Eurasian Intermodal Supply Chains

A Dynamic Systems Approach

Olli-Pekka Hilmola and Yulia Panova

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Trade and economic crises are everywhere in the world right now, however, new seeds of growth are already sown and growing in Eurasia.

CONTENTS

PREFACE

The world is simultaneously a "big place" and a "small one". Could the reader name the largest cities in Asia? Or in China? Or what about India and Russia? It is a demanding task, which illustrates the significant potential of these new markets for future economic growth. Europe and North America will, of course, remain as essential players in the global economy; however, Asia and the Middle East will take their share. We might be on the very long cycle of getting where we were 2000 years ago. Back then, China and India had significant shares of the global GDP. However, they were mostly local economies. Much of the world was also entirely local then. These countries will have the same success story in the coming decades in the context of globalization.

What makes the world then, a "small one"? Even today, we may reach these emerging markets rather swiftly with air transport. With container shipping, products are transported rather cheaply (but take a long time). In between these, there exist hinterland transports, and the use of different transportation modes to form a complete transportation service. This will make the world seem even smaller, and people will start to see that Eurasian markets are somewhat near to each other.

This book concerns simulation as much as it concerns Eurasian economies, supply chains and intermodality. It is the most valuable asset with which the researcher can both ask the right questions and also provide some answers. Through their modelling, from time to time, using computer-based simulation, the so-called "what if" situations can be studied. This will lead to sustainable economic growth in the future.

As authors, our backgrounds are diverse and different. Yulia has taken almost all possible levels of education in Russia and lived her childhood and early adult life in the Asian part of Russia. However, for doctoral studies, she was on the European side of Russia, in St. Petersburg. After completing another doctoral dissertation on a similar topic in Finland, she eventually moved from Russia to serve at a Chinese university. It makes her perspective a little bit different from that of a pure European, Asian or North American. Olli-Pekka, in turn, was educated entirely in Finland.

Afterwards, he served for years in the universities of this country, but also worked through visiting positions in foreign universities in countries like Sweden, Estonia and China. Again, a different background, which is mostly North European. It has been a long journey for us to learn from each other. We see what the other person means and understand the starting point of the other on pending issues such as intermodal transports or related solutions to different problems that arise. This book is one trial in this process. It is joint work in its best possible manner, as we have both contributed nearly the same amount to this endeavour.

We both acknowledge the critical role of knowledge about Eurasian economies and supply chains for professionals and scholars. Therefore, the book provides a journey from an everyday theory of logistics and supply chain management (SCM) application in intermodal transportation practices to some more advanced topics, such as building your models in simulation-based decision support systems.

Chapter 1 introduces you to the challenging growth of Eurasian supply chains. It lets you know what you need to be aware of regarding their dynamics once you start researching in this direction. From this point, the chapter details potential constraints of the critical Eurasian project development, known as the One Belt and One Road (OBOR) programme. In particular, currencies are in the spotlight. Whether to blame the strengthening Chinese currency and the weakening of others in emerging economies for hindering Eurasian supply chain development in the future is a pertinent question. The end of the chapter provides the answer, as well as warns you about other uncertainties in the Belt and Road Initiative (BRI). This is not to be utterly sceptical about all of the initiatives, but instead for the reader to be a well-informed optimist once this chapter has been read.

Chapter 2 takes a look at the essential elements you need to consider when planning your supply chain in the Eurasian space. Along the way, this chapter covers the essentials of what provides the analysis and the organization of intermodal transport systems, first and foremost, logistics and SCM foundations. You will understand that the development of this scientific framework has led to a new view on the possibilities of a combination of different modes of transport. In turn, it has resulted in the evolution of a conceptual apparatus of intermodal transport. To understand a rather complicated structure of intermodal systems formed by the present time, they have been decomposed into critical elements. They include 1) transmodal and intermodal technologies of transportation; 2) critical nodal points of intermodal traffic, such as dry ports; and 3) international transport corridors.

Chapter 3 discusses transport infrastructure mega-projects in the Eurasian space in terms of logistics and financial performance. You will get to know about the dynamics of cargo flows on recently introduced routes and learn key performance indicators of transport infrastructure operations. With just fundamental indicators, such as inventory costs and alternative costs, you can more thoughtfully compare different delivery options for a particular type of cargo. This chapter also covers the questions of risk assessment and capital budgeting. It is necessary to identify the risks of overspending in advance and take them into account in the designing phase of the investment project. The provided indicators and methods for assessing the effectiveness of the investments in the construction project seem to be reasonably and widely practised in countries where political and economic risks are perceived as high. The examples of their applications are presented at the end of the chapter. This will help take advantage of the proposed techniques.

Chapter 4 teaches you everything you need to know about the systems approach, its aspects and principles. This concept is contrasted to the classical (inductive) approach, which has its own applications. Information in this chapter is listed along with models and equations. It will make the use of these approaches in the development of your models as simple as possible. By going through the principal elements and stages of systems analysis, you will understand not only how simple systems work, but also chaotic systems, which are present everywhere. This chapter also explores the decision-making process in the dynamic world. In this type of world, things change over time. Therefore, a decision being rational today might be considered a so-called "truth of the past" by the end of the year. Finally, you will learn, for example, how pricing scenarios require an understanding of customer preferences to make the right final decision.

Chapter 5 continues to show you how to build system dynamics models, taking into account the main characteristics of dynamic systems and classifications of dynamic forecasting modelling. It also gives you a complete view of when it is best to use the system dynamics approach. At the same time, it gives an insight into how to apply other paradigms of simulation modelling, such as discrete-event, agent-based or even multi-approach modelling. By the end of the chapter, you will have a description of mixed models with the hybrid types of processes (discrete and continuous). This will immerse you further into the application of knowledge from the earlier chapters, and their enhancement with tools for optimization and sensitivity analysis of built models.

Chapter 6 covers vital information on simulation experiments and case studies that will help you to build models by going through detailed steps, grouped into several phases. Particular attention has been paid to the design of a "test stand" for the experiment and the collection of statistics about the model of the intermodal terminal. All intermediate steps are supplied with pictures to make explicit your model development. This chapter also uses other examples of simulation modelling applications, such as the economic assessment of investments in the container terminal with the consideration of new service provision and their diffusion according to the F. Bass Theory. At the end of the chapter, network optimization experiments for defining the best locations of the bonded warehouses, supporting cross-border e-commerce development, have been provided. Afterwards, models of inventory management and case studies with key performance indicators for the human resources and internal control processes of the balanced scorecard (BSC) were reviewed.

Chapter 7 summarizes the main ideas from previous chapters and covers some critical peculiarities of a building logistics infrastructure. Specifically, these are emerging Eurasian supply chains that should not be left out as unnoticed during decision-making. On the whole, in simulation-based decision support systems, we have tried to keep models simple and less complex, while simultaneously trying to build a link to the further competitiveness of manufacturing dominated intermodal supply chains.

Last but not least, we would like to state our warm and sincere thanks for proof readers of this book, namely: Sue, Oskari, Robert and Sean. Without your kind help we would never have achieved this level of quality and precision.

Yulia Panova,
Luoyang, China

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Chapter One

Introduction

Olli-Pekka Hilmola

1.1. Eurasian supply chain growth challenge

In manufacturing and trade, China is nowadays the largest actor in the world. Its progression in this regard has been consistent, as Figure 1-1 shows. In the year 2003, it was 35% smaller as an actor in trade than Germany but overtook it during the financial crisis year 2009. After that, German trade growth was mostly sideways with some small growth, while China progressed to catch the USA. China also overtook Japan to become the second-largest economy in the world only behind the United States, and its large population makes for an enormous target market. Investments from foreign companies were the most significant driver of China's growth in the decade from 2000 to 2010 (Hill and Hunt, 2018). Already in the year 2013, China was 5% higher in trade than the USA. This leadership role has remained. However, in 2016, the USA regained the most substantial trader nation status. Meanwhile, this gain was short-lived as China took the leading position back in 2017. In the following year, 2018, this situation persisted and China was 5.4% larger in overall trade as compared to the USA.

The change happened during the years 2003-2018. There has been an enormous restructuring of the economy (for a long-term review, please see Fenby, 2012). China was 58.3% below the USA in trade at the start of this period and now is somewhat above it. In the last observation year, it was a 67.2% larger trader as compared to Germany. Therefore, what China does in trade and logistics is no longer a marginal issue. Its actions are more important than previously thought, and still, its own branded goods are only moderately developed. It means that this leadership role could continue and develop further, despite many negative factors. These were mentioned in the press to hinder this development (like the ageing population, the amount of debt and currency valuation).

On the contrary, other factors will support the country's growth. Examples would be an expansion of the middle- and upper-income categories of people (about 190 million will be in these during 2020; Hill and Hunt, 2018). They have discretionary spending, stimulating an optimistic consumption forecast for foreign companies to engage with Chinese consumers. As a result, the motivation for many foreign companies to enter China is beyond what it has been for decades. Notably, low-cost production, which became negligible compared to other developing countries due to the triple growth of the Chinese economy from 2000 to 2010 (Panova and Hilletofth, 2017; Hill and Hunt, 2018).

