solutions soon emerge. These newfound necessary innovative better ways of working will organically lead to inventing solutions that will futureproof the business with new skills and ironically, in the first instance empower just the human only! Human only tools (HOT)

Am I going to be Lucky when I adopt this new way of working and is this the right timing to have a chance of becoming successful? Or will this disruptive new technology invent greater problems for me? This oxymoronic line of questioning is typical from a non-believer or to be fair, someone who has not had the time spent with them to explain even about evolutionary industrialisation such as the services transformation, 1973 to 2016 or more currently industry.40 or even industry.50 as the Artificial Intelligence (AI) era . I'll bet they have never even had their minds open to what history has taught us regarding modernisation and the reinvention of jobs, products and services? Now let's open our mind to exploring a positive way forward and start to act more positively and entrepreneurially.

Let's look at LUCK in the context of using the word created as an acronym -meaning: Learning. Under. Correct Knowledge: We already know there are platforms that map the skills, knowledge and expertise available across an organisation's total talent supply chain of internal, contingent and alumni workers. And subsequently we now know that through implementing solutions without the need to write code, organisations can now connect their workforces and business through matching people to people, people to work and automating workflow and process's. This is about getting on with delivering business critical solutions rapidly and instantaneously without having to know the granular working details. I suppose the best analogy for

this would be not having to know how a brick is made but to just get on and build with it. Now let's call this learning under correct knowledge, we have now made our own luck surely?! Having now embraced our luck we now understand the requirement and its necessity for business improvement, and we can now invent new solutions.

Once we now know what we didn't know and have uncovered the art of the possible we would look for an opportunity (chance) to implement it empowering rapid improvement and ultimately faster routes to success.

What is Luck? "good or even bad things that happen to you by chance, not because of your own efforts or abilities?" Yet, whilst chance is used as a descriptive part of the definition of luck "Chance the occurrence of events in the absence of any obvious intention or cause." Is not using luck?

Now if you would be good enough to allow me to indulge in some of my personal insights. Surely the difference between knowing and doing something with the knowledge could be deemed as the doing that enables and empowers the entrepreneur to become inspired, activated, inventive and entrepreneurially successful? Or … Could we just dismiss that innate charismatic leadership, magical talent, innovative learning skills and magnetic personality and just say they were Lucky?

Furthermore, one could then say it was circumstantial that they were lucky and even more circumstantial that they were by chance in the right place at the right time! Each observation and situation could be true to the event and yet the invention plus eureka moment still occur? The fact remains, the entrepreneur will not only talk the talk but will most definitely clearly identify & spot the opportunity to then deliver the vision by walking the walk.

Automation is evolving rapidly, a question that should be asked by the entrepreneur or more appropriately named the intrapreneur is: "don't you think we should enable a SWAT analysis or at the very least a competitor analysis, market share and possible risk assessment exercise to better understand our future"? "Come on, let's be doers!" "What's that I still hear as a distant nagging recurring doubt"? Transformation, "I need to transform, So what's that about"? "Why force change on us"? "Why automate"? "If it isn't broke why fix it"? "Looks like they want to get rid of me and automate my Job!" Some of the real-world statements we hear repeatedly when delivering change scenarios to invade a person's daily comfort zone and habitual work ethic.

This is a trait of the negative procrastinator and certainly not the confident entrepreneur.

"*The most common human fear of sharing knowledge is the fear of becoming redundant" The whole process fails when it is perceived as a threat by not communicating how the "people people "would evolve after automating their knowledgebase, workflow and process."* This naturally defensive and dismissive behaviour can be short circuited and instead of creating a negative effect can open their minds for a better smarter and secure future with the organisation. We can

stimulate and empower human adoption to drive productivity and innovate through rapid application development and implementing meaningful sustainable automation. Now let's explore how we do it and how we should engage:

Firstly, realise and unleash a shared vision, get global buy in and agree a timescale to implement adapt and adopt for a truly sharing economy.

How do we humans make a successful and sustainable business continuously grow yet remain a value? Why invention, why invent? Why innovation, why innovate? Without invention there is no innovation, so firstly, let's explore some current business rational starting with the proverb "Necessity is the mother of invention" attributed to the famous Greek philosopher, Plato. So now we have a focus and its necessary to continuously achieve, in fact we are constantly analysing the business and models that drive change naturally, don't we? We strive for having a technical edge, catalytical systems level change and agnostic collaborative cross platform collaborative tools to empower and create instantaneous solutions? WoooOh! Sorry, lets rewind and align and associate this specifically to our daily business. So, one translation of Plato's proverb could be compared with the stone age and described as bettering the ways of living and communicating smarter quicker and faster and with a focus being the necessity for survival. So, no matter how difficult the process is, if it is necessary for humans to achieve something, they will do it by any means and specifically survival of the fittest in a business context. You must have heard that global business is just like a jungle?

Transition for Transformation

Why do I need to automate and change? Yes, we know that one, don't we, sounds familiar? The fact remains that their needs to be a cultural change and above all else trust in the process. Let's imagine this scenario: An IT Director with a team of over 30 people. "We suggest that we are pretty sure you could reduce your IT Team by 50% and still deliver the same required outcomes. We might even be able to save you in excess of 65% of the cost as well and over the next five years recover any and all solution development and automation costs as well."

You would think that the IT Director would want to adopt that that capability to show the finance Director he is futureproofing the costs of the business? In actual fact whilst he would be nodding in agreement to that fact, he was inwardly defending himself and his true inner feelings, he would most likely be feeling - "What, take away my powerbase and interrupt my thief Dom (I mean domain), dissolve my asset base and undermine our expertise, capability and value"? You must be Joking! He would not even be open minded to other benefits about the power of many!

In fairness, why should he? If he doesn't know what he doesn't know how can he make a better-informed decision? Well now there begs the question "Are you

prepared to learn how to become more profitable and efficient and furthermore proactively promote trust in this new culture?"

"How about really evolving, how about becoming more entrepreneurial and visionary and become a valuable data Conductor in a global orchestra?" Please allow me to explain and to hypothesize. Just imagine how powerful it would be to harness and harmonize centralised and aggregated communication data coherently and in real-time; equal to that of a Maestro creating a magnificent symphony of multiple inputs by just the flick of a baton?" I guess that by L.U.C.K we can make these true comparison analogies and why not? Surely the fact that the conductor is expert in all the functions doesn't necessarily restrict him from inventing a magnificent collaborative musical invention. Surely the power of one is now better as a sum of all the parts than working in isolation?

Surely the transition into becoming the leader and conductor of a data symphony that you unleashed having not held hostage to the notes would be a better transformation that drives growth, Innovation and productivity through embracing sustainable automation.

However, if we then proposed "The art of the possible" with the CEO and Finance Director (both of whom would also need to accept they also need to accept, embrace and adopt transition for transformation), they would be more willing to explore the potential as they could see huge potential value to the bottom-line savings both immediately and for the long term, that would be achieved. Furthermore, they would realise that this project will indeed be a great focus and opportunistic method to harmonise, collaborate and globalise data in the process. So now, we learn about new solutions and new processes every day and we continue to improve in both business and in our own personal development adopting and embracing new and better ways of working in real time.

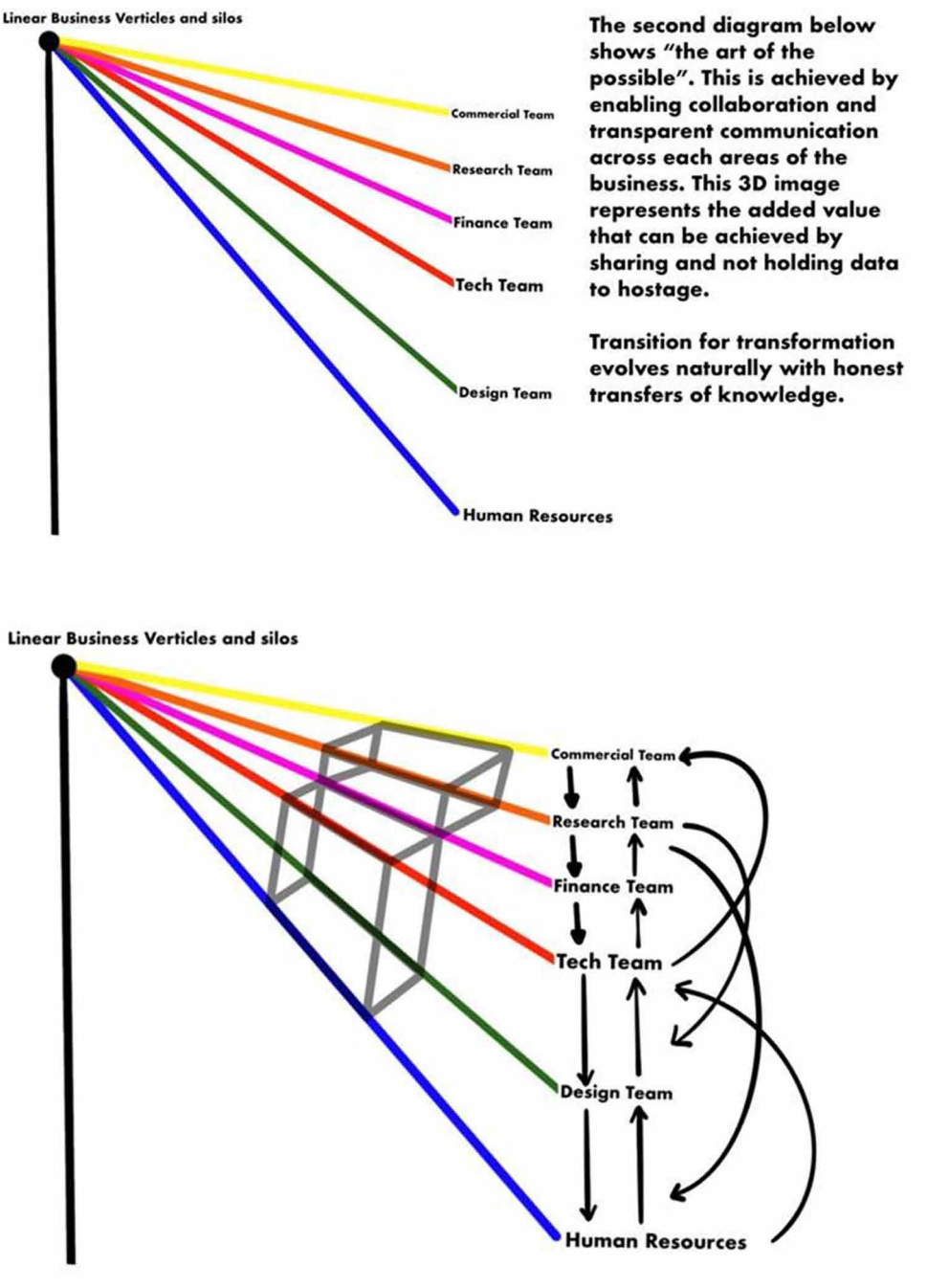
AI capability allows you to uncover and connect to all the knowledge of employees in a network. Use of intelligent systems can be to gain a high-resolution view of all of the skills and knowledge that exist within the minds of employees, members, students, alumni, or consultants and gain the ability to find them instantly. It also has integration modules linking to social media and emails etc providing the tools for sourcing relevant expertise and do things smarter and faster.

WHY AUTOMATE?

Collaborate to Innovate

Imagine creating a business-critical matching platform with some knowledge management capabilities and then using intelligent networking to link internal

Figure 1. The art of Possible



capabilities to the required demand across the projects. Empowered with an element of career functionality in teams of linking talents to internal opportunities and jobs across the network or vice-verse. Similar software like Microsoft Teams or Siemens PLM Team Centre offers similar capabilities (Tan, etl, 2006). These types of capabilities have advantage in enabling massive network connectivity and matching capabilities of knowledge, *however it lacks skills and career development pathway and the ability to train, re-skills and up-skill based on demand, rather they rely on existing capacities.*

Also, there are limitation in terms of connecting to existing LMS (Learning Management Systems) and issues with interoperability's of such systems, unless they are delivered totally online such as LinkedIn. Once this collaborative and inventive solution has joined up the business with meaningful access to meaningful real-time data, we just add volumes of added value for many business advantages. Imagine how powerful it would be to access the relevant data and details instantly and in real-time when dealing with an acquisition, merger or public floatation?

We can suggest that a one size fits all approach would only work well if managed expertly by the **experts** (i.e. people in their domains that have the required knowledge readily available and accessible to transfer for automation and with exact detail). Systems as we know are only as good as the data in /data out scenario. **Adoption** is the key for any inventive solution and application's success, this coupled with reoccurring usability (stickiness) equates to the go to solution. It is vital that organisations embrace new technology and wrap it into their workflows and embed it in the organisation's DNA and processes. The best way to do this is by inclusion and using the human skills participating in the innovation with recognition of their contribution (Barreto, 2010).

Innovation is speeding up by the second, so therefore why restrict the 'art of the possible'? We should encourage embracing new ways of doing things more efficiently and accurately and therefore it is highlighted that we need to control centrally, an agnostic, agile, dynamic centralised solution and marketplace (Luftman, etl, 2010). The enterprise would become the centralised global conductors, retaining full control of any additional global applications, solutions or services and deliver best practice and best value by default. Collaboration rather than competitive by default functional silos. By discovering the existing processes this creates a template for creating added value statements and innovating and establishing the next best workflows.

Skills and Career Development Engines

It is a consideration surely to develop platforms that enables up skilling and re-skilling of talents as well as connecting and matching talents with industry career opportunities and jobs internally and externally, globally. Innovative systems

engineering which if linked to any network would develop and deliver all aspects of skilling, up-skilling, matching and career development. The empowerment would be developed through pedagogical and industry collaboration discovered by enterprise matching in granular detail. systems and platforms which needs to be ***engineered***, ***modelled*** and ***architected*** to enable transition to transformation and manage connectivity, scalability, sustainability, agility and productivity of these complex systems internationally & developing enterprise standards. This enabling function if adopted and enabled could further re-engineer solutions and design solutions, providing a seamless and intelligent interoperability between systems of systems, optimising and enhancing service delivery, up skilling and re-skilling through the knowledge of the network and its career pathway to deliver and drive growth and innovation across the sectors and developing new and current enterprise standards. This process naturally would uncover "The Art of the Possible" and innovation -best value and best practice will be achievable. Training, delivery and enabling this could be implemented through creating leadership teams and creating Collaboratory's and we would intelligently innovate new leadership modules, learning pathways, examination structures which in turn embraces innovation to empower real -world meaningful and current learning in real-time.

Translation

Let's be realistic, if you have knowledge of software development or at least have worked in a tech-based organisation you will have a better understanding of what tech automation is capable of creating. Most organisations do not have this knowledge or have experienced a tech huddle or development process. The collaborative approach will ensure that any jargon is clearly explained, and all values are clearly articulated. Translation and clear explanation is vital in the initiation and discovery process and cross pollination of skills, business and mission critical function collaboration workshops are essential. This vision of creating fusion is for process, platforms, dynamic marketplaces, solutions and collaborative systems to retain independence, however - they should be made 'auto magically' and agnostically accessible. We would expect compliance and anonymisation for General Data Protection Regulation (GDPR) full compliance.

The future is almost now, now there's a oxymoron, what I mean is that the second technology is invented and has evolved there is an instantaneous advancement created and innovated. The speed of invention and communication is now unprecedented and especially if using machine learning code and artificial intelligence (Ai). All of which when consumed and implemented intelligently becomes an invaluable assistant to us humans. When Ai and Emotional intelligence (Ei) is adopted and implemented correctly, we surely can become over 80% more productive for over

20% of our current daily practical working period. What we don't know is how productive the automation and machine learning capability will enable and empower us to accelerate those percentages stratospherically. Imagine the ability to add even more value in the creation and invention that is likely to enable the inception of say new life sciences such as …cyborganics!

Is it humanely conceivable that we are unknowingly creating platforms and neural networks that are by default developing the potential intelligent dynamic cyborganic applications that will empower human versatility? Could we already be creating sustainable automation and increasing longevity that may become, or maybe is now even a reality by stealth? With advances in gene editing technology like CRISPR, even they will be suited to our liking and I suppose we could say confidently that we are actively now developing humanoids in a post humanisation era. This all now seems imminent and elementary …. don't you think so WATSON?

CONCLUSION AND RECOMMENDATIONS

This paper summaries the characteristics, approaches and techniques to transition for transformation, providing the enterprises a different lens to transformation enabling them to be adaptive, agile and consider not only the technological aspects of transformation, but the emotional intelligence involving organisation structure and people and the way to use various techniques such as automation and AI in conjunction to the softer enterprise's elements.

A collaborative and adaptive approach is recommended future transformation with transition in mind. Further work needs to be done to develop the framework and approached of transformation for transition with the characteristics defined in this a chapter from each industry perspective.

REFERENCES

Chesbrough & Rosenbloom. (2002). The role of the business model in capturing value from innovation: evidence from Xerox Corporation's technology spin-off companies. *ICC, 11*(3), 529-555. doi:10.1093/icc/11.3.529

Giudici, A., & Reinmoeller, P. (2012, November 1). Dynamic capabilities in the dock: A case of reification? *Strategic Organization*, *10*(4), 436–449. doi:10.1177/1476127012457977

Kearns, S. (2010, January). Strategic Alignment Between Business and Information Technology: A Knowledge-Based View of Behaviors, Outcome, and Consequences. *Journal of Management*, *36*(1), 256–280.

Luftman, J.N., Lewis, P.R., & Oldach, S.H. (2010). *Transforming the enterprise: The alignment of business and information technology strategies*. IBM Consulting Group.

Smaczny, T. (2001). Is an alignment between business and information technology the appropriate paradigm to manage IT in today's organisations? *Management Decision*, *39*(10), 797–802. doi:10.1108/EUM0000000006521

Tan, F.B., & Gallupe, R.B. (2006). Aligning business and information systems thinking: a cognitive approach. *IEEE Transactions on Engineering Management, 53*(2), 223 – 237.

Chapter 10
Automatic Photovoltaic Solar Panel Dust Cleaning System

N. Shibane
University of Johannesburg, South Africa

Nnamdi Nwulu
https://orcid.org/0000-0003-2607-7439
University of Johannesburg, South Africa

Eustace Dogo
University of Johannesburg, South Africa

ABSTRACT

Renewable energy sources are currently regarded as viable options for stabilizing the energy crisis globally as well as addressing global warming challenges. Solar energy is the most promising and sustainable energy source as compared to other renewable energy sources such as coal, nuclear, wind, gas, and hydro energy. The increasing demand for solar panels should be reason enough to investigate ways in which we can increase their efficiency as much as possible. Dust, dirt, and bird dropping are major factors that can affect the performance of solar panel systems. This work presents the development of a solar panel cleaning system that automatically detects dust particles and cleans the solar panel to ensure the continues efficiency of the solar system is at an optimal level. The system comprises of five subsystems: dust sensing, water pumping, microcontroller, cleaning mechanism, and the power system. Tests carried out on the system shows its quick response to signals and effectiveness in cleaning the solar panel whenever dust particles are detected.

DOI: 10.4018/978-1-7998-5879-9.ch010

INTRODUCTION

Electricity plays a huge role in all shares of lives and the economy. We have become so dependent on this energy source that life without it seems impossible. Almost all the devices used in homes and the industries depend on electricity. With the rapid growth in innovation and technological advances, one cannot ignore the impact and change that comes with this source of energy. In South Africa, electricity is most commonly generated using coal (Eskom, 2016; South African Department of Energy,). However, with the growing costs of electricity and the environmental impacts of fossil fuels, there is an urgent need to implement economically friendly energy sources (Nwulu & Agboola, 2011). Resources that are sustainable and that will reduce carbon gas emissions (Nwulu & Agboola, 2011). For this reason, investments in renewable energy have been tremendous over the last decade especially solar energy (USAID,). Solar energy is the harnessing of radiant light and heat from the sun. The sunlight harnessed is converted to electricity. A huge advantage of solar energy is that it is clean having no negative impact on the environment through the emission of harmful gasses and it is renewable since the sun is an infinite natural resource (Eskom, 2016).

The increasing demand for solar panels should be reason enough to investigate ways in which we can increase their efficiency as much as possible. With the increasing population growth, comes with a rise in energy demand. With the worldwide energy crisis where the world is confronted with energy depletion issues and the growing increase of global warming renewable resources is the answer. Solar energy is the most promising energy source as compared to other renewable energy sources such as nuclear, wind and hydro energy (Nwulu & Agboola, 2011). Consequently, a need to implement more effective ways of harnessing solar energy.

Problem Statement

Due to the upwards angle of solar panels, they are prone to build-up dust, bird dropping, falling leaves and dirt. These substances reduce the amount of light impact on the panel and in turn reduces the panels' output. When solar panels are left without being cleaned, the panel's efficiency is compromised. More so, manual cleaning of the solar panels with water is still the most commonly used method.

Aim and Objectives

This project aims to develop an automatic solar cleaning system, which is able to increase the efficiency of solar panels.

With the following specific objectives:

1. To design an automatic solar panel cleaner that will increase the efficiency of solar panels.
2. To implement the cleaning system based on the South African climate.
3. To evaluate the cleaning system by measuring and comparing the output voltages before and after cleaning.

Scope of Study

The scope of this study is to design and implement a prototype water-based automatic solar panel cleaner. The system is limited to household use and mainly designed to clean dust particles.

SOLAR PANEL CLEANING METHODS

Methods used to clean solar panels include electrical, mechanical, robotic, chemical and electrostatic, ultrasonic cleaning, scrubbing and mopping approaches (Alshehri et al., 2014; Mondal & Bansal, 2015b; Patil et al., 2017), (Mondal & Bansal, 2015a; Parrott et al., 2018). The methods can also be water-based or water-free cleaning solutions (Deb & Brahmbhatt, 2018). A brief overview of some methods developed for solar panel cleaning is described (Alshehri et al., 2014; Mondal & Bansal, 2015b; Patil et al., 2017). Other methods are described in details in (Alshehri et al., 2014; Mondal & Bansal, 2015b; Patil et al., 2017):

Removal of Dust Using Mechanical Methods

- Brush method: This is when a brush or scrubber is used for cleaning. Here a brush is driven using a machine. This cleaning method is not effective because of the sticky nature and small size of dust particles. It is also expensive and inefficient.
- Blowing air: When air is blown on the surface of a solar panel, the dust is removed but the negative features are low efficiency, a lot of energy is used and difficult to maintain.