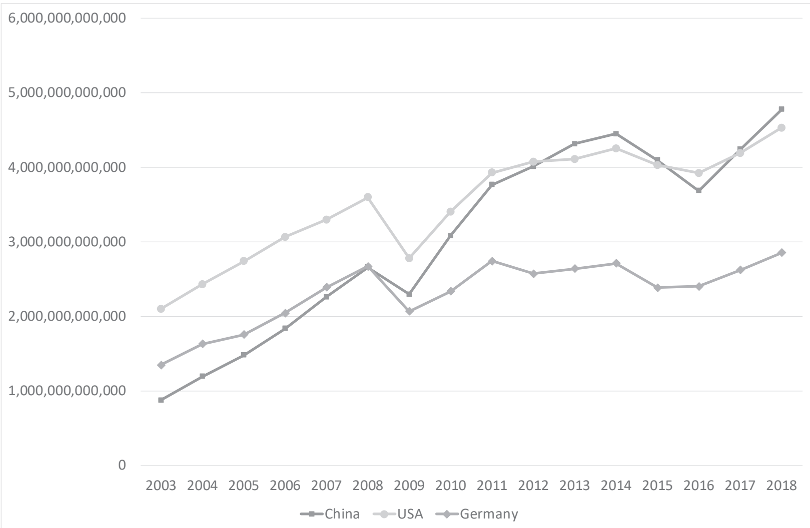

Figure 1-1. Total trade (import and export, in USD) of China, Germany, and the USA with all of the countries in the world (data source in each case, own country) during the years 2003-2018. Source (data): Comtrade (2019)

China's position as the largest trading nation could have happened in real life before the year 2013. Its overall trade volume could be much more significant today than assumed based on Chinese statistics. Partly, it is due to e-commerce. In recent years, most people in the developed economies have become acquainted with Chinese e-commerce – either directly or indirectly. Mainly, seeing family members or neighbours ordering cheap retail items delivered directly or close to their home (e.g., a postal office). However, most of these items are such that they are neither customs registered in the receiving country, nor in China. The reason is the low price of the item, as in most cases it is lower than a required customs registration limit for import tariffs.

Even if these parcels seem to look like the innocent and beneficial part of globalization, their impact on trade volumes cannot be underestimated. Hongfei (2017) argues that the total amount of China's cross-border e-commerce was in 2016 around 6.66 trillion yuan, and most of this trade was exports (83.1% in the year 2015). Cross-border e-commerce is also growing significantly all the time. It could only be guessed, to what extent this 6.66 trillion yuan (around 1 trillion USD with 2016 currency rates) was recorded in official trade statistics. Some part of e-commerce is business-to-business, where this is a must, and also in more expensive consumer orders. However, if 50% was not registered, then there was around 13.6% of non-registered trade, benefitting China (as compared to 2016 trade data).

Apart from the e-commerce phenomenon, additional facts were found based on a more in-depth and further examination of the trade statistics of Comtrade (2019). That is, German imports from China were on average 50% higher in the period 2008-2017 than the figures China is reporting as Chinese exports to Germany. The situation is similar in USA imports, which from China are reported on average to be nearly 30% higher in comparison to reported Chinese exports to the USA (in the same period, 2008-2017). Similar findings were reported in the study of Eriksson et al. (2013), and Shaar & Baharumshah (2016). Also, Day (2015) found differences, but emphasized that the kinds of differences existing depend on the country/region. In the case of Asian countries, it is typical for their exports to China to be much lower as compared to the claims of the Chinese import statistics. A similar difference in Chinese imports is present in USA exports (Shaar & Baharumshah, 2016).

Understandably, countries' trade statistics do not match each other. The imports of country A from country B do not equal the exports of country B to country A. This is due to delays in logistics and the delivery process as then imports could fall into the statistics of another year. Occasionally, transportation costs differ in the way they are included in import prices. Possible customs tariffs along the way (a third party used in the export process, like Hong Kong or Singapore) are yet another differing factor in import prices (as other delivery related costs). Finally, currencies change significantly during the delivery process. However, all in all, these possible causes of disparity between trade numbers should and could not be 30-50% (in reality, they ought to be well below 10%).

Differences could be explained by trading practices, where manufactured goods on the journey from China to the west change ownership once or several times during the trip (e.g., in Hong Kong; Shaar & Baharumshah, 2016). These changes take place most often due to taxation reasons (value-added tax, and profit tax of corporations). Prices and imported codes may change during the journey, too (Shaar & Baharumshah, 2016). However, this last mentioned and fraudulent activity is not the main reason (to enable lower customs tariffs in the country of destination). As a conclusion, it could be stated that China is currently, for sure, the largest trading nation in the world. There is a high possibility that it is much larger than the second position country, the USA.

China's manufactured products also probably have a higher value (price) as intermediaries can charge on the way to the final destination. Day (2015) emphasized that this depends on currency directions (USD vs. yuan). Notably, that is whether Hong Kong re-export is used to increase prices or if higher prices are charged to mainland companies in the case of a strengthening yuan. The current overall trade gap of the USA could be more extensive than what it is argued to be, possibly over 20% higher. Therefore, China's role in the real-world supply chains is far more significant than "official" statistics tell. Even if the final product is argued to be manufactured in the west, it does not necessarily mean that most of its content is from that region. A supplier network under cost pressure could, increasingly, use offshoring and low-cost production in sub-assemblies. At the same time, the supplier may order sub-assemblies through "middlemen" located, e.g., in Hong Kong or Singapore, which in turn use Chinese workshops.

The role of Hong Kong, and parts of Singapore, cannot be under-emphasized in the future development of Eurasian supply chains. Based on official Chinese statistics, the average trade with Hong Kong was 294.5 bn. USD per annum during the years 2008-2017. This trade was mostly represented by imports from China to Hong Kong. If compared to the volume of larger trading countries of China, it is in the neighbourhood of Japanese trade. So, this highlights the importance of Hong Kong in the future development of any supply chains in China. Specifically, one city area of slightly above seven million inhabitants has the same relevance as well-developed and industrialized Japan.

In official customs statistics, half of the massive Hong Kong and China trade is re-exported further. Hong Kong is not the only trading hub related to China, but it has traditionally been the source of foreign direct investments to Chinese manufacturing (Naubahar & Tseng, 2011). Singapore had an average trade of 67.5 billion USD with China in the same period. Re-export statistics are not available from Singapore (also concluded in Day, 2015). Singaporean trade during the period 2008-2017 was at the level of Chinese trade with India or Russia. Singapore has a population somewhat above five million. Purely due to business practice reasons, changes in the investment trend could be expected. Notably, future investments in infrastructure are made so that these two trading hubs (Hong Kong and Singapore) will be supported further. In other words, the prosperity and success of these flows are somehow assured. This not only means investments in sea ports and maritime supply chains, but also to connect these places much better with railways, air, and other hinterland modes. Based on the recent empirical study of Lee et al. (2018), Hong Kong and Singapore still have a competitive edge in the sea port-centric logistics as compared to Busan or Shanghai. For further trade-development analysis, between 2008 and 2018, additionally, some of the most critical Asian as well as North European countries were selected. Among these countries, average trade growth in this period with China was above 60%, and many countries showed a growth level higher than this (Figures 1-2 and 1-3).

Indian trade grew by 115.9%, while Pakistani trade, in turn, recorded the highest growth, 202.0%. Trade between the USA and China increased by 62.2%. Meanwhile, German trade was able to grow by 73.3%. Mainly growing over the last years, Russian and Chinese trade showed even higher growth than these two at 93.6%. From the smaller trading countries analyzed in Figure 1-3, Poland, Latvia, Estonia, and Belarus need to be mentioned as they showed growth within the range of 72-94.7%.

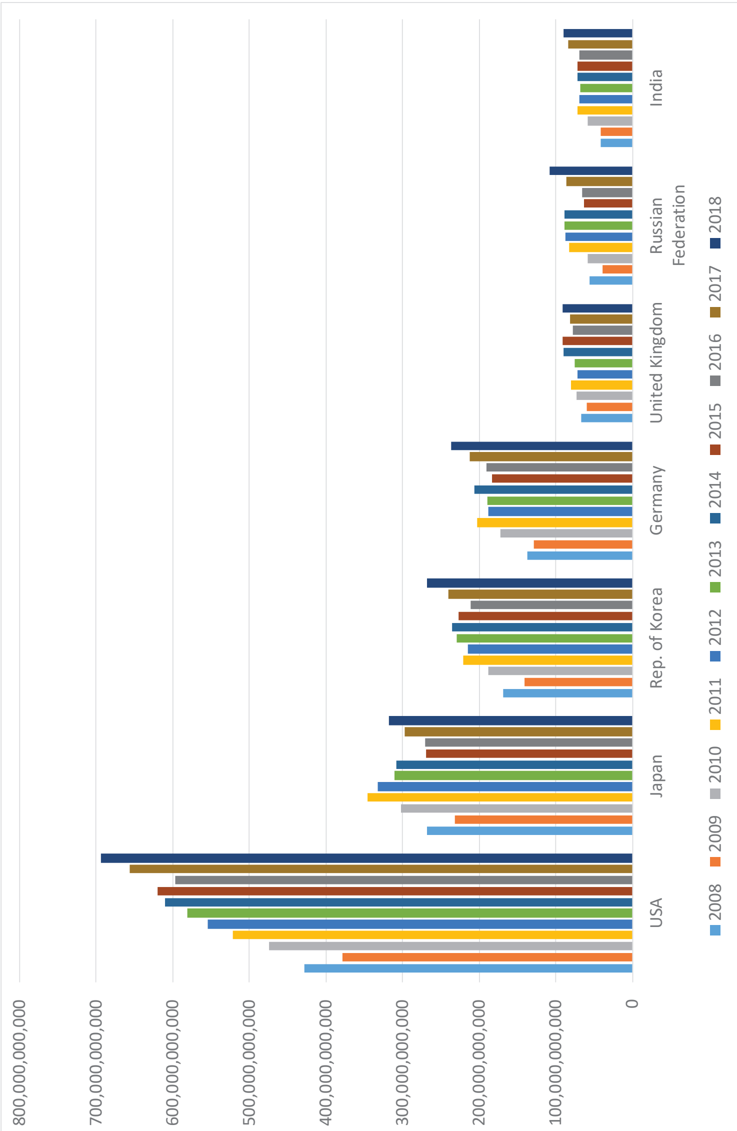

Figure 1-2. Chinese trade (import and export) with the seven largest countries in the group selected (in USD; data source each country in the figure). Source data: Comtrade (2019)

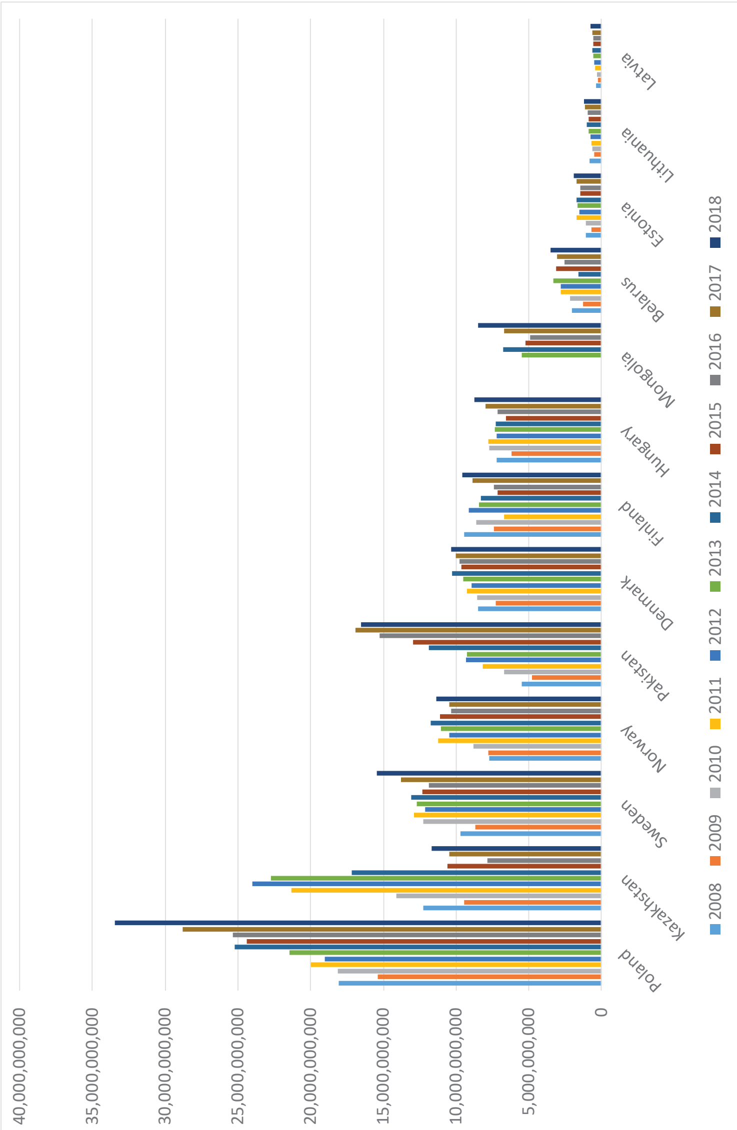

Figure 1-3. Chinese trade (import and export) with the remaining thirteen countries in the group (in USD; data source each country in the figure). Source data: Comtrade (2019)

The only exceptions to overall Chinese trade growth were Kazakhstan and Finland. Both have experienced a no-growth period in trade (actually Kazakh trade with China showed a decline of 4.5%). It should be emphasized that volumes of trade are of course in the hands of very few. The USA had trade with China worth 693.9 billion USD in 2018, and this was a 15.7% lower amount than the following three countries combined (Japan, Republic of Korea and Germany). Figures 1-2 and 1-3 do not contain European Union countries' total trade with China. In some years this has been even higher than USA trade (e.g. 2008-2011; e.g., Hilmola, 2014). Yet in the most recent years (2015-2017), the USA has retaken the lead. However, in the last foreign trade data year, the EU-28's trade with China is again a little bit larger. These changes can mostly be explained by the strengthening of the dollar (positive for USA-China trade) and the growing USA economy (again positive for USA-China trade), but are also due to trade disputes (harmful for USA-China trade).

In the next Figures 1-4 and 1-5, Chinese trade is observed from the angle of counters that are considered to be the most important export markets of the country. Both Japan and the Republic of Korea exported more in 2017-2018 than the USA. The Korean performance has been consistently reliable and outperforming the USA in the entire observation period. Meanwhile, a Japanese export peak was experienced in 2011 (this was probably due to a dispute and anti-Japanese demonstrations in China during 2012). Moreover, in some years its exports have been lower than those of the USA (2015-2016). However, there was an evident recovery in Japanese exports in the last observation years. In 2018, the Republic of Korea was the largest exporter to China in the entire world.

It should be remembered that from 2008 through to 2018 export growth to China has been active, and in the countries of Figures 1-4 and 1-5, it has been on average somewhat above 140%. The highest export growth could be found from small countries such as three Baltic States (Estonia, Latvia, and Lithuania). Their growth has been from somewhat below 200% to nearly 700% in the period. Other high growth countries (having around 100% improvement) have been Germany, United Kingdom, Russia, Pakistan, Poland, Hungary and Sweden. USA based Chinese exports grew by 68.1%. In this light, it is understandable why European countries are part of the Asian Infrastructure Investment Bank. At the same time, it is clear why the Belt and Road Initiative (BRI) includes Central and Eastern Europe as one of its infrastructure spending areas. Also, the role of Pakistan and India should not be underestimated in the BRI. However, challenges remain as most of the countries in Figures 1-4 and 1-5 are suffering from trade deficits

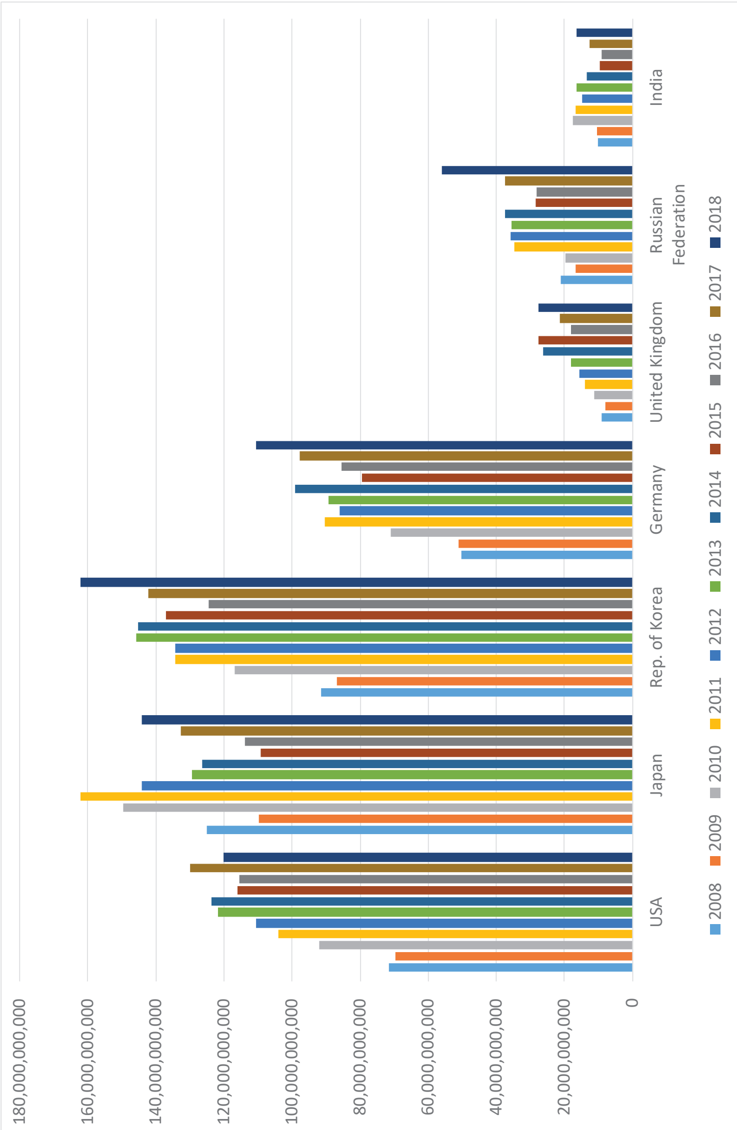

Figure 1-4. Exports to China from a selected group of countries, concerning the seven largest (in USD; data source each country in the figure). Source data: Comtrade (2019)