Removal of Dust Using (Chemical) Nano-film

This is when a layer of pellucid nano-films that are capable of self-cleaning is placed on the surface of a solar panel, this allows the solar panel to clean itself automatically. The self- cleaning nano-films method mainly uses two strategies for cleaning the solar panel, namely:

- Super-hydrophilic material: Has both hydrophilic as well as photocatalytic properties. The first stage in the cleaning process is when ultraviolet light falls on the film this slits the organic matters in the dust. Secondly, when there is rain the TiO2 film diffuses the rainwater diffuses on the surface of the panel and rinses the dust. This method is not popular since most solar power plants are mainly in regions of little rainfall.
- Super-hydrophobic material: These materials show high levels of repulsion. These structures are designed in such a way that when water droplets fall on the surface, they roll off caring the dust particles with them, thus cleaning the surface. This method, however, is not feasible in the real world.

Based on feasibility both technical and financial, this work proposes an automatic solar panel system that will use wiper brushes and water sprayers to remove dust particles on solar panels.

SYSTEM DESIGN AND IMPLEMENTATION

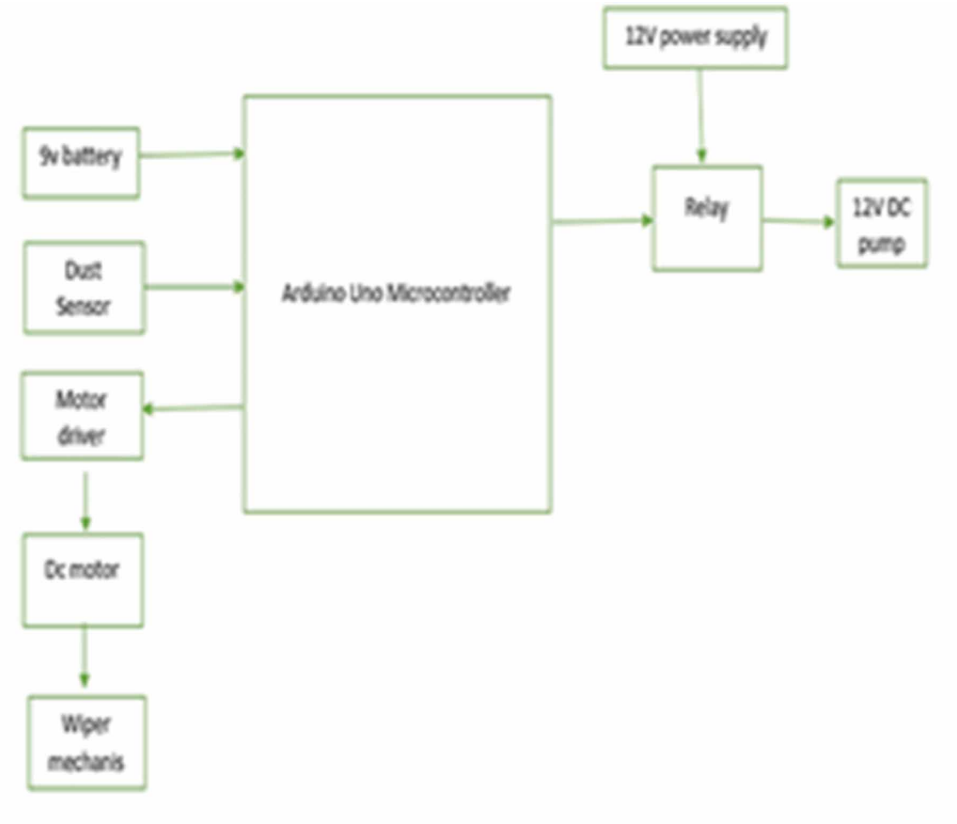
The main purpose of the system is to automatically clean a solar panel each time dust particles are detected. The microcontroller interlinks all the sub-sections of the system in terms of decision-making and control. The dust sensor detects the dust content on the solar panel, and this information is provided in terms of digital values that will be interpreted by the software code and displayed.

The motor controls the cleaning mechanism by moving up and down the panel, but this motion of the motor is based on the information obtained by the controller from the dust sensor. While the motor makes the cleaning mechanism to move up and down, water is sprayed onto the panel to ensure ease of cleaning. The motor will only move given that the panel is dirty. The water "pump is linked to the microcontroller by a switch that controls the flow of current that goes to" the pump to avoid unnecessary pumping of water.

The Functionality of the System

The system block diagram as depicted in Figure 1 is designed to clean the solar panel only when necessary, depending on the accumulation of dust particles. The output voltage of the sensor is proportional to the dust density on the panel, which implies that when the value from the sensor voltage is high, dirt has been detected. After receiving this high digital value from the sensor, the Arduino will send a 5V signal to the relay to turn on the water pump, simultaneously, the controller will send a signal to the motor to start rotating in the clockwise direction, after a specific

Figure 1. Cleaning system block diagram



time the motor will rotate in the anti-clockwise direction. This process will repeat itself until the sensor has small output voltage at the next alteration. The DC pump will be powered from a 12V power supply given that this signal is controlled by the state of the relay to avoid the continuous flow of water."

The design is a combination of five main sub-systems that would be tested independently before the final integrated system. The circuit is enclosed in a plastic case to avoid water damage and dust particles that can interfere with its functionalities. The following is a list of components classified under each of the five sub-systems.

Sub-Systems

1. Sensing System: Dust sensor
2. Pumping system: 12V DC water pump, 5V relay switch, water pipes
3. Power supply: 12V power supply, 9V battery

4. Microcontroller system: programming flow diagram
5. Cleaning mechanism: motor controller, DC motor, wiper

Sensing System

Dust sensor and its internal schematic is shown in Figures 2 and 3

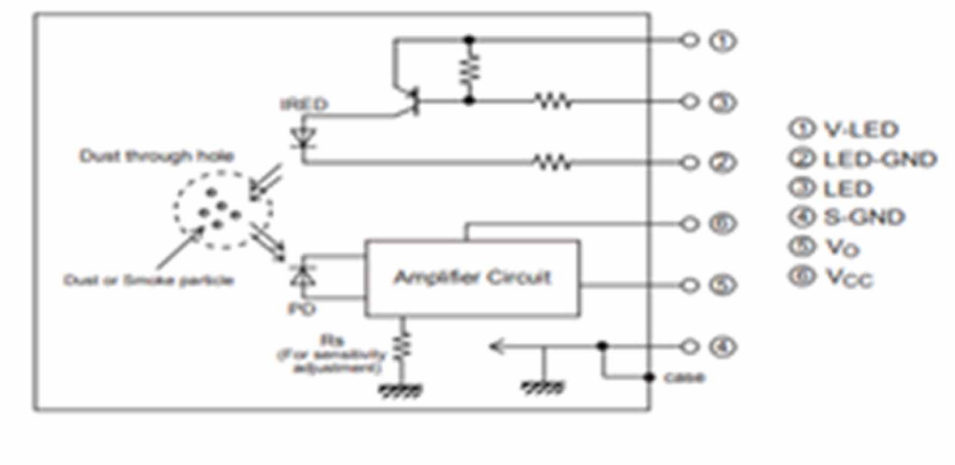
Figure 2. Dust sensor

Pumping System

Figure 4 shows the DC pump utilised in this work and its technical dimensions are shown in Figure 5.

Since the system is designed for small-scale areas, the supply of water should also be limited to a small amount. In this case, a small DC pump will be used, and Table 2 is outlined the specifications of the pump.

Figure 3. Internal circuit diagram of the dust sensor



Water Pipe

As proposed, the water pump will take water from a reservoir through a pipe and spray the water on the solar panel through a water pipe shown in Figure 6. The water will be directed into the pump using an 8 mm OD - 6.5mm ID pipe. Alternatively, the pump may be submerged into the water reservoir so that the pipes can be used for the supply of water given that the pump pressure is not enough, or the pump cannot pull the water from the reservoir.

Relay Switch

To control the flow of water from the pump, the method of switching between the on and off states should be controllable so that the pumping system can be linked to all other sub-systems through the microcontroller algorithm. The relay switch offers a good method of controlling the flow of electrical energy needed by the

Table 1. Technical specification of the dust sensor

Parameter	Symbol	Rating	Unit
Supply voltage	V_{cc}	-0.3 to +7	V
Internal terminal voltage	V_{LED}	-0.3 to V_{cc}	V
Opening temperature	T_{opr}	-10 to +65	°C
Soldering temperature	T_{sol}	-20 to +80	°C

Figure 4. DC pump

Figure 5. Technical dimensions of DC pump

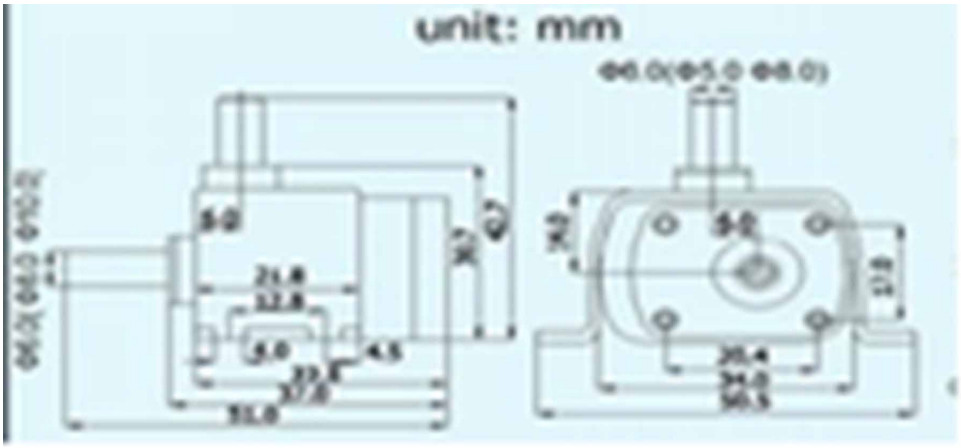


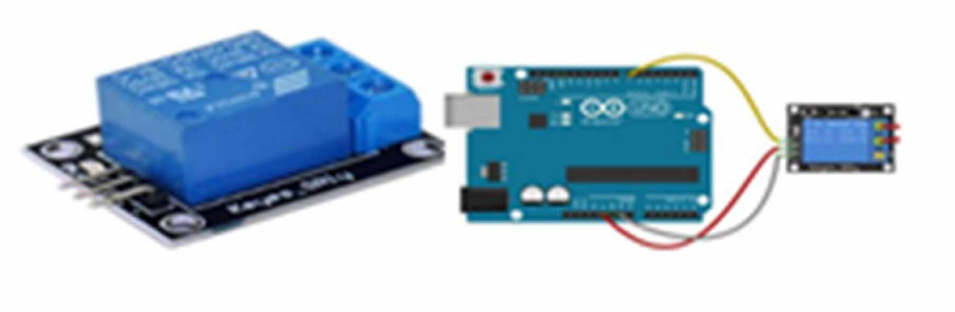
Table 2. DC pump technical specification

Rated voltage	12V
Power consumption	0.5W – 4.2W
Maximum rated current	350mA
Fluids	Water, oil, gasoline, acid and alkali solution
Weight	50g
Size	51x34x42mm
Noise	35dB
Power supply	Solar panel, battery, DC electric source
Waterproof class	IP68 (submersible)
Driving method	Brushless, permanent magnetic, 2-phase
Pump material	ABS + PC
Maximum flow rate	4L/min
Maximum static head	3m
Life span	>300000hrs

Figure 6. Water pipe

pump. The relay switch shown in Figure 7 is rated 5V 10A with a single channel and accepts from the microcontroller logic voltage signals between 3.3V and 5V.

Figure 7. Relay module board and connections



TESTS, RESULT AND DISCUSSION

To ensure that all the sub-systems are functional, a series of experimental tests were conducted to verify their functionalities. The experiments are reported as follows:

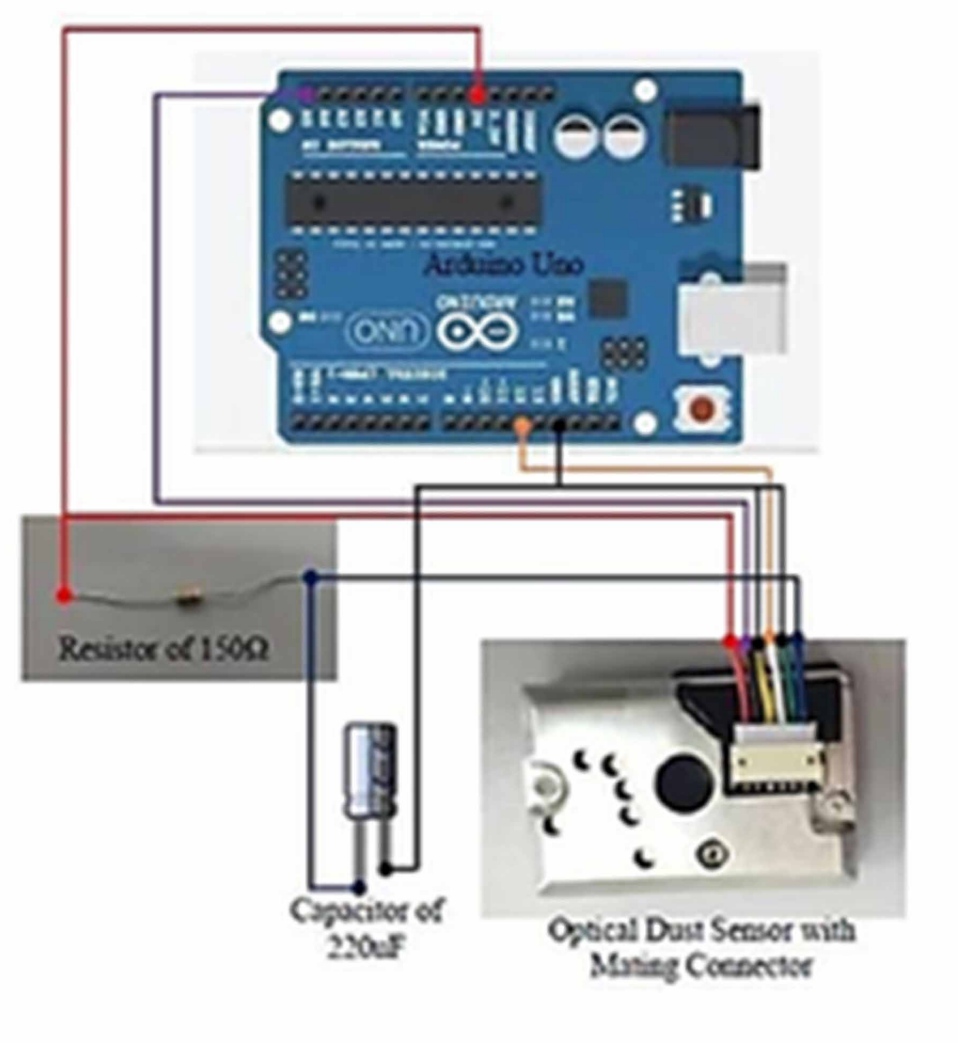
Experiment 1: Measuring the Output Voltage of the Dust Sensor at Different Dust Densities

This experiment aims to check the relationship between the density of the dust particles detected and the output voltage of the dust sensor. The experimental circuit layout is depicted in Figure 8. The dust sensor will be used to detect the dust particles before the cleaning process can take place. The output of the dust sensor is an analogue voltage value that is proportional to the dust density experienced by the sensor with a sensitivity of 0.5V/0.1mg/ m3. Different mass densities are tested through the dust sensor and the output voltage of the dust sensor recorded as shown in Table 3 and graphically represented in Figure 9.

Experiment 2: Water Pumping

This experiment aims to determine the amount of time it takes to pump the water to the solar panel and the amount of water that is pumped. The experimental setup is shown in Figure 10.

Figure 8. Circuit layout for experiment 1



Experiment 3: DC Motor Rotating Clockwise and Anti-Clockwise

The experiment aims to ensure that the DC motor moves both clockwise and anti-clockwise directions. The experimental setup is shown in Figure 11.

Table 3. Results of dust particles density and output voltage

Dust particles (Kg/m^3)	Output voltage (V)
0.1	1.46
0.2	2
0.3	2.55
0.4	3.25
0.5	3.57
0.6	3.55
0.7	3.56

Experiment 4: Complete System Test

This experiment aims to ensure that all the subsystems can work together once integrated and that the automatic solar panel cleaning system meets all the requirements and specifications. The integrated system comprises all the subsystems tested in experiment 1-3. The experimental setup of the complete system is shown in Figure 12.

Different amounts of sand dust were measured, sprinkled, and left to accumulate on the solar panel over 16 days. For the first 8 days, the panel was left uncleaned

Figure 9. Dust density against voltage graph

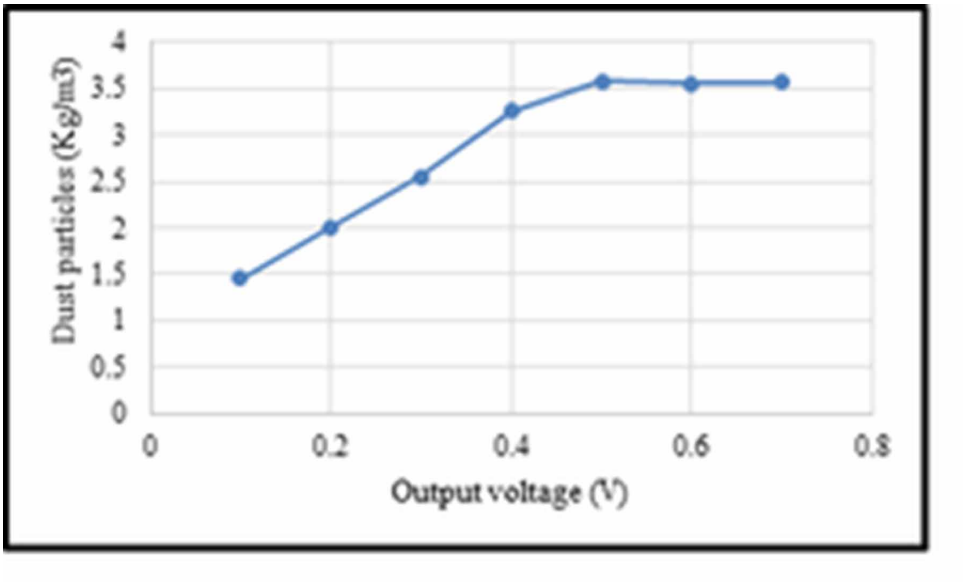
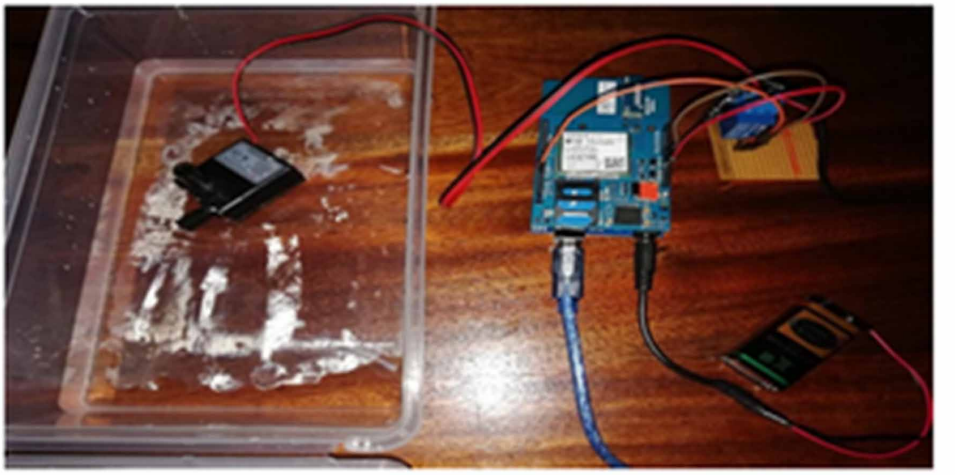


Figure 10. Water pumping experimental setup



and the following 8 days enough sand was thrown on the panel, which triggered the cleaning process. The output voltage, power and efficiency of the panel was recorded

From the results obtained in Table 3 and Figure 13 that when a solar panel is dirty the output voltage is low and the panel's efficiency is compromised. Leaving dust to accumulate over time impacts negatively on the panel's output as it was

Figure 11. DC motor experimental setup

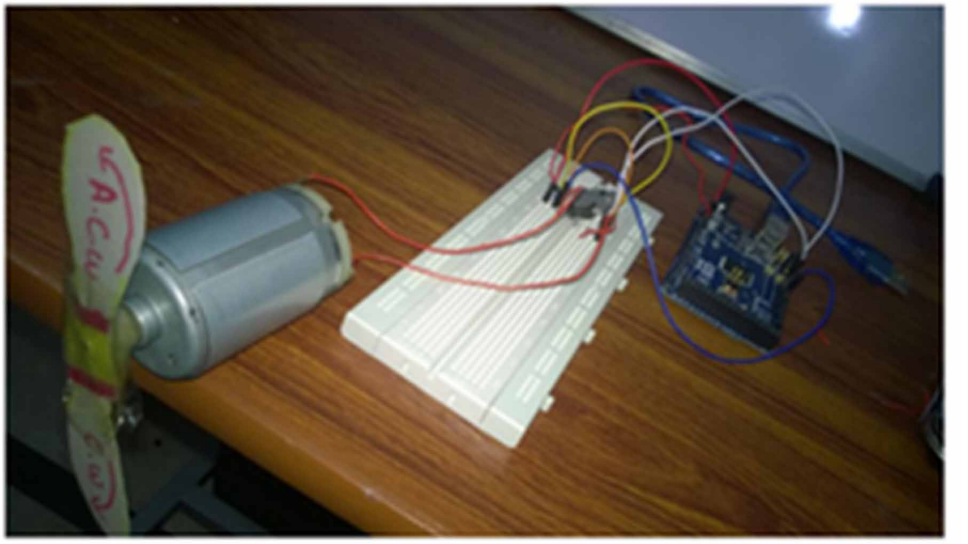
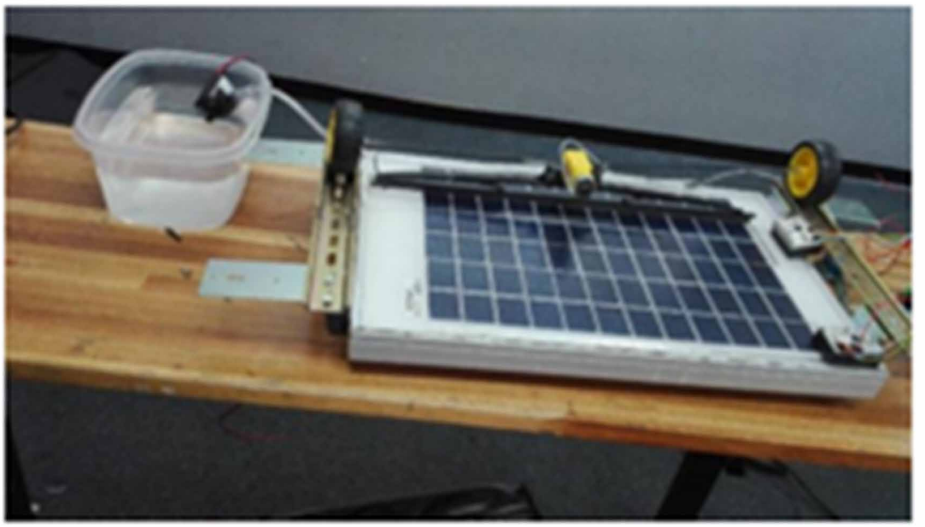


Figure 12. Experimental setup for the complete system



seen there was a gradual decrease in the output voltage of the panel. These results show the need for consistently checking the state of the panel and cleaning it if need be. The results obtained are as expected and shows that dirt does indeed affect the panels output and efficiency negatively.

Table 4. Data of dirty panel left to accumulate dust for the first 8 days

Day	Output	Current	Power	Efficiency
0 (solar panel rating)	17	0.60	10	-
1	16.27	0.60	9.7	0.9
2	15.92	0.60	9.5	0.9
3	15.11	0.60	9.0	0.9
4	14.58	0.60	8.7	0.87
5	13.29	0.60	7.9	0.7
6	10.36	0.60	6.2	0.6
7	8.32	0.60	4.9	0.49
8	5.96	0.60	3.5	0.3

Table 5. Results of obtained before and after cleaning the panel

Day		Output	Current	Power	Efficiency
1	Before cleaning	15.00	0.60	9	0.9
	After cleaning	16.95	0.60	9.9	0.99
2	Before cleaning	14.5	0.60	8.7	0.8
	After cleaning	15.92	0.60	9.5	0.9
3	Before cleaning	15.11	0.60	9.0	0.9
	After cleaning	16.11	0.60	9.66	0.96
4	Before cleaning	15.00	0.60	9	0.9
	After cleaning	16.9	0.60	9	0.95
5	Before cleaning	14.49	0.60	8.7	0.8
	After cleaning	15.9	0.60	9.5	0.9
6	Before cleaning	14.35	0.60	8.6	0.86
	After cleaning	16	0.60	9.6	0.9
7	Before cleaning	15.27	0.60	9	0.9
	After cleaning	16.95	0.60	10	0.99
8	Before cleaning	15.01	0.60	9	0.89
	After cleaning	16.95	0.60	9.9	0.99

Figure 13. The efficiency of the solar panel left without cleaning for the first eight days

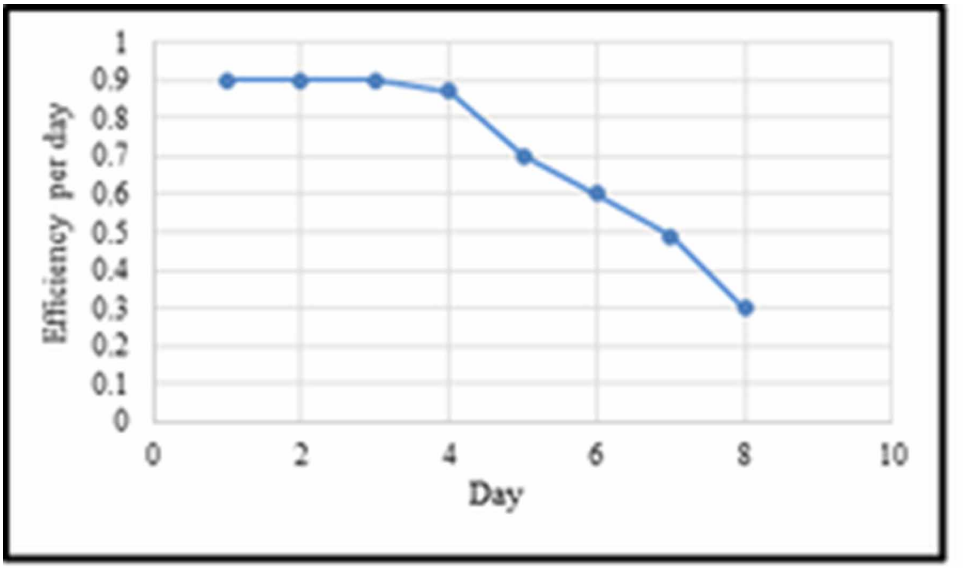
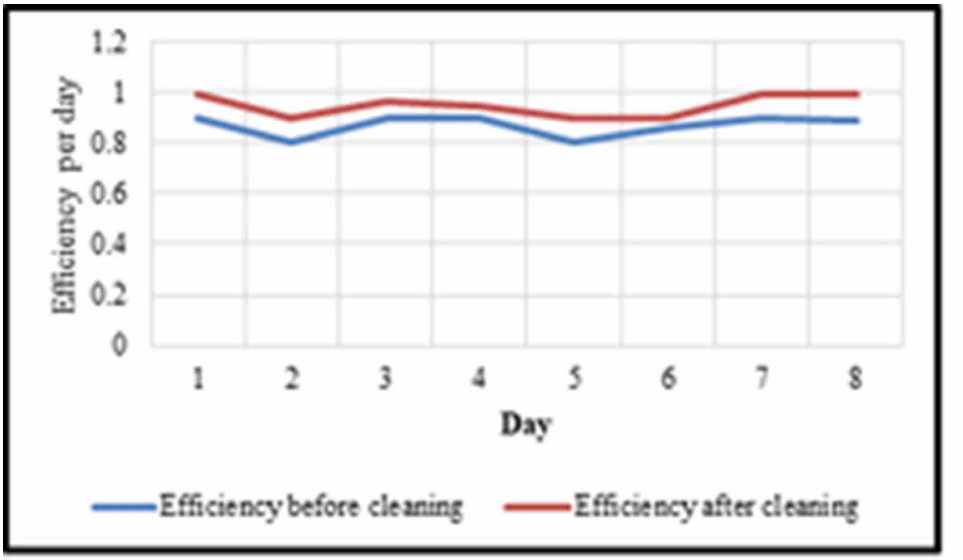


Figure 14. The efficiency of the solar panel before and after cleaning the solar panel



CONCLUSION

In this work is presented the research, design, implementation and test of an automated photovoltaic solar panel dust cleaning system, comprising of sensing, water pumping, microcontroller and the cleaning mechanism. The final prototype system functioned according to the expectation design consideration. The prototype system is cost-effective and would be a great investment in the renewable energy sector.

Incorporating a solar tracker with the automatic solar panel cleaning system to improve on its efficiency is an area of future interest and work. The cleaning system is also open for several improvements like connecting it to an internet module where the user will be able to receive the raw data and notification every time the cleaning process takes place.

REFERENCES

Alshehri, A., Parrott, B., Outa, A., Amer, A., Abdellatif, F., & Trigui, H. (2014). Dust mitigation in the desert: Cleaning mechanisms for solar panels in arid regions. In *2014 Saudi Arabia Smart Grid Conference (SASG)* (pp. 1-6). IEEE. 10.1109/SASG.2014.7274289

Deb, D., & Brahmbhatt, N. L. (2018). Review of yield increase of solar panels through soiling prevention, and a proposed water-free automated cleaning solution. *Renewable & Sustainable Energy Reviews*, *82*, 3306–3313. doi:10.1016/j.rser.2017.10.014

Eskom. (2016). *Electricity generation in South Africa*. Retrieved from Marc 22, 2020 from https://www.eskom.co.za/news/Pages/Nov2.aspx

Mondal, A., & Bansal, K. (2015a). Structural analysis of solar panel cleaning robotic arm. *Current Science*, *108*(6), 1047–1052. Retrieved March 22, 2020, from www.jstor.org/stable/24905423

Mondal, A. K., & Bansal, K. (2015b). A brief history and future aspects in automatic cleaning systems for solar photovoltaic panels. *Advanced Robotics*, *29*(8), 515–524. doi:10.1080/01691864.2014.996602

Nwulu, N. I., & Agboola, O. P. (2011). Utilizing renewable energy resources to solve Nigeria's electricity generation problem. *International Journal of Thermal & Environmental Engineering*, *3*(1), 15–20. doi:10.5383/ijtee.03.01.003

Parrott, B., Zanini, P. C., Shehri, A., Kotsovos, K., & Gereige, I. (2018). Automated, robotic dry-cleaning of solar panels in Thuwal, Saudi Arabia using a silicone rubber brush. *Solar Energy*, *171*, 526–533. doi:10.1016/j.solener.2018.06.104

Patil, P. A., Bagi, J. S., & Wagh, M. M. (2017). A review on cleaning mechanism of solar photovoltaic panel. In *2017 International Conference on Energy, Communication, Data Analytics and Soft Computing (ICECDS)* (pp. 250-256). IEEE. 10.1109/ICECDS.2017.8389895

South African Department of Energy. (n.d.). *Coal resources overview*. Retrieved from March 22, 2020, from http://www.energy.gov.za/files/coal_frame.html

USAID. (n.d.). *South Africa: Power Africa fact sheet*. Retrieved from March 22, 2020, from https://www.usaid.gov/powerafrica/south-africa

Chapter 11
Negative Effects of Presence of Dorsal Diseases in Workers of a Metallic Industry in Mexicali, Mexico

Gustavo Lopez
Universidad Autonoma de Baja California, Mexico

ABSTRACT

An investigation of the negative effects in the health of workers of a metallic industry located in Mexicali city was made in which they suffered daily, of discomfort in the head, neck, back, and spine. This occurred when people of the manufacturing area of the industry that was evaluated developing operations that required great physical effort without adequate equipment and the industrial operations were repetitive. The analysis was made in 100 workers (30% women and 70% men) and were evaluated in the morning and evening shifts, which performed functions of lifting, loading, and gluing pieces of window frames for homes made of aluminum material. The aluminum frames had a weight of 20 kilograms with repetitive operations of until 50 lift for each eight-hour shift, generating the discomfort and pain. The study was from 2017 to 2019, and more than 50% of the workers in the manufacturing areas, in the two shifts of the company, suffered from discomfort and pain in the mentioned body areas, which caused the concern of management and supervision personnel.

DOI: 10.4018/978-1-7998-5879-9.ch011

INTRODUCTION

An evaluation was made, at the time it was detected a risk situation of workers which operated in the area of cut and gluing aluminum materials was made, which is used especially in houses of social interest in the Mexicali city, where are required thousands of frames to the construction activities (CEC, 2006). These industrial processes are high risk when they do not have the appropriate equipment and tools, with operations repetitively, and in addition to not elaborate these industrial activities. Other factor was the elaboration of the industrial processes without an ergonomic method and with inappropriate posture, which initiated a small nuisance in the aforementioned body areas previously (G. Wallace, 2011). Of the 100 workers evaluated, at least five of each turn of each day, and this is 45%, were missing from one to two days, due to inconvenience, which resulted in staff turnover of the same company or hiring of new workers (Houshang Alamdari, 2017; Robson LS et al, 2011). The management and supervisory personnel were concerned that this caused errors by new personnel in this area and those were not trained were susceptible to suffering from a health symptom mentioned above. This contributed to delays in the fabrication in any area of this industry and in to the customer, and the customer requesting financial compensation for the delay of the finished product.

Occupational Health vs Industrial Operations

Industrial operations of a manufacturing area were evaluated, with rigid activities and with a high risk to suffer discomfort and pain in dorsal parts mentioned above of the body of workers. When analyzing the lift, charge and sustain metallic pieces used to fabricate the frames of windows, was observed that this industrial operation not was made with an ergonomic manner required, which generated that the employees suffered a negative effect on their health with discomfort and pain essentially head, neck, back and spine (Leticia Arenas-Ortiz et al, 2013). Even when the employees of the company were constantly trained, the lack of awareness of the personnel to elaborate the operations in an adequate way, caused that the workers continued to suffer from discomfort and pain in the mentioned areas of the body, and it was necessary generate the staff rotation continuously (Sierra OA et al, 2010) . According to the General Mexican Health Institution, about 15,000 workers suffer from dorsal diseases a year (IMSS, 2018). The constant repetitiveness of movements of lift, charge and sustain the metallic pieces, originated inadequate postures of workers in the welding process, and this increased up to 75% the number of employees in this area, with visits to the doctor of the company where the investigation was made, and visits to the Mexican hospitals located in the city of Mexicali. In addition, it caused that some people failed to his job for a few days, and in certain employees not work and

need visit the Mexican health institutions. This caused extra costs to the company due to this situation, and originating a rotation of personnel in manufacturing area evaluated, generating errors, which caused concern in the supervisory staff and managers of this evaluated industrial plant (Joan Burton, 2010). The concern was greater when certain aluminum frames arrived at the places where were used in the private residential with dimensions uneven, and it was a problem in the construction of homes. The health symptoms in workers caused two concerned diseases as cervicalgia and epicondylitis that generated an inability of workers, being a high risk in the workers of the manufacturing area analyzed. The information of the industry, and was correlated with information of data from visits to the medical institutions and records of health institutions in Mexicali.

Health Symptoms Generated in the Industry

In the field of occupational health in the industry, five health symptoms may occur due to efforts of various bodily areas and poor postures, when developing the activities of an industrial process. The health symptoms that reveal the presence of diseases are dosalgia, cevicalgia, kyphosis, torticolis and epicondylitis. In the investigation was made, with cervicalgia was occurred with more frequency, due to the great efforts of lifting, loading and holding activities of the metal parts for the gluing operations of the aluminum window frames of the analyzed industry (María Loreto DíazJ., 2014; Yunus Dogramaci et al, 2009). The metal parts that were moved from one place to another by the workers, have a weight of 20 kilograms, and it with the repetitive process generated fatigue and later discomfort and even some workers were discomforted by the health symptoms. The other disease observed in this study was epicondylitis. The year 2017, were presented the most severe period of the cervicalgia symptom, with the highest number of cases with 1230 cases, followed by 2018 with 1158 cases and 2019 with 1093. As a reference, in 2017, 66% of the 100 people evaluated presented the cervicalgia symptom, while 52% had epicondylitis and 36% of workers presented both diseases.

METHODOLOGY

The analysis was made in groups of 10 people, to evaluate the movements of the workers and observe at each stage of the activity, if if any health symptoms were present of discomfort or pain in the persons of the operations of this manufacturing process. The evaluation periods were in 30-minute period, analyzing in detail each movement of the workers and stopping the activities when observing something that had a negative effect on their health. The analyses were at the hour, daily, weekly,

monthly, annual and seasonal levels from 2017 to 2019. Once the activity of the workers a new proposal was developed that is in development of an automated exoskeleton system for the support of the lifting operations, loading and holding metal parts. This was to avoid the presence of the health symptoms mentioned above, that appeared in the workers in this investigation in the metallic industry evaluated, due to overstrain and repetitiveness of the operations

RESULTS

In the investigation was made, it was observed that in the elaboration of industrial activities, even though they were of little weight of the metallic frames, generated mild health symptoms and sometimes was presented a serious way in the workers of the manufacturing areas analyzed. The main cause of the occurrence of the diseases presented was due to the repetitiveness of the operations, and its was generated a fatigue until the discomfort and pain.

Analysis of Diseases in Manufacturing Processes

The evaluations prepared reflected the indices of the two diseases that were presented in this investigation, as observed in Tables 1, 2 and 3; indicating the average percentages per month of the three years analyzed.

The figures 1, 2 and 3 shows the percentage indexes of the diseases occurred monthly, in the three years evaluated, and indicated that the health symptoms were higher in 2017, but when was applied the adequate ergonomic methods, in in the begin of 2018, was decreased the health symptoms in 2018 and 2019, essentially in the disease of cervicalgia. The same process occurred with the symptom of epicondylitis, with the highest index in 2017, decreased in 2018 and 2019. The presence of cervicalgia and epicondylitis more frequently in 2017 caused an increase of the visits to the company doctor and health institutions in Mexico, staff turnover and human errors in the operations of the manufacturing area. It was observed that the average in 2017 of cervicalgia was 66% and 52% of epicondylitis, as well as in 2018 it was 62% and 47% and for 2019 58% and 44% respectively. From the beginning of the investigation, the supervisory and management personnel were informed of what was happening with the workers, but it was until the begin of 2018, that the decision was made to act with respect to what happened to the production workers of the business. The late reaction caused fines from the health sector of the Mexican Republic and labor demands from the operational staff that had been working for years, generating large expenses for these legal actions. The study was

Figure 1. Ocurrence of diseases (%) in 2017 of the manufacturing area

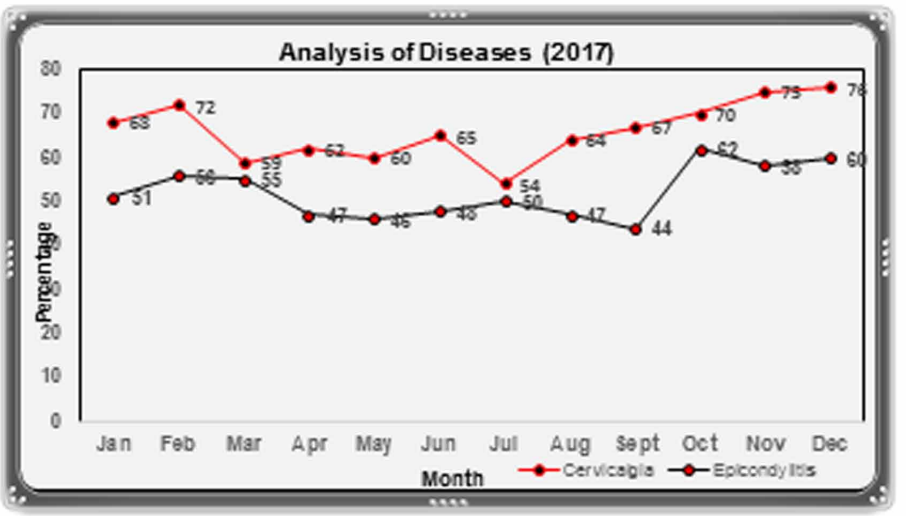
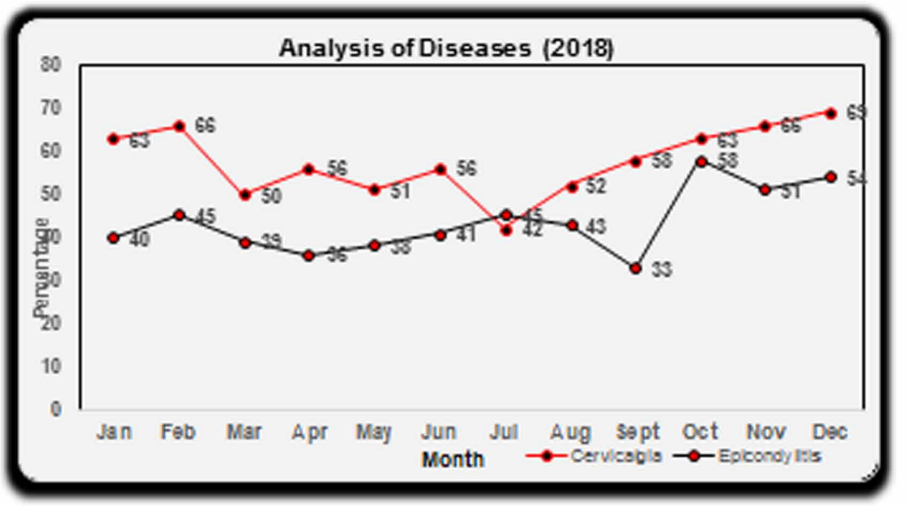
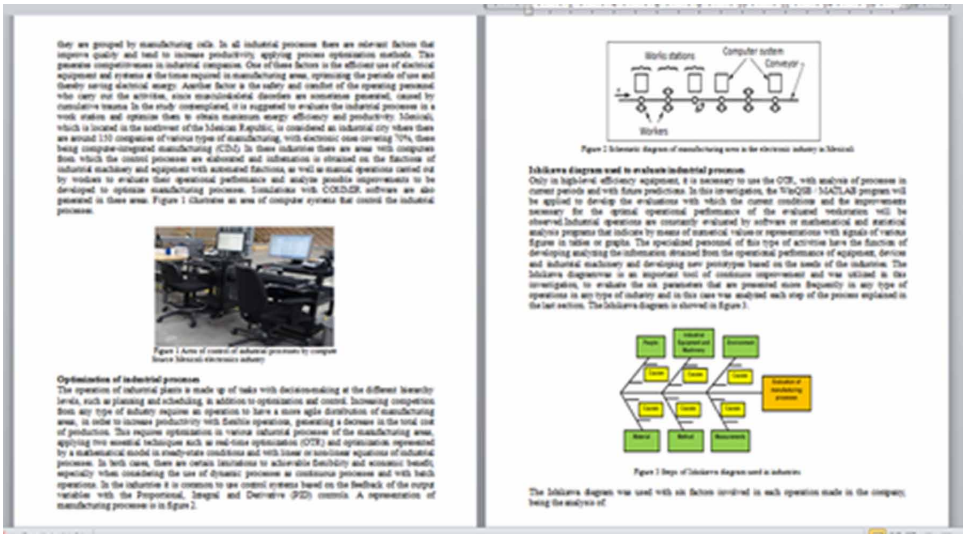


Figure 1. Ocurrence of diseases (%) in 2017 of the manufacturing area.



very useful to minimize the negative effects on the health of the workers and with it the legal actions.