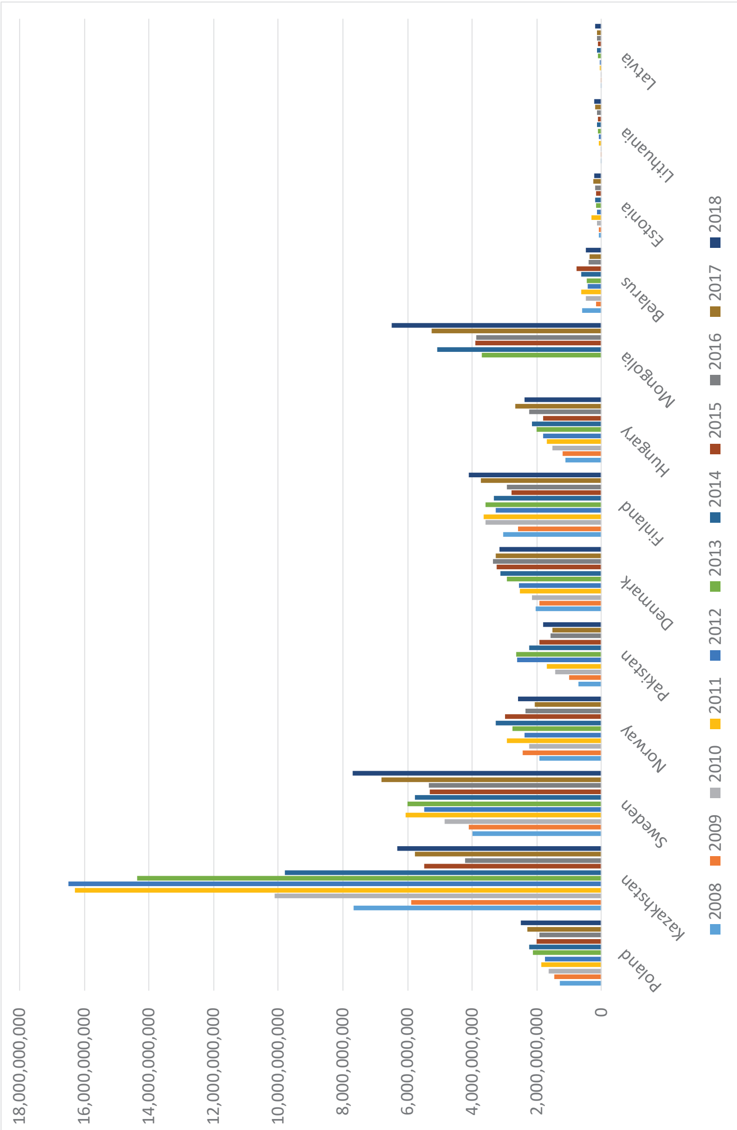

Figure 1-5. Exports to China from a selected group of countries, concerning the remaining thirteen countries (in USD; data source each country in the figure). Source data: Comtrade (2019)

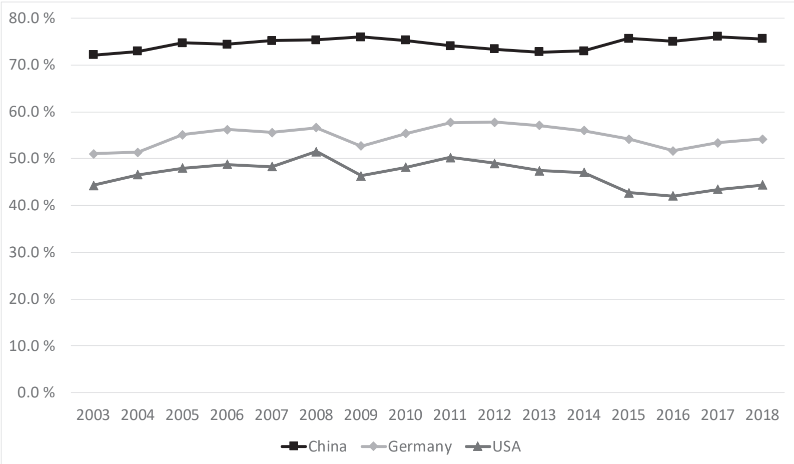

Figure 1-6. Share of intermediates from overall imports in China, Germany and the USA during the years 2003-2018. Source data: Comtrade (2019)

(especially European countries, like Poland, where deficits are abnormally high; see Choroś-Mrozowska, 2019), and in 2018 only South Korea, Mongolia, Russia and Kazakhstan showed a surplus within Chinese trade.

To further understand the practices of Chinese world trade, it is vital to examine its different imports compared to two other big trading nations. These are the USA and Germany, see Figure 1-6. For this purpose, China was in Comtrade (2019), examined through the BEC classification (Broad Economic Categories). From there, we took the sum of all sub-classes considered to belong to "intermediate" products (based on the guidance of the United Nations, 2018). It is interesting to note that still, China is mostly importing raw materials and semi-finished products ("intermediates"), while Germany and the USA have a larger share of other products such as "consumption" and "capital" goods.

Meanwhile, the United States is relatively abundant in capital compared to other nations. Therefore, according to the Heckscher-Ohlin theory, the country should be an exporter of capital-intensive goods. At the same time, the country has to be an importer of labour-intensive goods (Hill and Hult, 2018). However, in practice, a paradox may be identified, and it was found for the first time by Wassily Leontief (winner of the Nobel Prize in economics in 1973). This result (US exports were less capital-intensive than

US imports) was at variance with the predictions of the theory, and it has become known as the Leontief paradox. No one is quite sure why the Leontief paradox is present. Hill and Hult (2018) state that one possible explanation is that the United States has a unique advantage in producing and introducing new products or goods made with innovative technologies. Such products may be less capital-intensive than products whose technology has had time to mature and become suitable for mass production.

Chinese imports of consumer goods are still very low, and in proportional terms, the USA and Germany import four to five times more. In trade statistics, most intermediate goods imported to China are within the classes of “industrial supplies not elsewhere specified” (where the sub-class of “processed” is more extensive than that of “primary”) as well as “fuels and lubricants” (raw material sourcing strategy is described in detail within Moyo, 2012). This only illustrates further that China is well-positioned in global supply chains, and it has much value-adding activity in its own hands. It is not shown here, but Chinese exports of “intermediate” products are only somewhat above 40% (in the USA and Germany, this share is higher, but not significantly). Therefore, export items are mostly “capital” and “consumption” goods with higher prices – nowadays they both have significant size, and China exports both in proportionally high amounts. In comparison within the USA and Germany, export activity is more about “capital” goods rather than the consumption sector.

The role of intermediate goods in imports is not exceptional in China. A similar structure is present in other Asian countries such as South Korea, Vietnam and Japan. Figure 1-7 illustrates this further. It is interesting to note that South Korea is basically at the same proportional level with China, if the last three years of the observation period are not taken into account. However, its economy has a much higher GDP per capita. It could also be assumed that the consumer economy in South Korea is much more developed. Vietnam has followed the Chinese economic model in recent years, and has considerably increased its share of intermediates in imports; an indicator that this country is increasingly having a foothold in global supply chains. It also has the same low level of intermediates in exports. Japan is, of course, the most developed in terms of GDP among these countries, but still, its intermediate share of imports is higher than similar peers, the USA and Germany. These characteristics are just one additional learning point in Eurasian supply chains. Notably, much country-level manufacturing is present, and therefore imports are mostly raw materials or semi-finished items. It is different from the old west. Based on this, it could be stated that for exporters, the Asian consumer market is challenging and stressful.

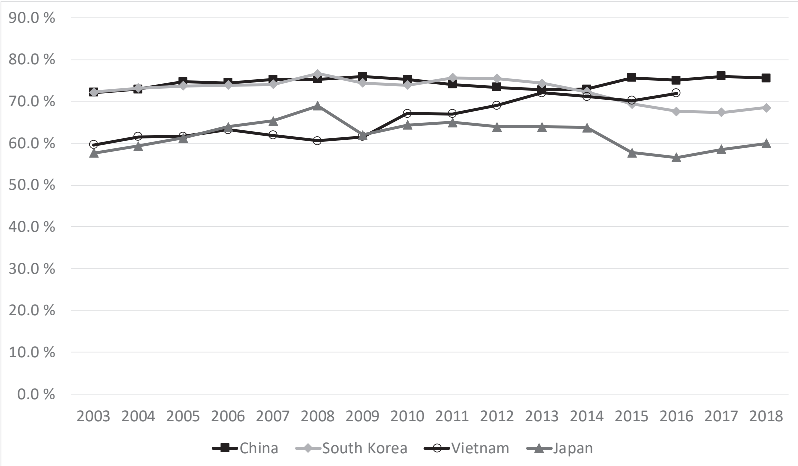

Figure 1-7. The share of intermediates from overall imports in China, South Korea, Vietnam and Japan during the years 2003-2018 (the years 2017-2018 have data missing from Vietnam). Source data: Comtrade (2019)

In many respects, China is similar to the USA. For example, the geographical size of the country is quite similar to that of the USA (the latter is only a little bit larger). The route to its prosperity is also reminiscent; particularly, with the USA's world dominance in manufacturing during the 20th century. In transportation and logistics, China is repeating the same dependency process on road transport, which happened earlier in the USA and Europe. In the late 1970s, the primary Chinese transportation mode domestically was the railway (Figure 1-8) as its share was 53.8%. It was, of course, typical for a centrally planned as well as closed economy, to tie itself around the railway. However, during the decades of economic opening and progress, waterways and primarily road transports prospered. At the same time, the railways were almost annually losing their market share.

Based on official statistics, the railway modal share from freight transports was 13.7% in 2017. This corresponds to around a 40%-point drop (absolute) in approximately four decades. In the same period, road transports grew from 3.5% to 33.8% (a nearly ten-times-higher modal share!). On the positive side during this period, the waterway modal share also increased, but rather conservatively from 38.3% to 50.0%. A quite significant part of this growth in waterways was due to coastal (ocean) transports. In Figure 8, changes are illustrated with the measure of ton-km, and this favours railways and other long-distance transportation modes.

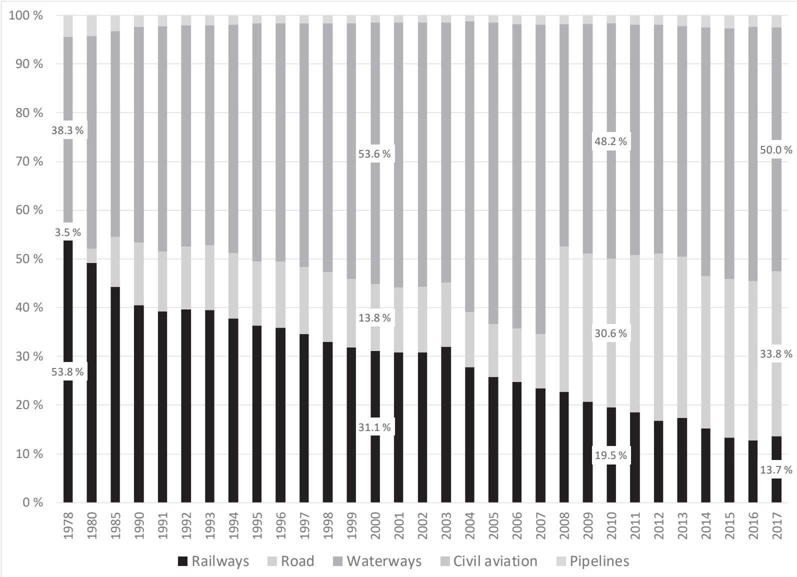

Figure 1-8. Freight transportation modes in China during the years 1978-2017 (in ton-km). Source (data): National Bureau of Statistics of China (2018)

If tons were used as a measure, then road transport dominance would be immense. In 2017, its modal share in tons was 76.7% (followed by 13.9% waterways, and 7.7% railways). Why then were railway transports unable to respond to the opening and increasingly international economy of China? Most of the growth took place by the coast and in coastal areas, and the hinterland had a secondary role. The volume of the largest Chinese container sea port is the illustration from this container-based system development. Also, the largest in the world in 2016 (United Nations, 2001 & 2017), Shanghai, during the year 2000, handled 5.6 m TEU containers. As of the year 2016, this had increased to 37.1 m TEU (+31.5 m TEU or +562.5%).

Also, sea transports for exports were dominant. At the same time, containers prospered significantly. It could be said that Chinese logistics innovation was an adaptation and use of containers and intermodal transports in supply chains. Similarly, the just-in-time system was first employed at a large scale by the Japanese (however, both of these have origins in the USA). In the coastal centric system, it is much preferable for transport tasks that are flexible and prompt at short distance to use road transport, instead of railways. It is also typically cost-competitive in short-to-medium-distance transport tasks. Road transportation capacity (infrastructure investments, but also actor entry to a business) is also much easier to expand as compared to railways.

In China, the strength of the railway system relies on passenger transport. A significant amount of new investment has been made in the railway network, rolling stock and serving infrastructure (e.g., stations). This is primarily the situation with the high-speed railway as approximately 40% of the overall passenger volume (whether it is in the number of passengers or passenger-km) uses these modern and state-of-the-art trains. A similar stronghold is in civil aviation, where passengers using air transports have increased tremendously. In 2017, the modal share of railways in passenger-km was 41%, followed by 30% for road transports and 29% for air transports. In future, it is an open question, how much additional freight volume the railway system can handle in China as the focus has been on passengers. At least, based on the plan up to 2030, the high-speed railway network continues to expand, and this will affect the central and western parts of China (Xu et al., 2018).

The significant downside of using road transport on a large scale, within domestic freight transports, is the building up of structural dependence on foreign oil imports. Of course, China has its own oil reserves and oil production. However, in the two last decades, these have not been able to grow along with consumption. Domestic production has slowly started to decline as, after the peak production of 2015, volumes have declined by 10.7% in two years. Interestingly, in 2014, China had a higher deficit than the USA in the oil trade (if estimated based on BP's 2018 data). The deficit only enlarged after that, and consumption in the domestic market, in turn, has increased. Consumption growth could also be noticed in the imports of natural gas. As a result, China is nowadays importing more natural gas than Japan, a country which was earlier the world's leading importer. Aizhu & Meng (2019) report that China has plans to increase the domestic drilling and production of gas to suppress import growth. Based on BP's (2018) data growth trajectory of gas consumption in China, it was very steep in the last decade. Moreover, both domestic production and imports are needed in increasing amounts in the future.

Even if it is a widely discussed issue that China has trade surpluses, these could continue to shrink. Especially if the oil-hungry economy does not consume less energy. One way to achieve this is to produce higher value-added products, and leave lower and higher polluting bulk manufacturing to others. The situation is pretty much the same elsewhere in the Asia-Pacific, especially in economies which are repeating the export-based growth model of China.

1.2. Currencies in the spotlight in emerging economies

The world turned to a fiat currency system at the end of the Bretton Woods system (effective during the years 1944-1971). Since late 1971, all world currencies have just been paper and a tremendous governmental promise as well as the guarantee from sound money and economic stability. Therefore, it has not been that surprising to identify, from time to time, crisis periods emerging in this system. Specifically, when some weaker economies face massive devaluation and a country's ability to serve foreign financial engagements significantly erodes. Economics books typically analyze the Asian and Russian currency crisis. From 1997-1998, it led to severe trouble in world trade, and finance. Banks, as well as central banks, were eventually forced to save the system (by mergers and bailouts). The same situation took place again in the 2008-2009 financial crisis. The US dollar was also depreciating significantly. Notably, in early 2000 one euro was worth somewhat above 0.8 USD, while in late 2008 one euro appreciated up to nearly 1.6 USD.

However, fiat currencies have been most harmful for emerging countries in trouble. Everyone knows the story of Zimbabwe's dollar from the previous decade, and most recently the similar rapid depreciation and hyperinflation experience of Venezuela. In the situation of hyperinflation, economies are barely able to benefit from depreciating currencies in terms of export growth opportunities. The reason is that no one trusts the currency and the economy more or less slows down. However, gradually over time, managed devaluations have been the secret weapon of many countries. Specifically, they were even used previously in currently wealthy EU countries in the pre-euro era to claw back manufacturing competitiveness.

There are many examples of successful yet currency-depreciating emerging economies. Take China as one. In the early 1980s one USD was worth around 1.5 Chinese yuan. However, it was depreciated so that, in the following decade time period, one USD was just below nine yuan (8.73 yuan per USD was the lowest value). It was not a great surprise to see that manufacturing-based export prospered significantly in the 1990s as the weak yuan policy was supported by the USA and China together until July 2005. After that, the world experienced a slightly appreciating yuan, but only modestly. There was even the situation, where the yuan was approved to be part of the world's elite currencies (from October 2016 onwards). Now it is one of the five currencies, the others being the pound, dollar, euro, and yen, forming daily Special Drawing Rights (SDR) of the International Monetary Fund (IMF). During 2018 the Chinese yuan was depreciating again (appreciation ended in 2014), and it was trading in the area of 6.8 yuan to one USD in the late summer of 2018. This means that from the lowest value of 1994 (8.73) the yuan has only appreciated by some 20%. The yuan is still weak in the long-term perspective and gives a competitive advantage for manufacturing export.

There are numerous other Asian countries which have built their economic success on a weak currency policy. For example, after the Second World War, Japan was tied to the USD with 360 yen. The weak currency continued until the Plaza Accord of September 1985 (agreement between the USA and different leading industrialized countries to weaken the USD in the forthcoming years). During the mid-1980s one USD was worth around 250 yen, but a decade later, it was approaching the level of 100 yen. It is not surprising to see that Japanese GDP growth also disappeared during this change, and the economy has been in trouble for decades. However, still, the yen has kept its strength against the USD.

A similar story could be told about South Korea, a country that was in the eye of the currency crisis in 1997-1998. Before the crisis, the South Korean won was valued so that one USD was worth around 800 won (even below 700 was recorded in the late 1980s). During the currency crisis period, the won declined significantly as nearly 2000 won were worth one USD. After this, the won has remained in the area of 1000-1400 won to the USD. The crisis also provided the opportunity for manufacturing-based export to grow, and its growth trajectory has been steep in South Korea since the early 2000s. The case is pretty much the same in Thailand and Indonesia; two other Asian countries that were hard hit by the currency crisis of 1997-1998.

What do currency devaluations of the past and the emerging economy's currency valuation weakness have to do with the One Belt and One Road (OBOR) programme as well as Eurasian supply chains? There is quite a lot of dependence, if the examination focus is switched from the short term to the medium and long term. There is still considerable debate all over the world about the Chinese currency and the need for it to appreciate in the following decades. For the Chinese domestic economy, it is also becoming increasingly important to have a stable currency. The reason for this, is that the country is importing increasing amounts of raw materials (e.g., oil, coal and gas), which are traded in USD. The weak currency would make life difficult for energy-hungry industries and a country undergoing change to become increasingly road transport dependent. A strengthening yuan will, of course, be difficult for manufacturers to absorb. However, their competitiveness has already been so significant in the world market, that Chinese manufacturing dominance will hold. Meanwhile, it is not yet necessary to grow that much in volume. Notably, it is not so, if compared with Japan during the transition from the 1980s to the 1990s and beyond.

China is also massively funding the OBOR programme and different investments in other emerging countries, and these debts are most probably yuan- or USD-based. It is a problematic part of the OBOR programme in the 2020s. Many investments in smaller emerging countries are taking a massive proportion of their economic assets and GDP. This is why even small changes in the number of loans would make their life very difficult (e.g., in the case of an appreciating yuan). Some initiated projects could face difficulties in execution due to this. Moreover, they can even be cancelled before they are even finalized. Examples of this are already present. For instance, Sri Lanka, which faced difficulties due to too large-scale (more than eight billion USD) Chinese investments (Schultz, 2017). Another example is African countries which have also gone to high debt levels due to infrastructure projects, and these are continuously increasing in scale (Sun, 2014).