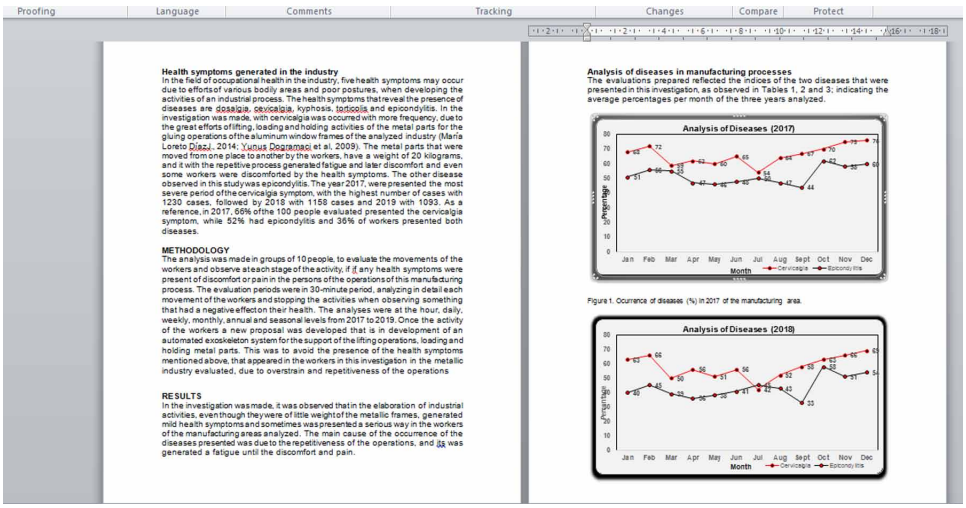
Figure 2. Ocurrence of diseases (%) in 2018 ofthe manufacturing area



EVALUATION OF DISEASES AND COSTS

The evaluation of costs for dorsal diseases in the industry, was based on the percentages obtained from the occurrence of the two diseases analyzed, with an evaluation of the costs generated by human errors and what caused by loss of customers for not delivering the products on time was carried out. According to the managerial staff,

Figure 3. Ocurrence of diseases (%) in 2019 of the manufacturing area



in the first year of the investigation period, five clients were lost and 50% of the sales were generated, so the study supported into recovering them in early 2018, when was checked the occurrence of the dorsal diseases and was presented the improvement to avoid these worrisome symptoms. Table 1 shows the correlation evaluation of the errors by workers occurred in the manufacturing area where was made the investigation, the time of rework and costs of the company by each 10 workers evaluated. The monthly analysis, showed in this table, the errors caused by pain discomfort in neck shoulders and back of workers with the average of 490 cases, related with the time of rework with 7455 minutes as a standard time, causing costs for this action, of average of 310625 dollars by each 10 workers in 2017. This worried to personnel of management, supervision and technical people of this industry where was made the investigation.

Table 1. Analysis of errors and costs (2017)

MONTH	HUMAN ERRORS BY DORSAL DISEASES	TIME OF REWORK (minutes by each 10 workers)	COSTS (Dollar by each 10 workers)
January	536	7350	306250
February	518	6990	291250
March	489	7560	315000
April	477	7320	305000
May	465	6900	287500
June	434	8010	333750
July	449	6570	273750
August	468	8400	359000
September	485	8160	347000
October	493	7800	328500
November	522	7470	311250
December	548	6930	288750

Climate Effect on Body Diseases in the Industry

The climate was an important factor in the generation of the health symptoms presented in the workers of the evaluated manufacturing area of the analyzed metalworking industry, as shown in Tables 2 and 3. This aspect was evaluated because in the summer months, workers sometimes were in front of air conditioning and with the movements of the activities in the manufacturing area, generated heat in its body and this caused some pain discomfort. Then, in sometimes workers were some part

of back a little uncovered, and originated several health symptoms mentioned above, especially in the back and spine. This is illustrated in the table 2 (from May to August of 2018), and in the months of winter analyzed, that is represented in table 3 (from November of 2017 to February of 2018). The movements of the operations in this manufacturing area, caused heat in their body and sometimes the operators of the industrial process evaluated, take off their jackets and winter clothes, generating a pain discomfort and several symptoms in the back, as in the summer analysis.

Table 2. Correlation of climate and generation of dorsal diseases (May to August 2019)

MONTH	AVERAGE TEMPERATURE, °C	AVERAGE RELATIVE HUMIDITY, %	DORSAL DISEASES
May	32	45	27
June	38	49	30
July	41	53	33
August	43	57	36

Consequences of Dorsal Diseases

Some workers were suffering of dorsal diseases after develop the activities in the production area evaluated and were necessary use an abdominal girdle to support a little the pain discomfort. This industry provided to the operators that needed this abdominal girdle, and increase its costs of the manufacturing process. Also some workers visited some Mexican health institutions and were checked its progress in the recovery of health for the symptoms mentioned above. This abdominal girdle was a cost of 45 dollars and was used by 40 workers of this industry.

Table 3. Correlation of climate and generation of dorsal diseases (November 2018 to February 2019)

MONTH	AVERAGE TEMPERATURE, °C	AVERAGE RELATIVE HUMIDITY, %	DORSAL DISEASES
November	24	58	32
December	19	63	37
January	13	69	41
February	21	72	44

Table 4. Correlation of dorsal diseases and costs (2017-2019)

YEAR	Costs presented in the industry, $	Costs presented in the health intuitions, $
2017	310,625	478,910
2018	224,279	367,345
2019	178,564	278,346

The table 4 represents the costs of any year from 2017 to 2019, about the of which the industry evaluated, dedicated as payment for visits to the doctor within the company, as well as for errors of new workers in the evaluated manufacturing area and for lack of delivery to the client in the established period. In addition, the cost of fines generated when the workers of the evaluated company visited the public health institutions of Mexico and for disabilities is resulted for each group of 10 workers.

Automated Exoskeleton Proposal

The results obtained, generated a proposal of an automated system was developed based on the structure of an exoskeleton as a block diagram and that now is working with the design of the exoskeleton system with a mathematical simulation and procedure of make the fabrication of it, to support to workers of this industry evaluated.

The block diagram consists of five steps that is explained next:

1. Power supply. Is for provide the electrical energy with 120 volts of voltage and 1 Amperes of electrical current, that is necessary to function the exoskeleton system, with a converter of 120 volts to 12 volts, to use the adequate motor of the next step.
2. Specific motor. Is a motor with 12 volts and 1 Amp of maximum electrical current, but was used normally 0.25 Amperes to not force the movements of workers and not generate a several pain discomfort.
3. Metallic structure. Is used the correctly structure to support the neck, shoulder and back of the worker. Is made from aluminum to be a light structure and not disturb the movements of the personal of the manufacturing area analyzed.
4. Electrical cable. Is used the adequate electrical cable to low voltage (12 volts) and electrical current (0.25 Amperes).
5. Electronic control. Has the hardware and software required in the movements of the exoskeleton system to support to the workers and not suffer some dorsal diseases.

Numerical Analysis of the Proposed Exoskeleton System

The proposed system consists of an engine weighing no more than 10 kilograms with a mechanical power of 25 watts that supports the lifting, loading and sustaining activities of the metal parts of the manufactured window frames. This potency factor is resulted from the next mathematical procedure:

W= M (Nm) x w (rad/s) Equation 1

W =16.4 Nm (dato del par a máximo rendimiento; Nm) *(Velocidad a máximo rendimiento; rad/s)

Mathematical procedure:

$15\,\text{rpm} = 15*(1\,\text{revolution})/\text{min} \times (1\,\text{min})/(60\text{s})*(2\pi\,\text{rad})/(1\text{revolution}) = (10*2*\pi)/60 = \underline{1.57\ \text{rad/s}}$

$W = (16.4\ \text{Nm})*(1.57)\ \text{rad/s} = \underline{25\ \text{Watts}}$

Table 5. Estimated analysis of errors and costs with the exoskeleton (2020)

MONTH	HUMAN ERRORS BY DORSAL DISEASES	TIME OF REWORK (minutes by each 10 workers)	COSTS (Dollar by each 10 workers)
January	54	1086	87456
February	53	978	88324
March	46	965	92123
April	42	1010	88823
May	45	899	87824
June	39	856	79690
July	44	847	70245
August	46	940	78923
September	42	969	84567
October	43	1011	94678
November	48	990	87896
December	52	945	89023

In table 5, is presented an estimation of the human errors, time of rework and costs to 2020, using a mathematical simulation, when is considered utilize the exoskeleton, observed that is reduced in the three factors evaluated.

CONCLUSION

The prevention of dorsal diseases in industrial operations is of great importance to avoid risk situations in workers of the metallic industry as the evaluation presented in this investigation in an industrial plant installed in the Mexicali considered as a desert city. In this analysis occurred the presence of two dorsal diseases, where cervicalgia was the principal symptom occurred with more frequency and the second disease was considered the epicondylitis with a lower range than the principal disease, with a high risk of suffer of the workers evaluated in this scientific study. This generated concern in the management and supervision staff, due to the increases in staff turnover that led to an increase in human errors, which had a negative effect on manufactured products by generating rework costs and losing customers due to late delivery to the customer.

REFERENCES

Alamdari, H. (2017). Aluminium Production Process: Challenges and Opportunities. *Metals - Open Access Metallurgy Journal, 7*(4), 133. https://www.researchgate.net/publication/316054514_Aluminium_Production_Process_Challenges_and_Opportunities

Arenas-Ortiz & Cantú-Gómez. (2013). Factores de riesgo de trastornos músculo-esqueléticos crónicos laborales. *Medicina Interna de México, 29*(4). https://www.medigraphic.com/pdfs/medintmex/mim-2013/mim134f.pdf

Burton, J. (2010). *WHO Healthy Workplace Framework and Model: Background and Supporting Literature and Practices*. https://www.who.int/occupational_health/healthy_workplace_framework.pdf

Commission of the European Communities (CEC). (2006). *Analysis of economic indicators of the EU metals industry: the impact of raw materials and energy supply on competitiveness*. Commission Staff Working Document; Brussels; 2 (8); SEC (2006) pp. 1069. https://ec.europa.eu/info/index_en

Dogramaci, Kalaci, Sava, Duman, & Yanat. (2009). Treatment of lateral epicondilitis using three different local injection modalities: a randomized prospective clinical trial. *Archives of Orthopaedic and Trauma Surgery, 129*, 1409–1414. https://link.springer.com/article/10.1007/s00402-009-0832-x

Instituto Mexicano del Seguro Social (IMSS). (2018). *Memoria Estadística en México: Coordinación de Salud en el Trabajo*. Reporte del IMSS. http://www.imss.gob.mx/conoce-al-imss/memoria-estadistica-2016

María Loreto Díaz, J. (2014). Cervicalgia myofascial. *Revista Médica Clínica Las Condes, 25*(2), 200-208. https://www.sciencedirect.com/science/article/pii/S0716864014700318

Robson, L. S., Stephenson, C. M., Schulte, P. A., Amick, B. C., Irvin, E. L., Eggerth, D. E., Chan, S., Bielecky, A. R., Wang, A. M., Heidotting, T. L., Peters, R. H., Clarke, J. A., Cullen, K., Rotunda, C. J., & Grubb, P. L. (2011). A systematic review of the effectiveness of occupational health and safety training. *Scand J Work Environ Health, 38*(3), 193-208. https://www.ncbi.nlm.nih.gov/pubmed/22045515

Sierra, O.A., & Pardo, N.A. (2010). Prevalencia de síntomas osteomusculares y factores asociados en los embaladores de leche de una pasteurizadora en Neumocón, Cundinamarca [en línea]. *Rev Col Enf, 5*(5).

Wallace, G. (2011). Production, Processing and Applications. *Fundamentals of Aluminum Metallurgy Journal*, 70-82. https://www.sciencedirect.com/science/article/pii/B9781845696542500043

Chapter 12
Successful Entrepreneurs Drive Innovation and Productivity Through Sustainable Automation

Moe Nawaz
Independent Researcher, UK

Arshad Mahmood
Birmingham City University, UK

ABSTRACT

How do we describe today's entrepreneur? The entrepreneur's life is far easier than what it was. The internet has made life very simple and brought the costs of entry for new businesses right down for most entrepreneurs. In the old traditional way of starting a business, you would have to rent or purchase premises, purchase computer equipment, license software, and hire programmers to design and develop the software. The cost of just the initial startup would be phenomenal. Nowadays, everything is on cloud servers, where you use and pay for what you need and expand and pay as you need more. What would have cost in the tens of thousands to start a new venture now is a fraction in comparison to before. Innovation in the technology sector has made this all possible.

DOI: 10.4018/978-1-7998-5879-9.ch012

WHAT IS THE ENTREPRENEUR MINDSET?

The entrepreneurial mindset is about driving growth, coming up with ideas and solutions that innovate new ways of working compared to how things were done before. A simple example of innovation, to look at the earlier days of the tape recorders. These were big and bulky reel to reel tape recorders for recording and playback of music and sounds. Then, the next innovation of the recorders were the size of a shoebox that could carry all the recordings held on a small cassette, but were still bulky. Also, the parallel to the tape recorders were the vinyl records which later were innovated and moved on to CD's. The next phase of the innovation cycle for the music industry then came when Sony released the Walkman player as a small hand-held device. The device started off with a small cassette then moved on to a smaller cassette and then to a digital memory card, built into the Walkman, which stored all the music to playback. Further, innovation came when Apple released the digital iPod device that could hold an equivalent of 5000 or 10,000 songs on a single memory card, the size of a thumbnail. Now, all the devices have been incorporated into our mobile phones, which has become the standard. This is called innovation, moving along and innovating all the time from point A to point B and more.

CAN YOU BE AN ENTREPRENEUR WITHOUT INNOVATION?

Can you be an entrepreneur without innovation? A lot of people get confused between a business owner and an entrepreneur. You can be a business owner, but not necessarily an entrepreneur. A business owner will not take risks, most entrepreneurs will take on risks and will cause casualties and cause chaos around them. On the other hand, a businessman will be more afraid to take on risk, and will gamble with minimal risk, the opposite of an entrepreneur. You can be a businessman without being an entrepreneur, but to be an entrepreneur you will need to take on a lot of risks. Taking on new ventures when nobody else is prepared is prepared to do. Like the spaceship Enterprise in Star Trek, venturing out into the unknown and unchartered territories, the traits of what innovation and entrepreneurship is all about. Majority of innovators are risk takers.

THE FOUR MAJOR TYPES OF INNOVATIONS

Incremental Innovation - in simple terms is work in progress. Innovating continuously to get to the end goal, like Tesla for an example. When Tesla introduced the first electric car to the market, the car generally provided about 200 miles range

distance and now have innovated the battery technology to provide over 500 miles. The next possible innovation could be targeting the 1000 miles battery. The constant innovation by Tesla has reduced the number of individual components and the time it takes to build the components. Therefore, innovation is a reoccurring continuous process, because once the milestone has been reached, does not mean innovation should stop (Ali, 1994).

Disruptive innovation - takes what you already have and reduces the overheads and fixed costs, leaving behind enormous amounts of profit at a minimal cost (Schmidt, 2008). If we can go back around 15-20 years, and search for companies that provided mobile network services. We would find about 4 major players in the industry, Orange, T-Mobile, Three and O2. To become one of the players, you would need to start from ground up, to build the infrastructure. Like, the software requirements, the installation of aerials into every urban area and throughout the whole country to ensure signal strengths. But then, Richard Branson came along, realized an opportunity existed and started up a mobile phone company, by tapping into, each one of the networks surplus capacity. There is no need to create an infrastructure when four companies in that sector already existed with very heavy investments in fixed assets. Branson was able to offer a service at a fraction of the cost, without the overheads of building and maintaining a physical network. By owning the right to license bandwidth and airtime from one or more of the existing networks. Airtime can be switched from one carrier to another to minimize cost. The service was and still is invisible to the consumers who can make calls without noticing who the carrier is providing service for the call. This is a great example of disruptive technology and innovation without all the huge investments and the big overheads (Samit, 2015). This can read further in the book by the author Jay Samit and the book titled Disrupt Yourself.

Architectural innovation - is where the core element remains the same, but the outers are constantly changing and innovating. If you take the earlier days, when most trains were powered by steam engines and steam, then along came diesel engines and then followed by electric motors. Similarly, the same applies to the early cars, from petrol and diesel cars, now we have electric cars. But the underlying principle is still the same, cars are a meant to get you from point A to point B. Just like, the locomotives have evolved from steam engines to diesel and from diesel to electric, there will still be a number of diesel engines around, just as there are diesel cars, this is what we know as architectural innovation (Bozdogan, 2002).

Radical Innovation - There are numerous cases of radical innovation, this form of innovation is something that disrupts markets and industries, in a massive way. For example, we have Airbnb, a market sector that never existed. Nobody ever thought of renting their spare bedroom, spare house, spare villa or apartment out to strangers. A market that never existed, then somebody just comes along and starts

renting these accommodations for a fraction of the price compared to the hotels, directly to the end consumer and taking out the middleman. If you take the current value of Airbnb, which has no real assets apart from the registered name and the software that it operates on. Airbnb is worth over $150 Billion far more than all the Hilton Hotels put together or the Marriott Hotels group. The net worth of Airbnb is worth far greater due to this radical move and the high return on investments.

It is all about entering a market, creating disruption amongst all the other players and having very little overhead compared to the brick-and-mortar competitors in the marketplace. Uber is another example; how did the taxi service operate before Uber came along? Looking at the UK, the TOA taxis are officially licensed taxis by most of the city councils to operate within their districts. They operate from anywhere, where passengers can hail and flag, to hiring the taxi. Whereas, on the other hand, you have the private hire taxis which only operate through by booking in an advance by phone or in person, by calling the local taxi office. The wait time could be anything from a few minutes, up to even an hour. Not providing the convenience and accessibility that we would like to have in a fast-moving society (Bicen, 2015).

Then Uber entered the market, with a software developed for mobile devices, which allowed to book a ride without hailing or phoning for a taxi service. Before, each taxi was operated by a local taxi rank. They would employ from 10 to a few hundred drivers. The drivers would pay a weekly fixed rate for services provided by the company. The taxis would be dispatched using the queue system, rather than the nearest to the customer, this is to balance the workload for the drivers. This caused unnecessary delays for the individual customer. Whilst, Uber came along with a software and a much bigger picture to serve anyone, anywhere, faster and quicker than existing service providers. The app allows you to see the available cars around the vicinity, and provides a good indication of the arrival time and with a press of the button. Money is not physically exchanged making it safe for the driver and passenger. All payments are made via the phone app payment system.

HOW CAN AN ENTREPRENEUR INFLUENCE PRODUCT, PROCESS AND BUSINESS MODEL INNOVATION?

The problem with most entrepreneurs, is the same as businesses, the lack of growth and therefore, most businesses fail to grow to a substantial size. If we take 100 entrepreneurs and 100 business owners and ask them to start a business, the business owners would probably end up with a higher success rate and a lower failure rate. This is due to the natural tendency of the entrepreneur to take more risks, because they have a bigger appetite to take far higher risks than the business owners. One of the common traits between a business owner and an entrepreneur is the lack of

the tendency to grow a business. They very rarely stop to think, to create processes or systems to help to encourage growth. How to create the necessary processes and how to create procedures? Focus on tasks for the members of staff and the employees to follow.

If these systems and processes are not in place, the business is not able to grow or expand further. The entrepreneurs need to surround themselves with people that are capable of understanding and implementing the systems and processes, to help the business grow. Where, the business owners will try and apply themselves individually, because they feel they need to reduce the risks associated with growth. While, the entrepreneurs will want to innovate, with the support of people around them, to allow them to come up with new creative ideas.

Can you Teach Innovation?

Can you teach someone to drive? Yes, you can teach someone to drive, but can you teach somebody to fly? Yes, you can teach someone to fly. Innovation can be taught just like any other skill. Mostly, you need to have the desire and the urge to become whatever you desire to be. This goes back to the mindset again, do you have the mindset that will help you to become an entrepreneur, if yes, and then it is important to start thinking like an entrepreneur. How can you be innovative and become an innovator? If you see problems, where most people just stare at the problems and it will still remain a problem. Meanwhile, entrepreneurs will see a problem and will address it as if it is an opportunity. Are you looking through the eyes or through the lens at the problem? Or you can look at it from an entrepreneur's point of view and see the opportunities, by finding the solutions and profiting? The bigger the problem, the bigger the opportunity.

Innovation as an Example Case Study

Using Tesla as an example case study. The company was not the first electric car manufacturer, as most people think. But, Tesla is the first high volume manufacturer of electric cars at a competitive price. Initially Elon Musk, the founder of Tesla made a statement, he was going to manufacture a sports car that would run at the speed of a normal combustion car. An electric car with minimum moving components compared to the existing cars, who have a few thousands of moving components. This would reduce the cost failure rate drastically, with less weight and more space in the car for storage and for other possibilities and lowering the cost to manufacture. Tesla started with a new canvas, a brand-new facility and painstakingly developed everything from ground up. But, we have the likes of the Fords, Chrysler and all of the other major car manufacturers, who have stuck with the combustion engine

and are now stuck with it. If we can look at a company like Toyota, it brought out a hybrid car 15 years ago, as early as 2012/2013. These plug-in hybrids, at most, gave an average of 30 miles on a full charge, enough to get you from your house to your office and to bring you back. This was over 15 years ago, and now 15 years later the same companies that launched the initial hybrid vehicle, are still offering around the same 20, 30 miles of range at the most.