As a result, these processes and projects have led to awkward situations. Notably, sea port concession contracts have been awarded in turn to Chinese companies (e.g., Hambantota in Sri Lanka, and Djibouti in Africa). Many countries have also frozen some of the ambitious projects of OBOR that were to be implemented. Examples are Malaysia, and also parts of Thailand, where projects have experienced delays. Mostly, it is due to the fear of not being able to serve loans in the future (Reuters, 2017 & 2018). A strengthening yuan, loans given in this currency and currencies of weak emerging economies are the combination which severely hinders Eurasian supply chain development in the future. This was already present in the earlier African investments of China, where the country was forced to forgive some of its loans (Moyo, 2012).

Which currencies have then depreciated in Asia in the last two decades? The biggest hope and promise for future growth in this geographical territory is the Indian economy. However, the Indian currency, the rupee, has continuously depreciated against the USD. In early 2000, around 40 rupees were worth one USD, and this was standing at around 70 in August 2018. The Pakistani currency is also called the rupee, and it was valued at around 55-60 rupees against one USD in early 2000. However, in August 2018, its valuation showed a 50% devaluation as 120 rupees were needed for one USD.

In early 2000, the Vietnamese currency, the dong, had a valuation such that 14,000 dong were worth one USD, and in August 2018 there were more than 23,000 dong for one USD. These are only some examples from Asia (out of the most critical countries in the region), and they have a weak currency challenge. The situation is already against the USD, but the yuan has been, since 2005, appreciating against the USD. Moreover, it should do so in forthcoming years (even if very recently it has weakened). Therefore, the Chinese provided debt challenge will only be getting more severe in the future. The OBOR programme has its demand, and Eurasian supply chains desperately need it, but the money could come with too high a price.

In One Belt and One Road (OBOR) research works, currency weaknesses (Li et al., 2018), as well as exchange rate stabilities (Duan et al., 2018) have been dealt with. Li et al. (2018) argue that smaller random fluctuations in the currencies of OBOR countries do not represent an exceptional risk from the broader perspective. However, having significant issues in significant South-East Asian currencies together, could be a more challenging risk to tackle. This research also concludes that geography drives exchange rates in OBOR countries. Investments should be spread to geographically different locations to deal with the possible closeness risks of currencies (Li et al., 2018). Duan et al. (2018), in turn, propose the model of energy investment decision evaluation. In this, exchange rate stability is one factor among many, such as foreign debt amounts, budget balance (government) and inflation rates. The model also incorporates political and business-related risks. However, the outcome of the energy investment model is impressive. It shows that the closest and highest potential countries of OBOR, such as Pakistan, India, Vietnam and Iran, possess the most fabulous investment risks.

1.3. Uncertainty and dynamics are present at the Eurasian railway land bridge

From the continental perspective, but also from a trade volume perspective, for Europe and Asia, there has been a long-time interest in using hinterland transports. First and foremost, these are railways to connect distant yet critical countries (Verny & Grigentin, 2009; Bulis & Skapars, 2013 & 2014; Rodemann & Templar, 2014; Moon et al., 2015). For example, by using railways from Europe to China, there is a clear lead-time advantage over maritime supply chains. However, costs and flexibility (if not daily departures and arrivals) are always much-debated issues. For Central Europe and China, this sort of railway land bridge connection is something new, that has only been used for less than ten years.

In most cases, the BRI brought the real volumes as the programme was able to provide financial support (subsidiaries) for railway transports. However, this trial is not the first to connect Asia with Europe. In the following, there is a report of Finnish experiences of a railway land bridge, which was used to connect Northern Europe with Japan, South Korea, and China. This earlier and, in its best years, high volume route used the Trans-Siberian Railway (TSR). It was used solely to reach the end of Russia on the Asian side (like Nahodka or Vladivostok). From there, containers were transported to the final destination by sea vessels. This route was not as lead-time competitive as the current direct trains to China. However, it was an early predecessor, and many learning points could be gained by studying it further.

Finland's Trans-Siberian Railway's (TSR) container traffic started in the late 1990s and proliferated from 10,000 TEUs (in the year 1998) to above 124,000 TEUs in the year 2004 (Figure 1-9). Reasons for this growth were numerous. One of them was the import of Asian goods and particularly South Korean electronics. Through this route, they were forwarded to Finland and then transported for final consumption in Russia. It was a transit type of railway transport, and products were not customs registered to Finland. They were handled in Finland, as in the South-East cities of Kouvola and Hamina (the latter at the vicinity of a sea port), by adding to the final consumer products operating manual leaflets as well as other localization items at terminals/warehouses. After this, products were transported from Finland to Russia, like Moscow, using trucks.

Another critical issue for the rapid growth of this route was the emergence of eastern economies from the late 1990s, and also the then still growing paper consumption. So, as economies grew, they consumed more paper products increasingly, like newsprint, magazine paper, tissues and book paper. Finland was (and still is, in the heavily restructured forest industry market) the leading producer of these products and the TSR offered a good option for their transportation. Destinations were not only Russia, Ukraine or Kazakhstan, but also Japan, China and South Korea. Together with forest industry products, some machinery and final products (e.g., wooden log houses) from Finland were also transported.

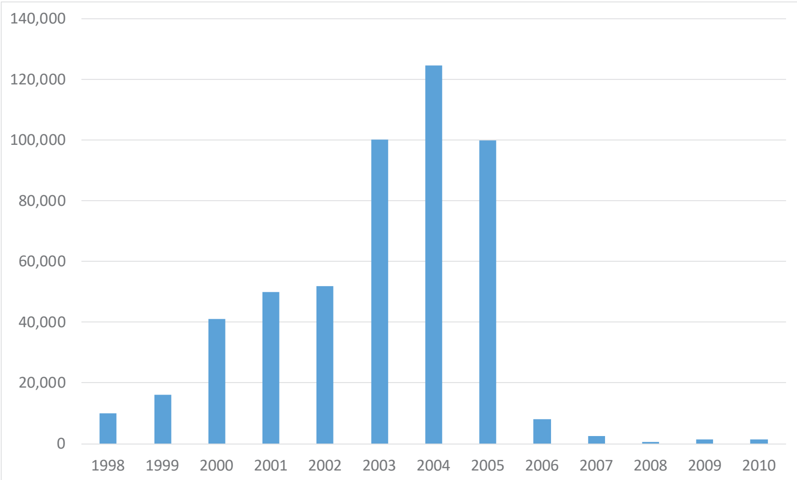

Figure 1-9. Trans-Siberian Railway container transports with Finland in the years 1998-2010 (volumes in Twenty-foot Equivalent Units). Source: own research and Finnish Railways

In a business newspaper article, published in October 1999, there was an interview about growing TSR volumes on the Finnish route (Repo, 1999). Respondents were from railway companies of Finland and Russia. It was argued that safety in the late 1990s increased substantially for container transports from Finland to the east. It was the useful equation of guards and an IT (and satellite) based tracking and tracing system. These two issues together with shorter lead times, were argued to have caused positive outcomes. The annual growth of TSR traffic in the year 1999 was 60%. In the annual reports of Finnish Railways, these same reasons were given several times for volume growth (Finnish Railways, 2002 & 2003).

However, the momentum of the late 1990s and early 2000 was lost in a matter of months, if not weeks, in early 2006. The reason for this was the sudden tariff increase in railway transport of the TSR, which was in the range of 20-40% (Lorentz & Hilmola, 2010). A business newspaper article from October 2006 says that the price increase was a bit higher, around 50% (for the full train; Pakkanen, 2006). These sorts of significant changes have a big downward force on volumes, and in TEU container terms volumes in 2006 were more than 90% lower than in the year 2005 (see Figure 1-7).

Together with TEUs transported on the TSR, Finnish foreign trade also suffered greatly in terms of the volume transported by rail. There was a steep decrease, in 2006, in the total trade and export trade of railway transported containers.

The decrease from the best container trade month by rail of August 2005 was in the year 2006, with January showing a decrease of 71.4%, and this level persisted for the entire year. It was roughly a decade before this decline was fully recovered (international container shipments by rail, but not the TSR and transit, which was the highest volume earlier). Many things were causing this prolonged recovery. In the credit crunch of 2008-2009, global trade decreased significantly, while more transportation capacity was in the delivery pipeline (sea container vessels). This caused sea container rates to stay at a deficient level for years. The credit crunch also hurt the excellent growth rate of nearby emerging eastern economies, and declines on consumption were severe. Recovery was also short-lived as the oil price started to decline and the Ukrainian dispute again resulted in 2015, in the downturn in Russia and economies affiliated to it.

However, it should be emphasized that the old Finnish style TSR traffic never really recovered. There were several serious attempts to start it again in the years 2008-2010, however, these all more or less failed. It has only, in very recent years (2015-2016), started to recover (not significantly but to some extent). This is mostly due to direct Chinese export trains from Finland (often loaded with forest industry products). This arising and new route is not that similar to the old TSR style. The trains proceed through the territories of Kazakhstan or Mongolia directly to China (instead of going to the eastern end of Russia and, e.g., having a sea vessel journey to some Chinese sea ports).

Tsuji (2007) analyzed price changes on the Finnish TSR route (Nahodka-Buslovskaya) in detail. He concluded that price increases were highest for transit containers, and in the direction from Buslovskaya to Nahodka (from the Finnish border to the Far East of Russia) price increases were more than 200%. In the case of empty containers, price increases were more than 400% (even if the total price change was around 20-50%, these are extreme classes of price change; Lorentz & Hilmola, 2010; Pakkanen, 2006). Price changes were significant, but they could have been expected a priori. The price level and setting of the TSR were originating from the Soviet era and were low. Russian currency depreciated after the early 1990s rather significantly. In a newspaper interview with the Finnish railway representative from the year

2000, it was said that TSR tariffs for transit cargo were very competitive. Moreover, they had remained the same for years (Repo, 2000).

The reason for this was that Russia desired to attract more cargo to this route (from deep-sea routes operating between Asia and Europe). Already in the year 2000, there was in-transit Asian cargo being transported to Finland, and after repacking, sent by trucks back to Russia. In the annual report of Finnish Railways (2000: 10) from the year 1999, it is mentioned that South Korean imports to Finland increased a lot on the TSR. In the annual report for the year 2002 (Finnish Railways, 2003), it is stated that imports had three different sources, namely: South Korea, Japan, and China. Most of the TSR traffic back then was consumer items of electronics which only visited Finnish warehouses for a short period of time. Then, goods were distributed further to Russian consumer markets. The same three countries, with the most important TSR connection volumes in Asia, were depicted at the peak, in the year 2004 (Finnish Railways, 2005).

In an interview of early 2006, the director of Samsung distribution Russia (from Finland), said they were already using a 40% share of deep-sea transport to distribute through Finland to Russia (Peltonen, 2006). In a newspaper interview in 2003, this share was argued to be 5%, so most of the cargo then came through the TSR. It was not long before Samsung changed its eastern distribution practices. As a result, the practice of sending products by deep sea to Finland, and then for distribution to St. Petersburg and Moscow was changed. Based on accounting records, the entire distribution company that completed these operations ceased to exist in Finland after the year 2011. The change was similar in many other transit logistics companies (Hilmola & Hämäläinen, 2016) as Russia's own logistics infrastructure developed further. Primarily, it concerned sea ports and warehouses. Also, other competing countries took higher shares (like the Baltic States). The change was mostly driven by lower costs, a lower quality difference between routes, and convenience. The year 2006 and the TSR tariff crisis were only a small "early warning" indicator of the coming changes. On the whole, transit transports (container-based Russian imports) increased until the year 2008. However, after that, they significantly declined to shallow levels (Hilmola & Hämäläinen, 2016).

It was tough to detect beforehand the tariff increase at the TSR and the volume collapse. On the Finnish side, the volumes of TSR traffic in 2004 were very high. Due to this fact, the argued hinterland starting/ending point of TSR transports, the city of Kouvola, was not able to handle all of the volumes. The nearby sea ports of Kotka and Hamina helped a lot. In a newspaper interview from the Hamina sea port in April 2004, the development director argues that in these high-volume moments (Ristimäki, 2004), the Hamina sea port handled 40% of the TSR cargo trains. This also corresponds to the knowledge gained by the authors of this research. In the 2004 interview, the sea port had just finalized the expansion of warehouses and the railway yard but was also planning to expand further.

In the annual report of 2005, Finnish railways concluded that collaboration on TSR transports had developed further, and expansion into China was on the agenda (Finnish Railways, 2006). The railway company still believed in the future and competitiveness of this route. It would have been so, even if the tariff increases were already happening at the time of writing of the 2005 annual report. Many other parties shared the same belief. For example, the Ministry of Transports in Finland evaluated in the large-scale study published in January 2005 that in the long-term (the year 2030) EU-Asia transports would even triple (Lautso et al., 2005). The role of Finland as the access point to the TSR and the land bridge would only strengthen. In the research report, it was highlighted that 90% of the then international TSR transit had been via the land bridge starting/ending in Finland. Moreover, the Polish/German route was insignificant and technically lagging behind.

Also, direct railway connections to China were questioned in this comprehensive study (Lautso et al., 2005). The reason is the lack of appropriate investments in the Chinese railway network. This was correct then of course, but this changed a lot in a decade, as concluded by Xu (2016). The change regarding TSR transit was sudden, unpredictable and significant, and according to our knowledge, no one expected it to happen. It also illustrates the nature of Eurasian hinterland-based transports – volumes could surely exist, and may grow significantly in a short amount of time. However, uncertainty is high, and changes to other routes and transportation modes could happen in months.

Currently, the Chinese BRI programme provides financial support for the railway land bridge to Europe, and every transported container receives a generous subsidy (Jakóbowski et al., 2018). The Finnish railway land bridge was also financially supported, but this was due to the heavily devalued Russian currency (in a decade, until 2002-2003) and infrequent or drastically updated transportation price lists. However, this new price level had just too much to absorb. There are two reasons for this. Firstly, changes were made to prices (to correct the situation). Secondly, the Russian ruble started to level off price development (until devaluation again in 2009 and 2015). Transportation volumes disappeared in a matter of months. The same development could happen if the BRI programme decides to cut financial support. The Chinese land bridge, however, has some natural competitiveness factors. Notably, this is the direct and rather short lead-time shipment to inland cities which will ensure that not all of the volume will be lost. However, the taking away of financial support could make volume development bumpy, and reverse functional growth trajectories.

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CHAPTER TWO

THEORETICAL BASIS OF INTERMODAL SUPPLY CHAINS

YULIA PANOVA

2.1. Transport, logistics and supply chain management

Supply chain management (SCM) is a relatively new concept in the business literature, which was described, for example, in the writings of Cooper et al. (1997) and Kuglin (1998). Some researchers and practitioners associate the concept of SCM with the ultimate development of logistics. It facilitates the synchronization of material and service flows through the internal production processes of companies and their interaction with suppliers and customers. Other authors (Lambert et al., 1998) refer to the management of incoming and outgoing flows and the integration of key business processes for value creation.

The formation of the fundamental basis of the scientific category of supply chain management can be attributed to the research of intra-production operations and distribution channels, according to Bucklin (1996) and Cooper et al. (1997). In the process of more than half a century of logistics and supply chain management development, there was a gradual transition from de-fragmentation to the integration of their components. This change allowed the reduction of duplicated operations and unnecessary resource expenditure. The intermediate stage of integration was characterized by the transition to a new level of organization. In this phase, two separate blocks occurred: (1) "material management" associated with the production and flow of incoming raw materials, the movement of materials from one operation to another, and (2) "physical distribution", connected with marketing and responsible for the outgoing flow of finished products. Nevertheless, this approach led to the artificial separation of the two functions; consequently, a further convergence of the blocks occurred.

In the process of internal and external integration of logistics, different definitions of this term emerged. Later, some of them were recognized by the international community. For example, the Council of Supply Chain Management Professionals (CSCMP; originally, the name consisted of logistics management instead of supply chain management) was founded in 1963. It defined *logistics* as a process of planning, implementing and controlling efficient and effective movement. This activity, in turn, concerns the processing and storage of goods as well as services and related information from the point of origin to the end-user in order to meet customer requirements (Council of Supply Chain Management Professionals, 2010). Thus, logistics is the process of organizing the delivery chain and managing this chain in the broadest sense. This chain can cover both the supply of raw materials necessary for production, as well as the management of material resources in the enterprise, delivery to warehouses and distribution centres, sorting, processing, packaging and final distribution in places of consumption (ECE, UN, 2001).

The term *logistics management* integrates logistics with other functions such as sales, marketing, and production (Council of Supply Chain Management Professionals, 2010). According to these definitions, logistics is a part of logistics management, which, in turn, is considered to be an integral part of *supply chain management*, defined by key categories, such as coordination, integration, and optimization. Supply chain management includes planning and management of all business processes related to purchasing and procurement, processing, and other logistics activities. In essence, supply chain management integrates supply and demand within and across companies as well as coordinates and interacts with partners represented by suppliers, intermediaries, third-party service providers and customers. Therefore, SCM plays an integrating role, which primarily provides the connection between core business functions and business processes within and between companies that leads to the creation of an integrated and high-performance business model. This model includes all of the activities related to logistics, which were described above. Specifically, it includes production operations that can all be effectively coordinated only with an integrated effort. It, in turn, comes from different spheres, such as marketing, sales, product design, finance and information technology (Council of Supply Chain Management Professionals, 2010).

Nowadays, the peculiarities and intensity of supply chain integration lead to multiple connections between companies involved in the movement of goods. At the same time, the mechanisms of integration in the supply chains are becoming more diverse and multidimensional, and these hinder the design of a simple supply chain (Bask and Juga, 2000). Therefore, according to Bovet and March (2000), the new business model should be conceived as a supply network rather than a supply chain. Moreover, supply networks are becoming more customer-oriented and flexible due to their digitalization. Therefore, without information technologies, the automated transaction and integration of information for joint management decisions are hardly possibly (Bask et al., 2001).

With the development of the phenomenon, the conceptual apparatus has continued to form over the last 60 years (Klaus, 2009; Arlbjørn and Halldorsson, 2002). In the authors' studies, the relationship between logistics and supply chain management was not unequivocal, which again indicated the genesis of scientific knowledge in a particular sphere of research. Larsson and Halderson (2004) examined in detail the use of the terms, supply chain management and logistics among the leading researchers in various parts of the world. Afterwards, they concluded that there are four opposing views. The first is the *"traditional"* one, according to which SCM is part of logistics and generally considered as inter-organizational logistics. Following the second approach, logistics is simply renamed as SCM (*"re-labelling"* view). The generally accepted view defines logistics as part of supply chain management, which corresponds to the interpretations of the terms given in the dictionary of the Council of Supply Chain Management Professionals (2010). In the last, *"cross-relationship"* view, SCM is defined as a broader strategic approach, while logistics mainly cover operational issues. The considered approaches cover a variety of concepts and ideas that can be tested in the context of intermodal supply chain management.