That is not innovation but can be regarded as copycat. Copying what they did 15 years ago rather than what we can do better, cheaper and faster now. But, what the future requires is electric cars that are safer, cleaner and cheaper to run. The legacy car manufacturers are lumbered with the old combustion engine, because it still sells and a provider of most of their income. Some attempt has been made to bring out newer electric vehicles, but the pace is way too slow for it to have any impact in the marketplace.

WHAT IS AUTOMATION?

Automation for entrepreneurs or for business, is to have an automated workplace. Once you have identified a process which is repeated continuously, then that process should be looked into being automated. If one process can be automated then there are chances other processes also can also be automated. The combustion engine can be considered as an automated process, as long as petrol is flowing into the engine, it will continue to run. Take an assembly line on most car manufacturers and you will see many people along the assembly line all doing different tasks at different stages of the assembly line. Someone somewhere had to sit down and plan all this in several stages before you had a smooth running assembly line that produced consistent output time after time The same can be applied to the processes and the system that need automating (Inagaki, 2003).

Examples of Automation

An advertisement can be created online or offline to drive traffic to your website, the process can also automatically generate a sale when a purchase is made using a credit card payment for the purchase of the goods. This is an automated sale without any human intervention of a salesperson. Other similar processes can also be automated, to simplify and increase efficiency of a business. Most petrol filling stations are being automated without having any attendants to take payments, you pay by card before purchasing, fill up and drive off, job done.

Why Should you Automate Your Business?

To be competitive and have sustainable growth, it is important to automate as much as possible. Unless you have systems and processes in any organization, you will not be able to grow your business. A small one-man business might get away with trying to do everything by itself, but at the price of growth and most likely will remain at the same point. This leads to the old saying, you are either working on the business, or working in the business. Most people may have heard this, but do not understand its true meaning. So, let us break it down. Working in your business, is you as an individual working doing everything from making a cup of tea to handling the sales inquiries, generating all the sales, packaging all the goods and delivery. But once you start to create systems and processes, you can then start to delegate those tasks and duties out to other people part time or full time employees. In McDonald's the average McDonald's employee who has been through their training process, it becomes easy for them to understand what to do next at every step of the way, their tasks and duties, because everything is broken down into tasks by numbers, this is how you make the coffee, one get paper cup, 2 hold under hot water dispenser, 3 push button for hot water and so on. They have systems and processes in place, which also help to automate most activities in McDonalds. It does not matter where in the UK, or in Europe or America, you will find the consistency of taste and quality the same. By simply following the systems and processes and procedures in place for the employees which leads to consistency in the food and everything else that goes on, and all through automation.

Can a Business Survive Without Automation?

Some people are happy to stay doing what they have been doing all their lives, as they would say the good old way. But if you are looking to grow a business successfully then you have to create systems and processes for as much as possible. If growth is not desired, then carry on running as you are. What are the disadvantages of automating the business? Apart from the cost and time, not much else. Automation is implemented once and repeats itself over and over again, with minimum human intervention. Automation is there to simply try and speed up the process and lower costs unless it creates more complications than before, otherwise, there is no real disadvantage in automation.

Is there such a thing as over automation? If automation helps you to create consistency, lower prices and to speed up the processes, then it is good. Over automation, if you are going the opposite way, then you need to scale back. If after automation the workload is not reducing costs, and is not creating consistency and

not delivering your expectations and then you need to scale back and find the right balance between automation and manual workload.

What Can't be Automated?

Anything that is unlikely to be repeated, this may vary from small businesses to the large corporations. If it is a one off, then there is no real need. Anything that is consistently required, that is repeatable, including repeatable procedures or processes, can be automated. And in most cases, they are, especially with the aid of software nowadays. Some things can always be automated due to costs also. A small business repairing bicycle punctures on a daily basis can afford a £55,000 automated puncher repairing machine because his demand is so low that he can not justify the investment. But on the other hand you had 10 people employed repairing punctures all day long then it would be a great investment which would pay for itself over and over again.

Example of Automation Case Study

If we look at Uber again, post Uber a city like Birmingham in the UK, had around 20 to 35 taxi bases. Each base was supported by drivers, ranging from as few as tens to a few hundred at each taxi base. Now, with Ubers presence with its automated software service, most of the bases are still operating, but only employ a fraction of the drivers, most of them are working for Uber. The physical processes have been removed, like collecting money or banking the money, because Uber's automated systems take care of it. The taxi driver can log into his app and he or she is ready to start taking passengers booking near to them. Whereas before they would have had to go to the base and wait in line till their turn came up to pick up a passenger from a location which might be miles away from the taxi base. Now when an individual customer requires a taxi, they can see where the nearest vehicle is without having to phone and physically speak to someone. This brings the costs down to the end consumer and the taxi driver.

HOW CAN ENTREPRENEURS HELP IMPROVE THE ENVIRONMENT?

If we look at the combustion engines, the pollution they have caused over the years and still continue to this very day. Now, Tesla with the electric vehicles, not only is it cheaper to run and economical, but almost no pollution. The entrepreneurs recognize the long term benefits of environment compliance and by looking at the side effects, are trying to minimize in their planning for the future. In the environment

compliance arena, the local governments are always looking for organizations that can help them to better build the future infrastructure. With the great push on the environment, in places like America, there are currently two companies, trying to bring out plant-based only based burgers that taste like chicken or beef burgers. Environmentally, it is the amount of methane gas that is produced by the cows, is a big contributor and needs to be reduced. Which is also increasing every year, having to breed more animals to keep the production lines going to keep up demand for meat. But, if the dependency can be reduced on the real burgers and shifted to the plant based, then we can reduce the cultivating of animals for our food supply.

Entrepreneurs around the world who are developing and building green business solutions through innovation and automation which might or might not make it to market. So, what's meant by green business? Again, it's a very, very broad definition. Anybody can pretend to be a green business but in reality, a green business that has a very minimal or has managed to reduce the carbon footprint to what it does for its processes. Take for instance, the supermarkets, the supermarket used to throw away all its food with last sell by date at night time and the cost to transport that food to waste plants. Now the bulk of the supermarkets in the UK give their food away to the homeless charities and to other charities who are able to use that food over the coming days. Just because the excuse of sell-by date or end of shelf life doesn't mean the foods are not consumable by individuals, so again, the supermarkets are now making better use of that and reducing their carbon footprint. This is a win situation for the supermarkets, the environment and also for the charities that desperately need the food daily.

Can Entrepreneurs Achieve Environmental Sustainability?

Environmental sustainability is not just the responsibility of entrepreneurs, it involves everyone from, retailers online and offline, manufacturers, distributors, importers, exporters right through to the local consumers. Our local authorities have in place waste collection by asking householders to separate normal waste from recyclable waste with different colored bins for weekly collections. With fines being imposed for those who don't sort their waste out in the correct order.

What are the Benefits of Going Green for a Business?

In most cases, there are government incentives and local authority incentives, the greener you can make your business, the more grants and government subsidies are available. If you want to cut down on any electric consumption, by using solar panels, there are available government incentives to support your transition to sustainable energy. If your old machinery or equipment is consuming high power, you should

consider replacing it with a low energy consuming more efficient machinery. In the long term consuming only a fraction of the cost of the energy compared to older machinery. There are available subsidies and grants, if you want to replace a boiler in your house with a more efficient one, plenty of incentives around to support more efficient use of energy at home as well as at work.

How can Entrepreneurs Ensure Sustainability?

It all depends on the nature of the product or service that is being provided and the market size. These are the key factors, if these tick the boxes, then sustainability is not a problem, providing you have the right people in the organization that can help to build sustainability into the business.

A company that is sustainable, like Tesla, if you look at the size of the electric car market, and compare it to the size of the combustion engine, probably less than 5% of the cars currently on the world's roads are electric. Therefore over 95% of the market is still available and also, an opportunity to take it away from the combustion engine. The electric car model is sustainable, until all those cars are replaced. The sustainable car model itself has huge potential for growth, so the quicker it can be scaled, the quicker it can get the vehicles out to the marketplace. The sustainability is there for the electric car and other products in other markets too.

WHAT DOES PRODUCTIVITY MEAN IN BUSINESS?

Productivity simply is producing the products or services continuously and achieving a result. Productivity can mean different things to different people, just success. Productivity is continuously providing a product or a service at a cost to the marketplace that has a need or a want. If you do not have a product or service, then you cannot produce anything. In most cases, to be productive, you need to be producing output of some sort, to be generating income for the business. Productivity and efficiency is always something at the forefront of most entrepreneur's minds, they are constantly looking to innovate, increase productivity and improve efficiency with new methods, processes, procedures and equipment. An ongoing process all the time, just like the innovation process (Smith, 1999).

What Tools can be Used to Improve Productivity?

Well, in every industry, there are useful tools and most of the tools have now been digitized and are available in the cloud. If we can use a simple example like the e-commerce business. Most retailers have some form of presence online nowadays,

but the retailers that do not have a strong presence online, will lose out and may go out of business. The new players with the strong online presence and brand awareness, do not have the overheads associated with the brick and mortar business and can jump the hurdles every time by undercutting and providing fast and quick deliveries. The e-commerce systems, processes and procedures can be written into the software, rather than implemented into the business. Which can be updated constantly to ensure better software for the business and software that is automated, to help to streamline smoother processes. Innovation is occurring and taking place at every stage of the way by the organization that are developing and extending their online software platforms.

A Case Study of a Productive Entrepreneur

A productive entrepreneur's job is to come up with the solutions and continuously be innovating. But in reality, you can come up with the solutions and ideas and burn money continuously. What is more productive, is what is making more money for your business and how can you help improve your bottom line. Looking at Steve Jobs, he continuingly came up with new ideas and concepts. Where it became his team's responsibility to hold him back from some of his ideas, otherwise, if left alone every day would have bought another and another product. It can be a matter of combining the demand in the marketplace, with the ideas and the demand of the cost of launching a new product or service. There are many factors to consider before you can say yes lets go ahead. Ideas are ten to a penny as they say, execution is everything. In reality how many of those ideas have a demand in the marketplace at the price that is affordable and margins that are achievable? It is not a matter of manufacturing for the sake of innovating.

The number of electric car manufacturers are still only a handful major players in the marketplace, this market is open and the cost of entry is much lower than the cost of the old combustion car. Everyone is holding back for the breakthrough in the battery power with longer distances and quicker charging. There will come a time that each electric car will be self-charging with solar paint on the car being its battery charger or miniature micro size solar panels.

THE ROLE OF THE FUTURE ENTREPRENEUR

Entrepreneurship is something not everybody will have inbred into them and not everyone will want to become one. It is like trying to define the crew on a ship, not every crew member wants to be a captain, most of them are quite happy to be ordinary sailors. In the workforce most are happy with being an employee and not

necessarily the independent entrepreneur who has to pull their own weight and drive the business. In the future, most likely it will be the young school leaver who will come up with the new ideas and will use technology to get there. The youngsters working from the bedroom coming up with disruptive technology and ways of doing or innovating things that no one else has been able to achieve. Almost everything is being digitized, take the old dial up modems which connected us to the internet have now been totally digitized and is just a piece of software which sits on your hard drive rather than a part of the computer.

There was a case, not so long ago, by Jay Samit, the world's authority on disruption shared a story about an 18 years old. Who reached out to Jay about and said he had developed a software, which could easily fit into a hearing aid and help people with vertigo. A device with sensors that could detect and check on a person's pulse and stability, whether they were going to fall or stumble and warn them before it happened. The young man from the comfort of his bedroom managed to carry out the research and found most of vertigo problems were also associated with hearing problems. Combining the two technologies into the same hearing aid, tackled both of the problems. In America, there are two major manufacturers of hearing aids and it was a question of working with them to bring the idea into practice. An idea that started from a bedroom which had the potential to be worth in the hundredths of millions. The internet has allowed us to become entrepreneurs from our bedrooms, allowing us to collate the data, convert it into useful information and allow us to find the solutions. Not just local solutions but world solutions in most cases (Samit, 2015).

What Kinds of Technologies can Benefit the Entrepreneur?

Any bright entrepreneur will embrace and maximize the available technologies needed for their industry, in order to automate, simplify and speed up the process for the growth of the business.

In the next decade, will the entrepreneur drive the technology or be driven by the technology? This question takes us to the chicken and egg scenario. Actually, it can be a combination of both, the entrepreneurs will be driving new technologies and providing benefits to the businesses. Also, availability of new technology to the marketplace, will make its way into the businesses providing unexpected benefits that were not previously released. A combination of the two with the right balance between automation and none automated activities. More innovation usually leads to more technology and automation, both helping each other to grow. Just like machine learning increases, the human capacity also increases, both go hand in hand to serve a particular purpose.

WHAT IS A GLOBAL ENTREPRENEUR?

The world is becoming a smaller place, due to the cost of cheaper flights and the adoption of the internet, so the marketplace has become smaller. Cost of employing people from abroad has become cheaper than employing people locally, especially when labor can be sourced globally with a touch of a button. The global entrepreneur is no more different to the entrepreneur working from his or her bedroom or basement, because we're all globally connected, and now have a global reach thanks to the internet. So, in reality, there is no such thing as a local industry as such, so if you're selling anything, from a pair of socks online to a private jet, in the local marketplace online, there is no reason why you can't sell those same socks or jet to, the other side of the world. So, now you know why an entrepreneur is a global entrepreneur, working from any place in the world, it makes no difference whatsoever, because you know, the world is your oyster (Williams, 2011).

How do you Become a Global Entrepreneur?

As an entrepreneur you can solve local, national or international problems. The problems being solved and the solutions being provided, do they impact locally, nationally or globally? An entrepreneur becomes a global entrepreneur once they start to impact globally. Elon Musk did not set out to be a global entrepreneur, he set out to solve a problem within the car industry, but the car industry is an international and a global industry and can manufacturers have factories in every country around the world.

When a business decides to launch a product or service, it is important to maximize the market potential, the global market is the biggest. As a global entrepreneur, it is important to adapt and deliver globally. A product can be sourced for the America market, by innovating, it can be adapted for other markets. The product perception can be altered to best suit the marketplace, controlling how it is seen and perceived in the targeted marketplace.

Take a company like Kindsox.com who have just started from a small location in the UK, first selling to the UK market 100% online and working with Amazon USA who will handle all their shipping daily for orders anywhere in America. There are no limitations as there used to be many years ago. The only limitations we have are in our own heads.

Do Entrepreneurs Need to Think Globally?

The global market is driven by benefits, if the benefits can be realized, then the focus can turn from the local, to the national and then to the international place.

Working on the global platform requires the entrepreneurs to solve global problems, rather than local or national. By looking at the problem required solving and then categorizing them into their regions, this will provide the answer where to aim for. Aiming for the world globally or a problem that only affects the local region, city or the host country.

If we look at the consultancy industry, most consultants are surviving and not thriving. The ones that are thriving are the ones that are out there solving the bigger problems to make bigger margins for bigger organizations. The bigger the problem, the bigger the payoffs. Solving a problem, for a small startup that is only surviving, will not make a fortune for helping to solve their problems. If you solve a problem for a company in the fortune 100, which will make a small difference by adding a few millions to the bottom line. The companies would be happy to pay an invoice for £100,000 or £200,000, to have their problems solved. The bigger the problem, solving it for the bigger organizations can make you more, than solving a big problem for a small startup who cannot afford to pay.

Globally, the entrepreneur is likely to earn more, by solving global problems, if the preparation is for the right global markets and the problems that exist. Most entrepreneurs look at the globe as their marketplace. Take for example Facebook, Google, Tesla, Vodafone and EE. If you look at Procter and Gamble or at Unilever, they are not just regional, they are also big international global companies. Whenever they innovate a product or a service, the chances are they have purchased a competitor's businesses and brands, most people assume that these big household names create all these products themselves. Take Reckitt Colman, which is now Reckitt Benckiser. They own the Vanish brand, now most people assume that companies like that create and invent all the products themselves. No, in fact about 70% of the brands they sell, they have purchased in from other companies.

The global companies are always looking to snap up bargains, which requires more marketing money, which the small businesses do not have. To find out if this might be the right product fit for them, they will buy those businesses or just the brand out and take them globally. Some businesses build brands knowing full well that one day will sell to the giants for a payday. Companies like Coca Cola buy out competitors to grow them with extra marketing budgets than a small company can do on their own. The entrepreneur working for a major corporate would be interested in acquiring and making it a national brand or a global brand. You can either look at the local market, national market or the international market, depending on the funding available to you and the risk involved.

What are the Risks of Working in the Global Economy?

If we only try to satisfy a regional demand, our overheads, cost of marketing are going to be marginal. If we are going to provide a product to the national market, our cost of marketing and customer market, cost of delivery are going to be more. If we go into the market globally, depending on which country, would mean more cost and more overhead. The risks are there and increase as you increase the size of each market. So, you need to be able to look at the facts of what you know, what you have and how can you reach into other markets? When considering the global market, do we supply the product or service to every country directly or appoint distributors? Or do we take one country at a time? This all depends on the costs of market penetration and the finances that are available for delivery and if the product fits into a global or a particular market?

What takes the entrepreneur into the global market? Usually a simple answer, the size of the market and the opportunity being offered are far greater than the ones offered by the local. If the demand is there globally then the business will be looking globally because it means better opportunities and more financial gain. Sometimes it's worth bringing in partners from each country who know the market better than you.

CONCLUSION

in today's world is complex and diverse because of the available modern technology. The major argument for why entrepreneurship is so important, are the number of opportunities that exist for entrepreneurs, unlike ever before. No longer do you have to own or rent a brick and mortar store. Any bright entrepreneur will embrace and maximize the available technologies needed for their industry, in order to automate, simplify and speed up the process for the growth of the business. Thanks to the internet, you are able to sell products and services from anywhere and to anyone. The global market is no more different to the entrepreneur working from his or her bedroom or basement, because we're all globally connected, and now have a global reach provided by the internet superhighway.

FUTURE RECOMMENDATIONS

The future entrepreneurs will be younger and smarter, because the younger generation now are more able, agile and quick on their feet. They have been born into the digital age and know very little about the past, nor are they interested. Supported

by computer technology, handheld devices, mobile phones are totally different ways of getting things done. A different way of data collection and using the data in a totally different way in order to see the information output. Any bright entrepreneur will embrace and maximize the available technologies needed for their industry, in order to automate, simplify and speed up the process for the growth of the business.

REFERENCES

Ali, A. (1994). *Pioneering versus incremental innovation: Review and research propositions.* Academic Press.

Bicen, P., & Johnson, W. (2015). *Radical Innovation with Limited Resources in High-Turbulent Markets: The Role of Lean Innovation Capability.* doi:10.1111/caim.12120

Bozdogan, K., Deyst., J. Hoult, D., & Lucas, M. (2002). *Architectural innovation in product development through early supplier integration.* doi:10.1111/1467-9310.00093

Inagaki, T. (2003, March). Automation and the cost of authority. *International Journal of Industrial Ergonomics*, *31*(3), 169–174. doi:10.1016/S0169-8141(02)00193-2

Samit, J. (2015). *Disrupt Yourself.* Flatiron Books.

Schmidt, G., & Druehl, C. (2008). *When Is a Disruptive Innovation Disruptive?* Retrieved from doi:10.1111/j.1540-5885.2008.00306.x

Smith, T., & Reece, J. S. (1999, January). The relationship of strategy, fit, productivity, and business performance in a services setting. *Journal of Operations Management*, *17*(2), 145–161. doi:10.1016/S0272-6963(98)00037-0

Wiiliams, E. (2011). *The Global Entrepreneur: How to Create Maximum Personal Wealth in the New Global Economic Era*. Iuniverse Books.

Compilation of References

Deb, D., & Brahmbhatt, N. L. (2018). Review of yield increase of solar panels through soiling prevention, and a proposed water-free automated cleaning solution. *Renewable & Sustainable Energy Reviews*, *82*, 3306–3313. doi:10.1016/j.rser.2017.10.014

Eskom. (2016). *Electricity generation in South Africa*. Retrieved from Marc 22, 2020 from https://www.eskom.co.za/news/Pages/Nov2.aspx

South African Department of Energy. (n.d.). *Coal resources overview*. Retrieved from March 22, 2020, from http://www.energy.gov.za/files/coal_frame.html

Nwulu, N. I., & Agboola, O. P. (2011). Utilizing renewable energy resources to solve Nigeria's electricity generation problem. *International Journal of Thermal & Environmental Engineering*, *3*(1), 15–20. doi:10.5383/ijtee.03.01.003

USAID. (n.d.). *South Africa: Power Africa fact sheet*. Retrieved from March 22, 2020, from https://www.usaid.gov/powerafrica/south-africa

Mondal, A. K., & Bansal, K. (2015b). A brief history and future aspects in automatic cleaning systems for solar photovoltaic panels. *Advanced Robotics*, *29*(8), 515–524. doi:10.1080/01691864.2014.996602

Patil, P. A., Bagi, J. S., & Wagh, M. M. (2017). A review on cleaning mechanism of solar photovoltaic panel. In *2017 International Conference on Energy, Communication, Data Analytics and Soft Computing (ICECDS)* (pp. 250-256). IEEE. 10.1109/ICECDS.2017.8389895

Alshehri, A., Parrott, B., Outa, A., Amer, A., Abdellatif, F., & Trigui, H. (2014). Dust mitigation in the desert: Cleaning mechanisms for solar panels in arid regions. In *2014 Saudi Arabia Smart Grid Conference (SASG)* (pp. 1-6). IEEE. 10.1109/SASG.2014.7274289

Mondal, A., & Bansal, K. (2015a). Structural analysis of solar panel cleaning robotic arm. *Current Science*, *108*(6), 1047–1052. Retrieved March 22, 2020, from www.jstor.org/stable/24905423

Parrott, B., Zanini, P. C., Shehri, A., Kotsovos, K., & Gereige, I. (2018). Automated, robotic dry-cleaning of solar panels in Thuwal, Saudi Arabia using a silicone rubber brush. *Solar Energy*, *171*, 526–533. doi:10.1016/j.solener.2018.06.104

Abadi, M., Barham, P., Chen, J., Chen, Z., Davis, A., Dean, J., ... Zheng, X. (2016). TensorFlow: A system for large-scale machine learning. *Proceedings of the 12th USENIX Symposium on Operating Systems Design and Implementation, OSDI 2016*.

Abbosh, O., Nunes, P., & Downes, L. (2019). *Pivot to the future: Discovering value and creating growth in a disrupted world*. PublicAffairs.

Ahlemeyer-Stubbe, A., & Coleman, S. (2014). A Practical Guide to Data Mining for Business and Industry. In A Practical Guide to Data Mining for Business and Industry. doi:10.1002/9781118763704

Alamdari, H. (2017). Aluminium Production Process: Challenges and Opportunities. *Metals - Open Access Metallurgy Journal, 7*(4), 133. https://www.researchgate.net/publication/316054514_Aluminium_Production_Process_Challenges_and_Opportunities

Albert, M. (2014). *Dynamic motion moves past old boundaries. Modern Machine Shop*. https://www.mmsonline.com/articles/dynamic-motion-moves-past-old-boundaries

Albort-Morant, G., Leal-Rodríguez, A. L., & De Marchi, V. (2018). Absorptive capacity and relationship learning mechanisms as complementary drivers of green innovation performance. *Journal of Knowledge Management*, *22*(2), 432–452. doi:10.1108/JKM-07-2017-0310

Albright, S., & Winston, W. (2017). *Business Analytics: Data Analysis and Decision Making* (6th ed.). Cangage Learning.

Ali, A. (1994). *Pioneering versus incremental innovation: Review and research propositions.* Academic Press.

Alpaydın, E. (2014). *Introduction to Machine Learning* (3rd ed.). The MIT Press.

Alpaydın, E. (2016). *Machine Learning: The New AI*. MIT Press.

Amer, M. (2017). Egyptian Intangible Heritage between Preservation Management and Sustainable Development Pattern: Analysis of the Popular Craft of Manufacturing Mats. *Egyptian Textile Museum e-Bulletin*, *1*, 226-242.

Anderson, D., Sweeney, D., Williams, T., Camm, J., Cochran, J., Fry, M., & Ohlmann, J. (2016). *Quantitative Methods for Business* (13th ed.). Book Only.

Arenas-Ortiz & Cantú-Gómez. (2013). Factores de riesgo de trastornos músculo-esqueléticos crónicos laborales. *Medicina Interna de México, 29*(4). https://www.medigraphic.com/pdfs/medintmex/mim-2013/mim134f.pdf

Asmae, A., Southail, S., El Moukhtar, Z., & Hussein, B. (2006). *Using ontologies for the integration of information systems dedicated to product (CFAO, PLM…) and those of systems monitoring (ERP, MES)*. IEEE.

Association for Advancing Automation. (2015). *Robots: Masters of the dirty, dull, and dangerous.* https://www.a3automate.org/robots-masters-of-the-dirty-dull-and-dangerous/

Axelsson, R., Angelstam, P., Degerman, E., Teitelbaum, S., Andersson, K., Elbakidze, M., & Drotz, M. K. (2013). Social and cultural sustainability: Criteria, indicators, verifier variables for measurement and maps for visualization to support planning. *Ambi*, *42*(2), 215–228. doi:10.100713280-012-0376-0 PMID:23475657

Axon, S. (2016). "The good life": Engaging the public with community-based carbon reduction strategies. *Environmental Science & Policy*, *66*, 82–92. doi:10.1016/j.envsci.2016.08.007

Azeved, S. C. (2011). The Influence of Green Practices on Supply Chain Performance: A Case Study Approach. *Transporation Research. Part E*, *47*(6), 850–871. doi:10.1016/j.tre.2011.05.017

Aziz, T. N. A. T., Jaafar, H. S., & Tajuddin, R. M. (2016). Green supply chain: Awareness of logistics industry in Malaysia. *Procedia: Social and Behavioral Sciences*, *219*, 121–125. doi:10.1016/j.sbspro.2016.04.052

Bal, Y., Faure, M., & Liu, J. (2013). The role of China's banking sector in providing green finance. *Duke Environmental Law & Policy Forum*, *24*, 89–140.

Bank, W. (2012). *Towards a Green, Clean and Resilient World for all*. Academic Press.

Barillet, C., Joffroy, T., & Longuet, I. (2006). A guide for African local governments: Cultural heritage and local development. CRATerre-ENSAG, 112.

Bartodziej, C. J. (2017). The concept industry 4.0. In *The concept industry 4.0* (pp. 27–50). Springer Gabler. doi:10.1007/978-3-658-16502-4_3

BBC. (2019). *Robots to replace 20 million factory jobs by 2030.* https://www.bbc.com/news/business-48760799#:~:text=Up%20to%2020%20million%20manufacturing,by%20automation%2C%20the%20firm%20said

Beamon, B. (1999). Designing the Green Supply Chain. *Logistics Information Management*, *12*(4), 332–342. doi:10.1108/09576059910284159

Beise, M., & Rennings, K. (2005). Lead markets and regulation: A framework for analyzing the international diffusion of environmental innovations. *Ecological Economics*, *52*(1), 5–17. doi:10.1016/j.ecolecon.2004.06.007

Belton, V., & Stewart, T. (2010). Problem structuring and multiple criteria decision analysis. In *Trends in multiple criteria decision analysis* (pp. 209–239). Springer. doi:10.1007/978-1-4419-5904-1_8

Ben Khedher, A., Henry, S., & Bouras, A. (2011). Integration between MES and Product Lifecycle Management. *IEEE International Conference on Emerging Technologies and Factory Automation (ETFA'11)*, Toulouse, France. 10.1109/ETFA.2011.6058993

Betz, C., Gardner, C., O'Donnell, G., McKeon-White, W., Caldwell, J., & Lynch, D. (2019). *Beware the automation paradox: Prepare for an automated world full of surprises and requiring higher skills*. https://www.forrester.com/report/Beware+The+Automation+Paradox/-/E-RES158237#

Bhattacharjee, K. (2015). Green Supply Chain Management - Challenges and Opportunities. *Asian Journal of Technology & Management Research, 5*(1).

Bicen, P., & Johnson, W. (2015). *Radical Innovation with Limited Resources in High-Turbulent Markets: The Role of Lean Innovation Capability.* doi:10.1111/caim.12120

Biron, J. (2017). *The state of the industrial internet of things 2017*. https://www.ptc.com/-/media/Files/PDFs/IoT/State-of-IIoT-Whitepaper.pdf

Blättel-Mink, B. (1998). Innovation towards sustainable economy—The integration of economy and ecology in companies. *Sustainable Development*, *6*(2), 49–58. doi:10.1002/(SICI)1099-1719(199808)6:2<49::AID-SD84>3.0.CO;2-I

Bontempi, G., Ben Taieb, S., & Le Borgne, Y. A. (2013). Machine learning strategies for time series forecasting. *Lecture Notes in Business Information Processing, 138*, 62–77. doi:10.1007/978-3-642-36318-4_3

Borgo, S., & Leitão, P. (2007). Foundations for a core ontology of manufacturing. *IntegratedSeries in Information Systems*, *14*(1), 751–775. doi:10.1007/978-0-387-37022-4_27

Bozdogan, K., Deyst., J. Hoult, D., & Lucas, M. (2002). *Architectural innovation in product development through early supplier integration.* doi:10.1111/1467-9310.00093

Brasil. (2004). *Decreto 5.296 de 2 de dezembro de 2004*. Available from http://www.planalto.gov.br/ccivil_03/_ato2004-2006/2004/decreto/d5296.htm

Braziliense, C. (2015). *Saiba qual é o custo-benefício de ter um lar inteligente*. Available in https://www.correiobraziliense.com.br/app/noticia/tecnologia/2015/08/20/interna_tecnologia,495363/saiba-qual-e-o-custo-beneficio-de-ter-um-lar-inteligente.shtml

Brealey, R., Myers, S., & Marcus, A. (2017). *Fundamentals of Corporate Finance* (9th ed.). McGraw Hill.

Brownlee, J. (2019). *What does stochastic mean in machine learning?* https://machinelearningmastery.com/stochastic-in-machine-learning

Brownlee, J. (2020). *Deep Learning for Time Series Forecasting: Predict the Future with MLPs ... - Jason Brownlee - Google Kitaplar*. Retrieved from https://books.google.com.tr/ books?hl=tr&lr=&id=o5qn DwAAQBAJ&oi=fnd&pg =PP1&dq= jason+brownleed+deep+learning&ots =yG8avKoh19&sig= 0XIzVsPbMQec 1K9OJ9niB0qHSnk &redir_esc=y#v=onepage&q= jasonbrownleeddeeplearning &f=false

Brungs, J., & Wyber, S. (2016). Preserving our digital culture for the future: Overcoming obstacles through collaboration. International Federation of Library Associations and Institutions (IFLA). *Global Information Society Watch*, 36-40.

Bruno, G. (2015). Measuring product semantic similarity by exploiting a manufacturing process ontology. *International Conference on Industrial Engineering and Systems Management (IESM'15)*, 1251-1257. 10.1109/IESM.2015.7380313

Bruno, G., Antonelli, D., Korf, R., Lentes, J., & Zimmermann, N. (2014, September). Exploitation of a semantic platform to store and reuse PLM knowledge. In *IFIP International Conference on Advances in Production Management Systems* (pp. 59-66). Springer. 10.1007/978-3-662-44739-0_8

Bruno, G., Korf, R., Lentes, J., & Zimmermann, N. (2016). Efficient management of product lifecycle information through a semantic platform. *International Journal of Product Lifecycle Management*, *9*(1), 45–64. doi:10.1504/IJPLM.2016.078864

Bruno, G., Taurino, T., & Villa, A. (2018). An approach to support SMEs in manufacturing knowledge organization. *Journal of Intelligent Manufacturing*, *29*(6), 1379–1392. doi:10.100710845-015-1186-6

Bruno, G., Traini, E., & Lombardi, F. (2019). A Knowledge-Based System for Collecting and Integrating Production Information. *20th IFIP Working Conference on Virtual Enterprises, PRO-VE 2019*, Turin, Italy. 10.1007/978-3-030-28464-0_15

Built, In. (2019). *Robotics technology*. https://builtin.com/robotics

Burnett, K. (2000). *The handbook of key customer relationship management: The definitive guide to winning, managing and developing key account business*. Ft Press.

Burra Charter. (2020). *The Burra Charter: The Australia ICOMOS Charter for Places of Cultural Significance.* Available online: http://openarchive.icomos.org/2145/

Burton, J. (2010). *WHO Healthy Workplace Framework and Model: Background and Supporting Literature and Practices*. https://www.who.int/occupational_health/healthy_workplace_framework.pdf

Cachon, G., & Terwiesch, C. (2012). *Matching Supply with Demand: An Introduction to Operations Management*. McGraw-Hill/Irwin.

Camprubí, R., & Coromina, L. (2016). Content analysis in tourism research. *Tourism Management Perspectives*, *18*, 134–140. doi:10.1016/j.tmp.2016.03.002

Cao, Q., Banerjee, R., Gupta, S., Li, J., Zhou, W., & Jeyachandra, B. (2016). Data driven production forecasting using machine learning. *Society of Petroleum Engineers - SPE Argentina Exploration and Production of Unconventional Resources Symposium*. 10.2118/180984-MS

Carbonneau, R., Laframboise, K., & Vahidov, R. (2008). Application of machine learning techniques for supply chain demand forecasting. *European Journal of Operational Research*, *184*(3), 1140–1154. doi:10.1016/j.ejor.2006.12.004

Chakrabarti, S. (2009). *Data Mining: Know It All*. M. Kaufmann.

Chang, K., Zeng, Y., Wang, W., & Wu, X. (2019). The effects of credit policy and financial constraints on tangible and research & development investment: Firm-level evidence from China's renewable energy industry. *Energy Policy*, *130*, 438–447. doi:10.1016/j.enpol.2019.04.005

Chan, H. K., Wang, X., Lacka, E., & Zhang, M. (2016). A mixedmethod approach to extracting the value of social media data. *Production and Operations Management*, *25*(3), 568–583. doi:10.1111/poms.12390

Chase, C. (2016). *Next Generation Demand Management: People, Process, Analytics, and Technology*. Wiley. doi:10.1002/9781119449591

Chen, H. J. (2012). *Research on green driving mechanism and driving strength evaluation method of supply chain* [Doctoral thesis]. Jilin University.

Chen, Y. S., Lai, S. B., & Wen, C. T. (2006). The influence of green innovation performance on corporate advantage in Taiwan. *Journal of Business Ethics*, *67*(4), 331–339. doi:10.100710551-006-9025-5

Chesbrough & Rosenbloom. (2002). The role of the business model in capturing value from innovation: evidence from Xerox Corporation's technology spin-off companies. *ICC, 11*(3), 529-555. doi:10.1093/icc/11.3.529

Chiabrando, F., Colucci, E., Lingua, A., Matrone, F., Noardo, F., & Spanò, A. (2018). A European Interoperable Database (Eid) to Increase Resilience of Cultural Heritage. ISPRS-. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *XLII-3*(W4), 151–158. doi:10.5194/isprs-archives-XLII-3-W4-151-2018

Chopra, S., & Meindl, P. (2016). *Supply Chain Management* (Global Edition).

Chouinard, Y., & Brown, M. S. (1997). Going organic: Converting Patagonia's cotton product line. *Journal of Industrial Ecology*, *1*(1), 117–129. doi:10.1162/jiec.1997.1.1.117

Chui, M., George, K., Manyika, J., & Miremadi, M. (2017). *Human + machine: A new era of automation in manufacturing*. https://www.mckinsey.com/business-functions/operations/our-insights/human-plus-machine-a-new-era-of-automation-in-manufacturing#

Chui, M., Manyika, J., & Miremadi, M. (2015). *How many of your daily tasks could be automated?* https://hbr.org/2015/12/how-many-of-your-daily-tasks-could-be-automated

Chungoora, N., Young, R. I., Gunendran, G., Palmer, C., Usman, Z., Anjum, N. A., Cutting-Decelle, A.-F., Harding, J. A., & Case, K. (2013). A model-driven ontology approach for manufacturing system interoperability and knowledge sharing. *Computers in Industry*, *64*(4), 392–401. doi:10.1016/j.compind.2013.01.003

CloudCheckr. (2019). *How to optimize smart manufacturing production with IIoT and the cloud.* https://cloudcheckr.com/cloud-automation/smart-manufacturing-iiot-cloud/

Columbus, L. (2019). *10 ways machine learning is revolutionizing manufacturing in 2019*. https://www.forbes.com/sites/louiscolumbus/2019/08/11/10-ways-machine-learning-is-revolutionizing-manufacturing-in-2019/#2321ca4c2b40)

Commission of the European Communities (CEC). (2006). *Analysis of economic indicators of the EU metals industry: the impact of raw materials and energy supply on competitiveness*. Commission Staff Working Document; Brussels; 2 (8); SEC (2006) pp. 1069. https://ec.europa.eu/info/index_en

Cooke, N. (2019). *The difference between files and databases – and what it means for CAD and product design*. https://www.onshape.com/cad-blog/the-difference-between-files-and-databases-and-what-it-means-for-cad-and-product-design

Costantini, V., Crespi, F., Marin, G., & Paglialunga, E. (2016). Eco-innovation, sustainable supply chains and environmental performance in European industries. *Journal of Cleaner Production*, *155*, 141–154.

Cui, L. (2017). Fuzzy approach to eco-innovation for enhancing business functions: A case study in China. *Industrial Management & Data Systems*, *117*(5), 967–987.

Cui, L., Chan, H. K., Zhou, Y., Dai, J., & Lim, J. J. (2019). Exploring critical factors of green business failure based on Grey-Decision Making Trial and Evaluation Laboratory (DEMATEL). *Journal of Business Research*, *98*, 450–461. doi:10.1016/j.jbusres.2018.03.031

D'Antonio, G. (2016). *Manufacturing Execution Systems for lean, adaptive production processes* (Doctoral dissertation). DIGEP, Politecnico di Torino, Torino.

D'Antonio, G., & Bedolla, J. (2015). PLM-MES Integration: A Case Study in Automotive Manufacturing. *12th IFIP International Conference on Product Lifecyle Management (PLM)*, Doha, Qatar.

D'Antonio, G., Macheda, Li., Bedolla, J. S., & Chiabert, P. (2017). *PLM-MES Integration to Support Industry 4.0*. Springer International Publishing. doi:10.1007/978-3-319-72905-3_12

D'Antonio, G., Sauza, B. J., Chiabert, P., & Lombardi, F. (2015). PLM-MES integration to support collaborative design. *International Conference on Engineering Design*, Milan, Italy

Darnall, N., Henriques, I., & Sadorsky, P. (2010). Adopting proactive environmental strategy: The influence of stakeholders and firm size. *Journal of Management Studies*, *47*(6), 1072–1094. doi:10.1111/j.1467-6486.2009.00873.x

Dassault Systems. (2015). *Solidworks API help.* http://help.solidworks.com/2015/English/api/sldworksapiprogguide/Welcome.htm#_ga=2.14223664.686212411.1591105404-25c358d0-a4d5-11ea-b73a-a1d588fa93fd

Dean, P. R., Tu, Y. L., & Xue, D. (2009). An information system for one-of-a-kind production. *International Journal of Production Research*, *47*(4), 1071–1087. doi:10.1080/00207540701543593

Delen, D., Zaim, H., Kuzey, C., & Zaim, S. (2013). A comparative analysis of machine learning systems for measuring the impact of knowledge management practices. *Decision Support Systems*, *54*(2), 1150–1160. Advance online publication. doi:10.1016/j.dss.2012.10.040

Dewi, S. T., & Susetyo-Salim, T. A. (2017). Challenges and Opportunities in the Protection and the Preservation Indigenous Knowledge of "Rabab Music Art" Pariaman. *Social Sciences*, *12*(2), 262–265.

Digital Transformations Monitor. (2017). *Key lessons from national industry 4.0 policy initiatives in Europe*. https://ec.europa.eu/growth/tools-databases/dem/monitor/sites/default/files/DTM_Policy%20initiative%20comparison%20v1.pdf

Ding, H., Bi, Q., Zhu, L., & Xiong, Y. (2010). Tool path generation and simulation of dynamic cutting process for five-axis NC machining. *Chinese Science Bulletin*, *55*(30), 3408–3418. doi:10.100711434-010-3247-7

Dogramaci, Kalaci, Sava, Duman, & Yanat. (2009). Treatment of lateral epicondilitis using three different local injection modalities: a randomized prospective clinical trial. *Archives of Orthopaedic and Trauma Surgery, 129*, 1409–1414. https://link.springer.com/article/10.1007/s00402-009-0832-x

Dunlop, J., & Hart, L. (2005). *Digitization projects at the University of Cape Town Libraries.* Available: www.innovation.ukzn.ac.za/InnovationPdfs/No30pp32-42Dunlop&Hart.pdf

Duriau, V. J., Reger, R. K., & Pfarrer, M. D. (2007). A content analysis of the content analysis literature in organization studies: Research themes, data sources, and methodological refinements. *Organizational Research Methods*, *10*(1), 5–34. doi:10.1177/1094428106289252

Durst, S., & Wilhelm, S. (2012). Knowledge management and succession planning in SMEs. *Journal of Knowledge Management*, *16*(4), 637–649. doi:10.1108/13673271211246194

Dvorkin, M., & Bharadwaj, A. (2019). *Which countries and industries use the most robots?* https://www.stlouisfed.org/on-the-economy/2019/november/robots-affecting-local-labor-markets

El-Kassar, A. N., & Singh, S. K. (2019). Green innovation and organizational performance: The influence of big data and the moderating role of management commitment and HR practices. *Technological Forecasting and Social Change*, *144*, 483–498. doi:10.1016/j.techfore.2017.12.016

El-Khalil, R., & Darwish, Z. (2019). *Flexible manufacturing systems performance in U.S. automotive manufacturing plants: A case study.* https://www.tandfonline.com/doi/abs/10.1080/09537287.2018.1520318

Elo, S., & Kyngäs, H. (2008). The qualitative content analysis process. *Journal of Advanced Nursing*, *62*(1), 107–115. doi:10.1111/j.1365-2648.2007.04569.x PMID:18352969

Esty, D. C., & Winston, A. S. (2006). *Green to gold: How smart companies use environmental strategy to innovate, create value, and build competitive advantage*. John Wiley.

Etzion, D. (2007). Research on organizations and the natural environment, 1992-present: A review. *Journal of Management*, *33*(4), 637–664. doi:10.1177/0149206307302553

Everett, A., & Ebert, R. (1986). Production and Operations Management: Concepts, Models, and Behavior (3rd ed.). Prentice-Hall.

eWeLink. (2020). *Features*. Available in https://www.ewelink.cc/en/intro/

Feiz, S., Khalifah, Z. B., & Ghotbabadi, A. R. (2011). Custtomer relationship management in organizations. *International Conference on Management (ICM 2011) Proceeding*.

Fischer, J. A., Pohl, P., & Ratz, D. (2020). A machine learning approach to univariate time series forecasting of quarterly earnings. *Review of Quantitative Finance and Accounting*, *55*(4), 1163–1179. Advance online publication. doi:10.100711156-020-00871-3

Frey, B. (1997). The Evaluation of Cultural Heritage: Some Critical Issues. In M. H. A. I. Rizzo (Ed.), *Economic Perspectives on Cultural Heritage* (pp. 31–49). Palgrave MacMillan. doi:10.1007/978-1-349-25824-6_3

Fujii, H., & Managi, S. (2019). Decomposition analysis of sustainable green technology inventions in China. *Technological Forecasting and Social Change*, *139*, 10–16. doi:10.1016/j.techfore.2018.11.013

Fuller, J., & Martinec, L. (2005). Operations Research and Operations Management: From Selective Optimization to System Optimization. *Journal of Business & Economics Research*, *3*(7), 16.

Gábor, S. (2001). Modelling nonlinear regenerative effects in metal cutting. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, *359*, 1781.

Gao, C., Na, H., Song, K., Tian, F., Strawa, N., & Du, T. (2020). Technologies-based potential analysis on saving energy and water of China's iron and steel industry. *The Science of the Total Environment*, *699*, 134225. doi:10.1016/j.scitotenv.2019.134225 PMID:31677463

García-Peñalvo, F. J., Conde-González, M., & Matellán, V. (2014). Mobile Apps for Older Users – The Development of a Mobile Apps Repository for Older People. In *International Conference on Learning and Collaboration Technologies*. 10.1007/978-3-319-07485-6_12

German, K. (2020). *Boeing 737 max could stay grounded until late 2020*. https://www.cnet.com/news/boeing-737-max-8-all-about-the-aircraft-flight-ban-and-investigations

Giudici, A., & Reinmoeller, P. (2012, November 1). Dynamic capabilities in the dock: A case of reification? *Strategic Organization*, *10*(4), 436–449. doi:10.1177/1476127012457977

Global Data and Analytics Survey. (2016). Retrieved 5 September 2020, from https://www.pwc.com/us/en/services/consulting/analytics/big-decision-survey.html

Gou, Z., Lau, S. Y., & Chen, F. (2012). Subjective and objective evaluation of the thermal environment in a three-star green office building in china. *Indoor and Built Environment*, *21*(3), 412–422. doi:10.1177/1420326X11419311

Grazuleviciute-Vileniske, I. (2006). Cultural heritage in the context of sustainable development. *Environmental Research, Engineering and Management*, *3*(37), 74–79.

Gunasekaran, A., & Spalanzani, A. (2012). Sustainability of manufacturing and services: Investigations for research and applications. *International Journal of Production Economics*, *140*(1), 35–47. doi:10.1016/j.ijpe.2011.05.011

Guo, Y. C., & Niu, D. X. (2007). A knowledge-based intelligent system for power customer service management. *International Conference on Machine Learning and Cybernetics*. 10.1109/ICMLC.2007.4370648

Guttag, J. (2013). *Introduction to computation and programming using Python*. Academic Press.

Hagen, L. (2018). Content analysis of e-petitions with topic modeling: How to train and evaluate LDA models? *Information Processing & Management*, *54*(6), 1292–1307. doi:10.1016/j.ipm.2018.05.006

Halila, F., & Rundquist, J. (2011). The development and market success of eco-innovations: A comparative study of eco-innovations and "other" innovations in Sweden. *European Journal of Innovation Management*, *14*(3), 278–302. doi:10.1108/14601061111148807

Hasanzadeh, M., & Mahaleh, S. F. S. S. (2013). Effect of knowledge management on success of customers relationship management in Eghtesad Novin Bank of Tehran. *International Journal of Business Management and Economic Research*, *4*(6), 839–848.

Hashemi, S. H., Karimi, A., & Tavana, M. (2015). An integrated green supplier selection approach with analytic network process and improved Grey relational analysis. *International Journal of Production Economics*, *159*, 178–191. doi:10.1016/j.ijpe.2014.09.027

Heizer, J., Render, B., & Munson, C. (2017). *Operations Management: Sustainability and Supply Chain Management* (12th ed.). Pearson Education Limited.

Hitchcock, M., King, V., & Parnwell, M. (2010). *Heritage Tourism in Southeast Asia*. NIAS Press.

Hosagrahar, J. (2019). UNESCO Thematic Indicators for Culture in the 2030 Agenda for Sustainable Development. In *Analytical Report of the Consultation with the Member States*. UNESCO World Heritage Centre.

Hyndman, R. J., & Athanasopoulos, G. (2018). Forecasting: Principles and Practice (2nd ed.). Retrieved from OTexts.com/fpp2

IFLA. (2018). *IFLA - Global Vision Report Summary*. https://www.ifla.org/node/11905

Ifttt. (2020). *Every thing works better together*. Available in https://ifttt.com/

Inagaki, T. (2003, March). Automation and the cost of authority. *International Journal of Industrial Ergonomics*, *31*(3), 169–174. doi:10.1016/S0169-8141(02)00193-2

Infosys. (n.d.). *Green Supply Chain Management*. Academic Press.

Instituto Mexicano del Seguro Social (IMSS). (2018). *Memoria Estadística en México: Coordinación de Salud en el Trabajo*. Reporte del IMSS. http://www.imss.gob.mx/conoce-al-imss/memoria-estadistica-2016

Irena, V. (2015). Triple Helix Model of university–industry– government cooperation in the context of uncertainties. *Procedia: Social and Behavioral Sciences*, *213*, 1063–1067. doi:10.1016/j.sbspro.2015.11.526

ISA-95. (2000). *Enterprise Control System Integration*. www.isa-95.com/

Jackson, a. R. (1998). Where's the profit in industrial ecology. *Journal of Industrial Ecology, 2*(1), 3–5.

Jacobs, F. R., & Chase, R. B. (2018). *Operations and supply chain management* (15th ed.). McGraw-Hill/Irwin.

Jigyasu, R. (2014). The Intangible Dimension of Urban Heritage. In F. Bandarin & R. v. Oers (Eds.), *Reconnecting the City: The Historic Urban Landscape Approach and the Future of Urban Heritage*. Wiley-Blackwell. doi:10.1002/9781118383940.ch5

Johsson, M. (2013). *On manufacturing technology as an enabler of flexibility – Affordable reconfigurable tooling and force-controlled robotics*. https://www.diva-portal.org/smash/get/diva2:601924/FULLTEXT01.pdf

Joseph, E. E., & Winston, B. E. (2005). A correlation of servant leadership, leader trust, and organizational trust. *Leadership and Organization Development Journal*, *26*(1), 6–22. doi:10.1108/01437730510575552

Joshi, S. (2009). ERP-MES-PLM integration-making information technology strategy compliment business strategy. *IADIS International Conference on Information System, IS 2009*, Barcelona, Spain.

Kalycito. (n.d.). *What is OPC UA, industry 4.0 and the interoperability challenge?* https://www.kalycito.com/opc-ua-interoperability/

Kandiller, L. (2007). Principles of Mathematics in Operations Research. Springer.

Kanyengo, C. W. (2009). Managing digital information resources in Africa: Preserving the integrity of scholarship. *The International Information & Library Review*, *41*(1), 34–43. doi:10.1080/10572317.2009.10762795

Kearns, S. (2010, January). Strategic Alignment Between Business and Information Technology: A Knowledge-Based View of Behaviors, Outcome, and Consequences. *Journal of Management*, *36*(1), 256–280.

Kemp, R., & Pearson, P. (2007). *Final report MEI project about measuring eco-innovation*. United Nations University–MERIT.

Kim, J., & Park, K. (2018). Effect of the Clean Development Mechanism on the deployment of renewable energy: Less developed vs. well-developed financial markets. *Energy Economics*, *75*, 1–13. doi:10.1016/j.eneco.2018.07.034

Klancnik, S., Brezocnik, M., & Balic, J. (2016). Intelligent CAD/CAM system for programming of CNC machine tools. *International Journal of Simulation Modelling*, *15*(1), 109–120. doi:10.2507/IJSIMM15(1)9.330

Knez, M., Bajor, P., & Seme, S. (2011). Green logistics—A solar warehouse concept. *Logistics & Sustainable Transport*, *2*(2), 1–8.

Koch, F., & Krellenberg, K. (2018). How to Contextualize SDG 11? Looking at Indicators for Sustainable Urban Development in Germany. *ISPRS International Journal of Geo-Information*, *7*(12), 464. doi:10.3390/ijgi7120464

Kondracki, N. L., Wellman, N. S., & Amundson, D. R. (2002). Content analysis: Review of methods and their applications in nutrition education. *Journal of Nutrition Education and Behavior*, *34*(4), 224–230. doi:10.1016/S1499-4046(06)60097-3 PMID:12217266

Kottoor, N. (2013). How Timbuktu's manuscripts were smuggled to safety. *BBC World Service Magazine.*

KPMG. (February 2017). *Capitalising on green governance in retail supply chain.* KPMG.

Krajewski, L., Malhotra, M., & Ritzman, L. (2016). *Operations Management: Processes and Supply Chains* (11th ed.). Pearson.

Krispin, R. (2019a). Retrieved 5 September 2020, from https://github.com/PacktPublishing/Hands-On-Time-Series- Analysis-with- R /tree/master/ Chapter12

Krispin, R. (2019b). *Hands-on Time Series Analysis with R*. Packt.

Kronbauer, A., Gomes, F., & Campos, J. (2018). Specification of a Universal Remote Control for Interaction in Residential Environments. *IEEE Latin America Transactions.*, *16*(11), 2680–2688. doi:10.1109/TLA.2018.8795108

Kurowski, P. (2012). *When good engineers deliver bad FEA*. https://www.machinedesign.com/3d-printing-cad/fea-and-simulation/article/21831586/when-good-engineers-deliver-bad-fea

Laari, S., Töyli, J., & Ojala, L. (2017). Supply chain perspective on competitive strategies and green supply chain management strategies. *Journal of Cleaner Production*, *141*, 1303–1315. doi:10.1016/j.jclepro.2016.09.114

Li, Q. H. (2014). *Green innovation of production enterprises: Influencing factors and performance* [Doctoral thesis]. Southwestern University of Finance and Economics.

Liang, J., Feng, C. J., & Song, P. (2016). A summary of large data correlation analysis. *Journal of Computational Science*, *1*, 1–18.

Liao, L.-D., Chuang, C.-C., Ger, T.-R., Wang, Y., Tsao, Y.-C., Wang, I.-J., Jhang, D.-F., Chu, T.-S., Tsao, C.-H., Tsai, C.-N., & Chen, S.-F. (2019). Design and Validation of a Multifunctional Android-Based Smart Home Control and Monitoring System. *Design and Validation of a Multifunctional Android-Based Smart Home Control and Monitoring System.*, *7*, 163313–163322. doi:10.1109/ACCESS.2019.2950684

Liao, Z. (2018). Content analysis of China's environmental policy instruments on promoting firms' environmental innovation. *Environmental Science & Policy*, *88*, 46–51. doi:10.1016/j.envsci.2018.06.013

Liburd, J. J. (2007). Sustainable Tourism, Cultural Practice and Competence Development for Hotels and Inns in Denmark. *Tourism Recreation Research*, *32*(1), 41–48. doi:10.1080/02508281.2007.11081522

Li, D., Zhao, Y., Zhang, L., Chen, X., & Cao, C. (2018). Impact of quality management on green innovation. *Journal of Cleaner Production*, *170*, 462–470. doi:10.1016/j.jclepro.2017.09.158

Li, D., Zheng, M., Cao, C., Chen, X., Ren, S., & Huang, M. (2017). The impact of legitimacy pressure and corporate profitability on green innovation: Evidence from China top 100. *Journal of Cleaner Production*, *141*, 41–49. doi:10.1016/j.jclepro.2016.08.123

Lin, J. (2007). *Sustainable Supply Chains in the Food and Beverage Industry*. Academic Press.

Lipp, T. (2013). Materializing the Immaterial. On the Paradox of Medializing Intangible Cultural Heritage. In M.-T. Albert, R. Bernecker, & B. Rudolf (Eds.), *Understanding Heritage: Perspectives in Heritage Studies*. UNESCO Digital Library. doi:10.1515/9783110308389.135

Liu, P., Zhou, Y., Zhou, D. K., & Xue, L. (2017). Energy performance contract models for the diffusion of green-manufacturing technologies in China: A stakeholder analysis from SMEs' perspective. *Energy Policy*, *106*, 59–67. doi:10.1016/j.enpol.2017.03.040

Li, W. Y., Chow, P. S., Choi, T. M., & Chan, H. L. (2016). Supplier integration, green sustainability programs, and financial performance of fashion enterprises under global financial crisis. *Journal of Cleaner Production*, *135*, 57–70. doi:10.1016/j.jclepro.2016.06.048

Li, Z., Mahbobur Rahman, S. M., Vega, R., & Dong, B. (2016). A hierarchical approach using machine learning methods in solar photovoltaic energy production forecasting. *Energies*, *9*(1), 55. Advance online publication. doi:10.3390/en9010055

Luftman, J.N., Lewis, P.R., & Oldach, S.H. (2010). *Transforming the enterprise: The alignment of business and information technology strategies*. IBM Consulting Group.

Mace, R. L., Hardie, G. J., & Place, J. P. (1991). *Accessible Environments: Toward Universal Design*. Van Nostrand Reinhold.

Mackenzie, A. (2015). The production of prediction: What does machine learning want? *European Journal of Cultural Studies*, *18*(5), 429–445. doi:10.1177/1367549415577384

Manda, V. L. K. B., Kushal, V., & Ramasubramanian, N. (2018). An Elegant Home Automation System Using GSM and ARM-Based Architecture. *IEEE Potentials*, *37*(5), 43–48. doi:10.1109/MPOT.2016.2515644

Manufacturing Institute. (2014). *Small companies dominate the industrial landscape.* https://www.themanufacturinginstitute.org/Research/Facts-About-Manufacturing/Economy-and-Jobs/Company-Size/Company-Size.aspx

Manufacturing.gov. (2020). *Funding*. https://www.manufacturing.gov/funding

Marcus, G. (2012). *Why making robots is so darn hard*. https://www.newyorker.com/news/news-desk/why-making-robots-is-so-darn-hard

María Loreto Díaz, J. (2014). Cervicalgia myofascial. *Revista Médica Clínica Las Condes, 25*(2), 200-208. https://www.sciencedirect.com/science/article/pii/S0716864014700318

Marr, B. (2018). *What is industry 4.0? Here's a super easy explanation for anyone*. https://www.forbes.com/sites/bernardmarr/2018/09/02/what-is-industry-4-0-heres-a-super-easy-explanation-for-anyone/#76efaaae9788

Masso, J., & Vahter, P. (2008). Technological innovation and productivity in late-transition Estonia: Econometric evidence from innovation surveys. *European Journal of Development Research*, *20*(2), 240–261. doi:10.1080/09578810802060751

Mathews, K. (2018). *How robot precision has evolved, enabling more uses.* https://www.roboticsbusinessreview.com/manufacturing/robot-precision-evolves

McKay, C., Pollack, E., & Fitzpayne, A. (2019). *Automation and a changing economy.* https://assets.aspeninstitute.org/content/uploads/2019/04/Automation-and-a-Changing-Economy_The-Case-for-Action_April-2019.pdf?_ga=2.29984255.1325231099.1591271424-1863845613.1591271424

Melanson, A. (2018). *Robotic automation in manufacturing driving US growth*. https://aethon.com/robotic-automation-in-manufacturing-driving-us-growth/

Mele, C., & Russo-Spena, T. (2015). Eco-innovation practices. *Journal of Organizational Change Management*, *28*(1), 4–25. doi:10.1108/JOCM-08-2013-0146

Mensah, J. (2019). Sustainable development: Meaning, history, principles, pillars, and implications for human action: Literature review. *Journal of Cogent Social Sciences*, *5*(1), 1–21. doi:10.1080/23311886.2019.1653531

MESA International. (1997). *MES functionalities & MRP to MES data flow possibilities*. Technical report.

Miah, S. J., Gammack, J., & Hasan, N. (2017). Extending the framework for mobile health information systems research: A content analysis. *Information Systems*, *69*, 1–24. doi:10.1016/j.is.2017.04.001

Mina, H., Mirabedini, S. N., Kian, H., & Ghaderi, S. F. (2014). A new two stage integrated approach for green supplier selection. Applied Mathematics in Engineering. *Management and Technology*, *1*, 1247–1126.

Ming, X. G., Yan, J. Q., Lu, W. F., Ma, D. Z., & Song, B. (2007). Mass production of tooling product families via modular feature-based design to manufacturing collaboration in PLM. *Journal of Intelligent Manufacturing*, *18*(1), 185–195.

Min, Q., Lu, Y., Liu, Z., Su, C., & Wang, B. (2019). Machine Learning based Digital Twin Framework for Production Optimization in Petrochemical Industry. *International Journal of Information Management*, *49*, 502–519. Advance online publication. doi:10.1016/j.ijinfomgt.2019.05.020

Moldavska, A., & Welo, T. (2017). The concept of sustainable manufacturing and its definitions: A content-analysis based literature review. *Journal of Cleaner Production*, *166*, 744–755. doi:10.1016/j.jclepro.2017.08.006

Moones, E., Kermad, L., Vosgien, T., & El Mouloudi, D. (2015). *PLM Standards Modelling for Enterprise interoperability: A Manufacturing Case Stady for ERP and MES Systems Integration Base on ISA-19.* Enterprise Interoperability 6th International IFIP Working Conference, IWEI 2015, Nîmes, France.

Morais, B. S. G., Sobrinho, A., Oliveira, H., Silva, L. C. & Macedo, R. L. (2019). *Design of a Home Automation App to Assist Elderly and Limited Mobility People The IoT and the Next Revolutions Automating the World*. IGI Global. . doi:10.4018/978-1-5225-9246-4.ch005

Moran, G. (2019). *Your job will be automated—Here's how to figure out when A.I. could take over*. https://fortune.com/2019/08/01/predicting-job-automation-ai/

Morel, G. (1992). *Contribution de l'automatisation et à l'ingénierie des systèmes intégrés de production*. Habilitation à Diriger des Recherches de l'Université Henri Poincaré.

Moreno, A. G., & Melendez, A. P. (2011). Analyzing the impact of knowledge management on CRM success: The mediating effects of organizational factors. *International Journal of Information Management*, *31*(5), 437–444. doi:10.1016/j.ijinfomgt.2011.01.002

Mourão, L. (2012). *Automação residencial: sem fio, controlada por celular e mais barata*. Available in https://casa.abril.com.br/construcao/automacao-residencial-sem-fio-controlada-por-celular-e-mais-barata/

Muffatto, M., & Roveda, M. (2000). Developing product platforms: Analysis of the development process. *Technovation*, *20*(11), 617–630.

Muratori, J. R., & Dal Bo, P. H. (2017). *Home automation: concepts and applications. 2*. Educere.

Myers, D. (2016). Heritage inventories: Promoting effectiveness as a vital tool for sustainable heritage management. *Journal of Cultural Heritage Management and Sustainable Development*, *6*(2), 102–112. doi:10.1108/JCHMSD-02-2016-0009

Nahmias, S., & Olsen, T. (2015). *Production and Operations Analysis* (7th ed.). Waveland Press.

Namjoyan, M., Esfahani, A. N., & Allameh-Haery, F. (2013). Studying the effects of customer relationship management on the marketing performance (Isfahan Saderat Bank as a case Study). *International Journal of Academic Research in Business & Social Sciences*, *3*(9), 302–314. doi:10.6007/IJARBSS/v3-i9/211

Nengomasha, C. T. (2009). Managing public sector records in Namibia: A propose model. *Information Development*, *25*(2), 112–126. doi:10.1177/0266666909104712

Ngulube, P. (2012). "Ghosts in our machines": Preserving public digital information for the sustenance of electronic government in sub-Saharan Africa. *Mousaion: South African Journal of Information Studies*, *30*(2), 127–135.

Nguyen, T., Zhou, L., Spiegler, V., Ieromonachou, P., & Lin, Y. (2018). Big data analytics in supply chain management: A state-of-the-art literature review. *Computers & Operations Research*, *98*, 254–264. doi:10.1016/j.cor.2017.07.004

Nicols, G. (2018). *Paradigm shift: Can anyone be a robotics programmer with sensor-embedded clothes?* https://www.zdnet.com/article/paradigm-shift-can-anyone-become-a-robotics-programmer-with-sensor-embedded-clothes/

Nieminen, E., Linke, M., Tobler, M., & Beke, B. V. (2007). EU COST Action 628: Life cycle assessment (LCA) of textile products, eco-efficiency and definition of best available technology (BAT) of textile processing. *Journal of Cleaner Production*, *15*(13–14), 1259–1270. doi:10.1016/j.jclepro.2006.07.011

Nmeir, E. (2018). The Syrian heritage archive project in Berlin: Protecting and Interpreting Cultural Heritage in the Age of Digital Empowerment. India Habitat Centre.

Nocca, F. (2017). The Role of Cultural Heritage in Sustainable Development: Multidimensional Indicators as Decision-Making Tool. *Sustainability*, *9*(10), 1882. doi:10.3390u9101882

Noury, N., Barralon, P., Vuillerme, N., & Fleury, A. (2012). Fusion of Multiple Sensors Sources in a Smart Home to Detect Scenarios of Activities in Ambient Assisted Living. *International Journal of E-Health and Medical Communications*, *3*(3), 29–44. doi:10.4018/jehmc.2012070103

Ociepa-Kubicka, A., & Pachura, P. (2017). Eco-innovations in the functioning of companies. *Environmental Research*, *156*, 284–290. doi:10.1016/j.envres.2017.02.027 PMID:28395239

Omor. (2020). Retrieved 26 August 2020, from http://operations-management-research.essec.edu/home

OpenHab. (2020). *Documentation*. Available in https://www.openhab.org/docs/

P, R. (2007). Greening of the supply chain: an empirical study for SMES in the Philippine context. *Journal of Asia Business Studies, 1*(2).

Paulus, G. B., Piloti, J. S., Antoniazzi, R. L., & Antunes, E. F. (2017). Residential Automation System: Accessibility in Domestic Control. XXII Jornada de Pesquisa, (13).

Petti, L., Trillo, C., & Makore, B. C. N. (2019). Towards a Shared Understanding of the Concept of Heritage in the European Context. *Heritage*, *2*(3), 2531–2544. doi:10.3390/heritage2030155

Pfaff, B. (2008). *Analysis of Integrated and Cointegrated Time Series with R* (2nd ed.). Springer. doi:10.1007/978-0-387-75967-8

Pouchard, L., Ivezic, N., & Schlenoff, C. (2000, March). Ontology engineering for distributed collaboration in manufacturing. In *Proceedings of the AIS2000 Conference* (pp. 1012-7). Academic Press.

Power, A. (2004). Sustainable communities and sustainable development: A review of the sustainable communities plan. The Sustainable Development Commission.

Press, G. (2019). *Predictions about automation and the future of work from Forrester.* https://www.forbes.com/sites/gilpress/2019/10/30/2020-predictions-about-automation-and-the-future-of-work-from-forrester/#33a2f1541318

Programme, U. N. (2012). *Global Environment Outlook: Environment for the future we want*. Author.

Raju, J. (2014). Knowledge and skills for the digital era academic library. *Journal of Academic Librarianship*, *40*(2), 163–170. doi:10.1016/j.acalib.2014.02.007

Reynolds, J. (2002). *A practical guide to CRM: building more profitable customer relationships*. CRC Press. doi:10.1201/9781482280784

Roade, M. (2018). *The future of finite element analysis*. https://www.midasoft.com/mechanical/learning-1/the-future-of-finite-element-analysis-meshfree

Robins, S. (1990). *Organization theory: Structure, design and applications*. Prentice Hall.

Robotic Industries Association. (2020). *Unimate: The first industrial robot*. https://www.robotics.org/joseph-engelberger/unimate.cfm

Robotics Business Review. (2019). *Cobot market will exceed $11B by 2030, ABI Research Says*. https://www.roboticsbusinessreview.com/research/cobot-market-will-exceed-11b-by-2030-abi-research-says/

Robotics Online Marketing Team. (2016). *How robots cut costs*. https://www.robotics.org/blog-article.cfm/How-Robots-Cut-Costs/11

Robson, L. S., Stephenson, C. M., Schulte, P. A., Amick, B. C., Irvin, E. L., Eggerth, D. E., Chan, S., Bielecky, A. R., Wang, A. M., Heidotting, T. L., Peters, R. H., Clarke, J. A., Cullen, K., Rotunda, C. J., & Grubb, P. L. (2011). A systematic review of the effectiveness of occupational health and safety training. *Scand J Work Environ Health, 38*(3), 193-208. https://www.ncbi.nlm.nih.gov/pubmed/22045515

Roderick, O., Marko, N., Sanchez, D., & Aryasomajula, A. (2016). Data Analysis and Machine Learning Effort in Healthcare. In Internet of Things and Data Analytics Handbook (pp. 295–328). doi:10.1002/9781119173601.ch18

Rodriguez, R. A., Martínez, A., Barcenas, E., & Rangel, A. J. (2018). Electronic Emulator Circuit to the Muscle Movement in Response to a Stimulus. *IEEE Latin America Transactions.*, *16*(4), 1030–1035. doi:10.1109/TLA.2018.8362133

Ruthven, I., & Chowdhury, G. G. (2015). *Cultural heritage information: access and management*. Facet Publishing.

Saenz de Ugarte, B., Artiba, A., & Pellerin, R. (2009). Manufacturing execution system–a literature review. *Production Planning and Control*, *20*(6), 525–539.

Safari, A., Salehzadeh, R., Panahi, R., & Abolghasemian, S. (2018). Multiple pathways linking environmental knowledge and awareness to employees' green behavior. Corporate Governance. *The International Journal of Business in Society*, *18*(1), 81–103.

Salah, O., Yusof, Z. M., & Mohamed, H. (2018). Factors affecting customer relationship management system adoption in small and medium enterprise in Palestine. *International Journal of Information System and Engineering*, *6*(2), 52–75. doi:10.24924/ijise/2018.11/v6.iss2/52.75

Samit, J. (2015). *Disrupt Yourself.* Flatiron Books.

Schiederig, T., Tietze, F., & Herstatt, C. (2012). Green innovation in technology and innovation management—An exploratory literature review. *R & D Management*, *42*(2), 180–192. doi:10.1111/j.1467-9310.2011.00672.x

Schmidt, G., & Druehl, C. (2008). *When Is a Disruptive Innovation Disruptive?* Retrieved from doi:10.1111/j.1540-5885.2008.00306.x

Science Daily. (2019). *Algorithm tells robots where nearby humans are headed.* https://www.sciencedaily.com/releases/2019/06/190612141314.htm

Secretaria Especial dos Direitos Humanos. (2006). *Portaria 142, de 16 de Novembro de 2006*. Author.

Seifert, C., Bailer, W., Orgel, T., Gantner, L., Kern, R., Ziak, H., Petit, A., Schlötterer, J., Zwicklbauer, S., & Granitzer, M. (2017). Ubiquitous Access to Digital Cultural Heritage. *Journal on Computing and Cultural Heritage*, *10*(1), 1–27. doi:10.1145/3012284

Shah, M. (2020). *Smart Factory Market is expected to be valued at US$ 276.12 Billion globally by end of 2027, Says CMI.* https://www.globenewswire.com/news-release/2020/05/11/2031220/0/en/Smart-Factory-Market-is-expected-to-be-valued-at-US-276-12-Billion-globally-by-end-of-2027-Says-CMI.html

Shah, K. (2016). Creation of cultural heritage inventories: Case of the historic city of Ahmadabad. *Journal of Cultural Heritage Management and Sustainable Development*, *6*(2), 166–194. doi:10.1108/JCHMSD-02-2016-0011

Shao, W., Feng, J., Liu, J., Yang, G., Yang, Z., & Wang, J. (2017). Research on the status of water conservation in the thermal power industry in China. *Energy Procedia*, *105*, 3068–3074. doi:10.1016/j.egypro.2017.03.639

Shaw, M. J., Park, S., & Raman, N. (1992). Intelligent Scheduling with Machine Learning Capabilities: The Induction of Scheduling Knowledge. *IIE Transactions*, *24*(2), 156–168. Advance online publication. doi:10.1080/07408179208964213

Shumway, R., & Stoffer, D. (2017). *Time Series Analysis and Its Applications* (4th ed.). Springer. doi:10.1007/978-3-319-52452-8

Sierra, O.A., & Pardo, N.A. (2010). Prevalencia de síntomas osteomusculares y factores asociados en los embaladores de leche de una pasteurizadora en Neumocón, Cundinamarca [en línea]. *Rev Col Enf, 5*(5).

Sin, L. Y. M., Tse, A. C. B., & Yim, F. H. K. (2005). CRM: Conceptualization and scale development. *European Journal of Marketing*, *39*(11/12), 1264–1290.

Smaczny, T. (2001). Is an alignment between business and information technology the appropriate paradigm to manage IT in today's organisations? *Management Decision*, *39*(10), 797–802. doi:10.1108/EUM0000000006521

Smith, T., & Reece, J. S. (1999, January). The relationship of strategy, fit, productivity, and business performance in a services setting. *Journal of Operations Management*, *17*(2), 145–161. doi:10.1016/S0272-6963(98)00037-0

Smuts, K., Mlungwana, N., & Wiltshire, N. (2016). SAHRIS: South Africa's integrated, web-based heritage management system. *Journal of Cultural Heritage Management and Sustainable Development*, *6*(2), 138–152. doi:10.1108/JCHMSD-01-2016-0002

Soga, S., Hiroshigo, Y., Dobashi, A., Okumura, M., & Kusuzaki, T. (1999). Product lifecycle management using radio frequency identification technology. *Emerging Technologies and Factory Automation. ETFA '99, 7th IEEE International Conference on, 2*, 18-21.

Srivastava, S. (2007). Green supply-chain management: A state-of-the-art literature review. *International Journal of Management Reviews*, *9*(1), 53–80. doi:10.1111/j.1468-2370.2007.00202.x

Stark, J. (2015). Product Lifecycle Management – Volume 1: 21st Century Paradigm for Product Realisation. Academic Press.

Stephenson, J. (2008). The Cultural Values Model: An integrated approach to values in landscapes. *Landscape and Urban Planning*, *84*(2), 127–139. doi:10.1016/j.landurbplan.2007.07.003

Stock, J. H., & Watson, M. W. (2015). *Introduction to Econometrics* (3rd ed.). Pearson.

Sustainable Development Goals (SDGs) 2015-2030. (2015). United Nations.

Suwelack, S. (2020). *What is AI-assisted engineering?* https://renumics.com/blog/what-is-ai-assisted-engineering/

Sweenor, D., Hillion, S., Rope, D., Kannabiran, D., Hill, T., & O'Connell, M. (2020). *ML Ops: Operationalizing Data Science A Four-step Approach to Realizing the Value of Data Science through ML Operations | TIBCO Software*. Retrieved from https://www.tibco.com/resources/ebook-online/ ml-ops-operationalizing- data-science-four-step-approach- realizing-value-data

Tan, F.B., & Gallupe, R.B. (2006). Aligning business and information systems thinking: a cognitive approach. *IEEE Transactions on Engineering Management, 53*(2), 223 – 237.

Tayalı, H. A., & Tolun, S. (2018). Dimension reduction in mean-variance portfolio optimization. *Expert Systems with Applications*, *92*, 161–169. doi:10.1016/j.eswa.2017.09.009

Tetlock, P., & Gardner, D. (2015). *Superforecasting: The Art and Science of Prediction*. Crown.

Thieullent, A., Colas, M., Buvat, J., Kvj, S., & Bisht, A. (2016). *Going Big: Why Companies Need to Focus on Operational Analytics*. Academic Press.

Tilley, J. (2017). *Automation, robotics, and the factory of the future.* https://www.mckinsey.com/business-functions/operations/our-insights/automation-robotics-and-the-factory-of-the-future

Tobe, F. (2015). *Innovation and growth driver for robotics industry.* https://spectrum.ieee.org/automaton/robotics/industrial-robots/collaborative-robots-innovation-growth-driver

Toke, L. K. (2010). Green Supply Chain Management; Critical Research and Practices. *International Conference on Industrial Engineering and Operations Management*. *Unilever Sustainable Living Plan: India Progress 2017.*

Tolun, S., & Tayalı, H. A. (2016). Data Mining for Multicriteria Single Facility Location Problems. In N. Celebi (Ed.), *Intelligent Techniques for Data Analysis* (pp. 147–170). doi:10.4018/978-1-5225-0075-9.ch007

Tsay, R. (2013). *An Introduction to Analysis of Financial Data with R.* Retrieved from https://www.worldcat.org/title/ an-introduction-to-analysis-of-financial-data- with-r/oclc/ 904835289&referer=brief_results

Tsay, R. (2010). *Analysis of Financial Time Series* (3rd ed.). Wiley. doi:10.1002/9780470644560

Tsay, R. (2014). *Multivariate Time Series Analysis: With R and Financial Applications*. Wiley.

Tu, Y. (1997). Production planning and control in a virtual one-of-a-kind production company. *Computers in Industry*, *34*(3), 271–283.

UNESCO Institute for Statistics. (2009). *UNESCO Framework for Cultural Statistics*. UNESCO Institute for Statistics.

UNESCO. (1972). Convention Concerning the Protection of the World Cultural and Natural Heritage. United Nations Educational Scientific and Cultural Organization (UNESCO).

UNESCO. (2003). *Convention for the safeguarding of the intangible cultural heritage*. UNESCO.

United Nations. (2015). The Sendai Framework for Disaster Risk Reduction 2015-2030. *The Third UN World Conference in Sendai*.

United Nations. (2016). *Sustainable Development Goals.* Available online: https://www.un.org/Sustainable development/sustainable-development-goals/

Uršic, M. (2011). The Diminished Importance of Cultural Sustainability in Spatial Planning: The Case of Slovenia. *Cult. Local Gov.*, *3*, 101–116. doi:10.18192/clg-cgl.v3i1.189

Vacher, M., Portet, F., Fleury, A., & Noury, N. (2011). Development of Audio Sensing Technology for Ambient Assisted Living: Applications and Challenges. *International Journal of E-Health and Medical Communications*, *2*(1), 35–54. doi:10.4018/jehmc.2011010103

Vaidya, S., Ambad, P., & Bhosle, S. (2018). Industry 4.0–a glimpse. *Procedia Manufacturing*, *20*, 233–238.

Vassilakaki, E., & Moniarou-Papaconstantinou, V. (2015). A Systematic Literature Review Informing Library and Information Professionals' Emerging Roles. *New Library World*, *116*(1/2), 37–66. doi:10.1108/NLW-05-2014-0060

Verschoor, A. H., & Reijnders, L. (1999). The use of life cycle methods by seven major companies. *Journal of Cleaner Production*, *7*, 375–382.

Waldmon, C. (2016). *Automation investment in U.S. manufacturing: An empirical picture*. https://static1.squarespace.com/static/58862301f7e0ab813935c244/t/58bf6e81440243643252b2b2/1488940682272/Rockwell_Automation_Investment_0.pdf

Wallace, G. (2011). Production, Processing and Applications. *Fundamentals of Aluminum Metallurgy Journal*, 70-82. https://www.sciencedirect.com/science/article/pii/B9781845696542500043

Weber, A. (2019). *Lights-out automation: Fact or fiction?* https://www.assemblymag.com/articles/94982-lights-out-automation-fact-or-fiction

West, D. (2015). *What happens if robots take the jobs? The impact of emerging technologies on employment and public policy.* https://www.brookings.edu/wp-content/uploads/2016/06/robotwork.pdf

Widjaya, I. (2016). *What are the costs of big data?* http://www.smbceo.com/2019/09/04/what-are-the-costs-of-big-data/

Wiiliams, E. (2011). *The Global Entrepreneur: How to Create Maximum Personal Wealth in the New Global Economic Era*. Iuniverse Books.

Wolchover, N. (2018). *Machine learning's 'amazing' ability to predict chaos.* https://www.quantamagazine.org/machine-learnings-amazing-ability-to-predict-chaos-20180418/

Wortmann, J. C., Muntslag, D. R., & Timmermans, P. J. (1997). Why customer driven manufacturing. In *Customer-driven Manufacturing* (pp. 33–44). Springer.

Zelinski, P. (2019). *10 takeaways on how artificial intelligence (AI) will influence CNC machining. Modern Machine Shop*. https://www.mmsonline.com/blog/post/10-takeaways-on-how-artificial-intelligence-ai-will-influence-cnc-machining

Zhao, L., & Huchzermeier, A. (2015). Operations-finance interface models: A literature review and framework. *European Journal of Operational Research*, *244*(3), 905–917. doi:10.1016/j.ejor.2015.02.015

About the Contributors

Ardavan Amini is an experience complex adaptive systems engineer with expertise in enterprise systems, knowledge-based engineering and innovation management. He have held number of senior roles in academia and industry including a title of Professor of enterprise systems and Non-Exec Director for business transformation and digital innovation, Chairman of SAP UK & Ireland User Group, and Advisor to local governments in smart cities and industry 4.0. He is currently the CEO of Essesystems, and Chairman of the Digital Centre for Midlands Think Thank. Prof Amini has over 40 international publications to date.

* * *

Giulia Bruno is Assistant Professor at the Department of Management and Production Engineering of Politecnico di Torino, and she holds a M.Sc. degree in Computer Engineering and Ph.D. in Computer and System Engineering from Politecnico di Torino. Her research activity is mainly focused on process modelling, IIoT data analysis and simulation of production systems.

Stephen Bushell Board Member, university visiting fellow and advisor to business and leaders in development of innovative ideas, over 35+ years' experience as an investor, director and business consultant. Having worked with governments and global entrepreneurial business at both Director and Ministerial level, I have driven creative thinking to inspire innovation, instrumental in leading and achieving the Queens Award for innovation and innovative global solutions plus opening doors to new collaborative relationships which has ultimately empowered sales and business growth coupled with Ei, dynamic solutions and marketplaces.

Paulo César do Nascimento Cunha is graduated in Biomedical Systems from the State University of Health Sciences of Alagoas (2009) and has a Master's. degree in Computational Modeling of Knowledge from the Federal University of Alagoas (2012). Currently, he is a professor at the Federal Institute of Alagoas, with

experience in electronics and emphasis on R&D Systems, acting on the following topics: Microcontroller, Operational Amplifier, and Biomedical Instrumentation.

Maryam Ebrahimi has working experience as an assistant professor at some universities and a senior researcher in several industries. She is currently an independent researcher in Germany. Her post-doctoral research was in the area of Information Systems Management funded by the Alexander von Humboldt Foundation, Germany. She has oriented her studies towards systems science in business management. Her interest is the use of modeling and simulation methodologies for the purpose of policymaking. A few of her publications are 'hybrid simulation approach for technological innovation policymaking in developing countries' and 'modeling and simulation techniques for improved business processes'.

Alberto Faveto is a PhD candidate in Management, Production and Design at Politecnico di Torino. In 2018 he graduated in management engineering, in this context he learned the basics of management and process control. He has worked as technology analyst in a consulting company, where he increased its management skills working on the integration of information flows from different companies in the financial sector. His research activity is mainly related in the modelling, simulation and analysis of complex systems in support to the decisional processes with a particular outlook on cost estimation and bid management.

José Irineu Ferreira Júnior has done a technical course in Electronics Technician from the Federal Institute of Alagoas, Brazil (2012-2016). He has a bachelor's degree in Electrical Systems from the Federal Institute of Alagoas, Brazil (2016-2019), and is currently a master`s degree candidate in informatics from the Federal University of Alagoas. Since 2017, He has also being a laboratory technician in Electronics of the Federal Institute of Alagoas, Brazil.

Franco Lombardi is Full Professor in Manufacturing Technologies and Systems at Politecnico di Torino. He contributed to various national and international research projects on High Speed Cutting, Product Quality, CAE/CAPP tools development, FMS modelling and evaluation, PLM systems. He is coauthor of several scientific papers on mentioned topics, involving the adoption of data driven methodologies since 1998. He is member of the Academic Senate of Politecnico di Torino.

Arshad Mahmood is a senior lecturer and program director at Birmingham City University with over 10 years of industrial experience in project and business management, helping companies in the midlands to transform and innovate. He was

a passionate and dedicated individual to developing the next generation of talents for industry needs in project management and business systems.

Tlou Maggie Masenya holds a PhD in Information Science from University of South Africa(UNISA) and has a remarkable academic record at all levels of education. She has five years of work experience in academia, in the field of Information Science and Information Technology. She is currently a Senior Lecturer in the Department of Accounting and Informatics at Durban University of Technology, teaching Information Systems (IS) related courses at both under- and post-graduate levels. She is currently supervising Masters and PhD students at both Durban University of Technology and University of Zululand in the field of Information Systems, Information Science and Technology. She published journals articles and book chapters, and presented papers in local and national conferences. She is currently a reviewer for South African Journal of Information Management(SAJIM), Mousaion-South African Journal of Information Studies, Library management, South African Journal of Library and Information science (SAJLIS) and IGI-global book chapters. Her research interests encompass the fields of ICT for development (ICT4D), Digitization, Digital curation and Preservation of electronic records and archives, Technology and Entrepreneurship (Technopreneurship), Digital Entrepreneurship, Innovation and Creativity, IT Project Management, Management of Information Systems, Information and Knowledge Management, Indigenous Knowledge System, Cloud computing, Mobile and Digital technologies and Social networks.

Craig Seidelson has over 20 years' experience in manufacturing of which 16 were spent in China building and managing factories. He has worked as a scientist, manager of R&D and chief engineer. He is currently a reviewer for the International Journal of Operations Research and Information Systems as well as a Professor of Operations and Supply Chain Management at the University of Indianapolis where he teaches logistics, operations, quality management and quantitative methods at the graduate and undergraduate levels. Prof. Seidelson also teaches Manufacturing in China based on his book Operations Management in China. Through his work as Vice President of the Board at the America China Society of Indiana, he helps to bring U.S. and Chinese businesses together. He frequently consults with industry, media as well as government officials on matters relating to manufacturing. His contributions in China were recognized with an honorary professorship at Changsha University of Science and Technology.

Nonkululeko Shibane was born May 18, 1994 in Free State, South Africa. Raised in Welkom she received a BEng degree (Electrical and Electronics Engineering) from University of Johannesburg in 2019. She workes as a software engineering

intern at Ario Genix. She is a motivated young female engineer that is strategic in nature and her greatest expertise revolve around the worlds of innovation. She enjoys solving complex problems and coming up with sustainable solutions to everyday engineering problems.

Vitor Gabriel Nunes Soares has done a technical course in Electronics Technician from the Federal Institute of Alagoas, Brazil (2019). He has student research experiences in the area of electrical engineering, with emphasis on industrial electronics, electronic systems, and control systems.

Alvaro Sobrinho has a B.Sc. degree in Systems Analysis from the CESMAC University Center (2010), a M.Sc. degree in Computational Modeling of Knowledge from the Federal University of Alagoas (2013), and a Ph.D. degree in Computer Science from the Federal University of Campina Grande (2016). He was a researcher and professor at the Federal Rural Univerisity of the Semi-Arid from 2017 to 2019. He is currently a researcher and professor at the Federal Rural University of Pernambuco. His research interests are formal methods, pervasive computing, and embedded medical systems.

Anusha Thakur has done B.Tech in "Electronics and Instrumentation Technology" from Tumkur, Karnataka, and Master's in Business Administration (MBA) in "International Business" from University of Petroleum & Energy Studies, (UPES) Dehradun. In addition to this, she has also completed a Post-Graduation certification in "Market Research and Data Analytics" from MICA, Ahmedabad. Anusha has also been writing few papers and chapters for the journals/books in India and abroad. One of her published works includes chapter on "Market for Plant-Based Meat Alternatives" for the book "Environmental, Health, and Business Opportunities in the New Meat Alternatives Market" which has won accolades across the world. The book was considered #1 in the WORLD in the category of Vegetarian Writing. Further, the book was also announced as the national winner for Australia in the Vegetarian Writing Category. Further, she has a work experience of approximately 4 years in the Market Research industry. Her work primarily focuses, on the secondary research, market analysis, market sizing, interpretation, forecasting, and report writing.

Emiliano Traini is a PhD candidate in "Management, Production and Design" doctoral course at Politecnico di Torino, with MSc in Mathematical Engineering. His research interests are related to the applications of AI tools and methodologies to the manufacturing field.

Index

F

G

H

I

K

L

M

O

P

R

S

T

W