At the same time, the theoretical foundations of logistics and SCM are essential for the analysis and organization of intermodal transport systems. Meanwhile, they are studied in the applied science discipline and lack the reach of a methodological ground. Therefore, the theoretical apparatus of logistics that includes a wide variety of methods and models (Lukinskiy, 2008) can serve as a useful framework for this phenomenon as well as other cross-functional disciplines. The use of modern research methods, such as simulation (Lukinskiy et al., 2016), creates preconditions for effective decision-making in the planning, organization, and management of intermodal transport.

2.2. Evolution of the conceptual apparatus of intermodal transport

The development of logistics and supply chain management has led to a new view on the possibilities of the combination of different modes of transport. Mainly, these are rail, road, air, inland water (river), and sea. The organization of their interaction has led to the expansion of the economic potential of transportation systems. According to Rodrigue et al. (2013), road transport is favourable for use within distances of 500-750 km, while, for longer distances of up to 1500 km, railways are preferable. From this break-even point and for further distances the competitiveness of the maritime mode of transport increases. At the same time, the distribution of the distances mentioned above, and corresponding cost functions for each mode of transport, does not always follow the realities of individual countries. For example, in the USA, less than 5% of intermodal transports (employing a combination of both rail and road modes for the delivery of containers) are carried out by the rail part at distances of less than 1,050 km. This distance, as a rule, is to the advantage of truck services, which is contrary to Europe, where road transport is competitive at distances up to 500-750 km. The break-even point for the choice of a rail mode over a road by transport costs per unit, for USA conditions, is on average 3,050 km, with about 65% of intermodal transport (carried out by the rail part) at distances exceeding 3,200 km.

The competitiveness of transport modes in passenger traffic is also mainly determined by cost performance. Rail transport is less competitive than air transport for long distances and road transport (notably, buses) for commuter traffic (Table 2-1). Over long distances (800-1000 km), the competitiveness of air transport increases on the cost performance and delivery time of passengers. Intercity bus transportation gains competitive advantages over short distances (up to 300 km).

The possibility of choosing the most rational transport option from the whole mass of possible alternatives and the variety of combinations requires a systems point of view. In this regard, the phenomenon of intermodal transport or the problem under consideration should be viewed as the system, encapsulating several elements. Breaking down the system into components aids a faster understanding of all the details of any complex mechanism. For example, when there is a need to study the activity of a particular institution, first of all, it is vital to identify its underlying foundations and key concepts. A similar approach can be applied to the studies on intermodal transport. Its concept, like logistics and SCM, is based on the evolvement of different elements. Their definitions have since been systematized into a piece of scientific knowledge.

Table 2-1. Advantages and disadvantages (-) of transport modes in passenger traffic. Source (modified): Panova et al. (2014)

Road transport	Railways	Air transport
High risk of accidents (-) Flexible schedules (+) Less comfort (-) Door to door delivery (+)	Transport safety (+) All-weather traffic (+) High carrying capacity (+) Great comfort (+) Less mobility (-)	Cost performance over longer distances (+) Short delivery time (+) Additional time for airport activities (-)

In 1975, the International Chamber of Commerce issued “Uniform Rules for a Combined Transport Document” in which the definition of intermodal transport appeared. It reads that “combined transport” is also referred to in the United States as “intermodal transport”, while, in other parts of the world it is referred to as “multimodal transport”. This implies two aspects. The first concerns the issue of a series of separate single-mode transport documents, which, however, is inefficient from the international trade viewpoint. The second assumes their replacement by a new, thorough, “start-to-finish” transport document. Such a new transport document, a “CT document”, or combined transport document, would need to be issued by someone who might be the actual provider of the transport (or at least part of it). At the same time, it could be issued by someone who might merely be an arranger for the provision of all, or part of, the transport by others (International Chamber of Commerce, 1975).

Later on, in 1996, Carlos F. de Castro, in order to avoid confusion in the classification of transportations of goods in one document with the use of different modes, carried out their systematization (Table 2-2).

Table 2-2. Classification of transportation with the use of different types of transport and one transportation document issued for the whole route. Source (modified): Castro (1996)

Types of transportation	Definitions
Intermodal Transport	Several modes of transport One of the carriers organizes the whole transport
Multimodal Transport	Several modes of transport Full responsibility is on the service provider
Segmented Transport	Responsibility of the carrier organizer only for that part of transportation, which is carried out by it
Combined Transport	Several modes of transport Transport in the same loading unit or road vehicle

It should be noted that the definitions given in Table 2-2, are primarily applicable to the geographical framework of North America, where the term intermodal is also used to refer to container rail transport (United Nations, ASEAN, 2014). All definitions relating to modal transport terminology in Europe and intended for use by other countries were developed in 2001 by three intergovernmental organizations: the European Union (EU), the European Conference of Ministers of Transport (ECMT), and the Economic Commission for Europe of the United Nations (UN/ECE). The proposed document "Terminology on Combined Transport" (ECE/UN, 2001) defines *intermodal transport* as the sequential transportation of goods by two or more modes of transport in the same loading unit or road vehicle, without the handling of the cargo itself when changing the mode of transport. At the same time, the terms *"combined transport"* and *"intermodal transport"* are often used interchangeably. However, there is a slight difference: combined transport is a narrower term. It means an "intermodal transport where the major part of the European journey is by rail, inland and waterways or sea and any initial or final legs carried out by road are as short as possible" (ECE/UN, 2001). The combined transport actors are presented in Figure 2-1.

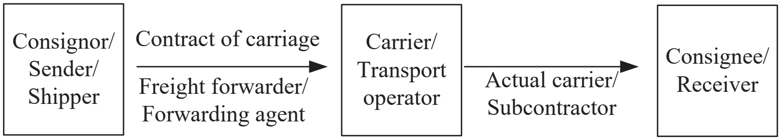

Figure 2-1. Actors of combined transport. Source (modified): ECE/UN (2001)

A *consignor*, *shipper* or *sender* is a person or company, who puts goods in the care of others (a forwarding agent/freight forwarder, and a carrier/transport operator) to be delivered to a consignee, person or firm named in the freight contract to whom goods have been shipped or turned over for care (ECE/UN, 2001). The consignor concludes the transport contract with the before-mentioned actors to deliver the *consignment*, which is a freight sent under a single contract of carriage. A *forwarding agent* or *freight forwarder* is an intermediary (person or business) that arranges the documentation and transport facilities and/or associated services on behalf of companies (shippers) dispatching goods to customers, while the *actual carrier* or *subcontractor* is a third party that performs the carriage completely or partly. A *transport operator* or *carrier*, in turn, is a person or business responsible for the carriage of goods, either directly or using a third party.

In other types of transport, additional actors could be recognized. For example, a *multimodal transport operator* is a person or firm named in a multimodal transport contract to assume entire responsibility for the performance thereof as a carrier or a transport operator. *Multimodal transport* refers to the transportation of goods by two or more modes of transport on the basis of a multimodal transport contract, while *unimodal transport* is considered as the transportation of goods using one mode of transport. An example of unimodal transport would be the case, where goods are delivered by one carrier that issues its own transport document (*bill of lading*) for the carriage of goods from one port to another port. Another example of unimodal transport is when more than one carrier is involved in the maritime carriage. For instance, when goods are transported from one port through another port of transshipment or a so-called intermediate port to the final port of destination. If the carrier that first takes the goods for carriage issues a bill of lading with full responsibility covering this entire port-to-port route, then it is unimodal transport.

In the second example of unimodal transport, it is appropriate to apply the broader term of *transmodalism* (Rodrigue et al., 2013). This implies the connection of different segments of the same mode between an origin and a destination. In the case of transmodalism, the transshipment occurs between the same modes of transport. For instance, the larger container ships, that are used in Asia-Europe shipping, firstly call at the hub of transshipment (e.g. Hamburg and Rotterdam in Europe, and Shanghai and Singapore in Asia). Then, from there, the lower capacity ships are sent to the final ports of destination. This approach depicts transmodal operations between large and small ships — also, named as the hub-and-spoke principle of service. The rail-rail transmodal operations take place during the delivery of cargo over longer distances, e.g., the Eurasian land bridge, which covers different countries with non-unified gauge standards. Transshipment of cargo/containers between broad (1,520 mm) and standard gauge (1,435 mm) wagons happens due to gauge "breaks" at the borders of transiting countries (Panova et al., 2018).

General definitions can be formulated from the above-described characteristics and specifications. Based on the conditions and technologies, intermodal transport is *no-handling cargo transportation*, that is without the overloading of the cargo itself. However, it requires change in the modes of transport at least once between the points of departure and destination. At the same time, the organization of transportation is the responsibility of a single carrier (transport operator). It also follows a single or a through contract with an integrated tariff between the shipper and the consignee.

Meanwhile, multimodal transport can be attributed to transport with transshipments of goods during the change of transport modes (Table 2-2). Intermodal transport is aimed at reducing the processing of goods when changing modes of transport. Therefore, it saves corresponding resources (time and money), achieved by the delivery of goods in loading units, such as containers.

Meanwhile, from country to country definitions of transportations by different modes of transport may vary due to the application of internal rules and regulations. Some definitions can be general, while others are more specific and detailed. For instance, the "Rules for International Carriage of Passengers, Baggage and Cargo" in the old edition (Ministry of Transport of the Russian Federation, 2006) defined multimodal transport as the carriage of passengers, baggage or cargo by carriers of different modes of transport. The other Federal Law called the "Charter of Railway Transport of the Russian Federation" (State Duma, 2002) has a more specific classification of combined transport, which is included in the systematization of transportations with the use of different modes shown in Figure 2-2.

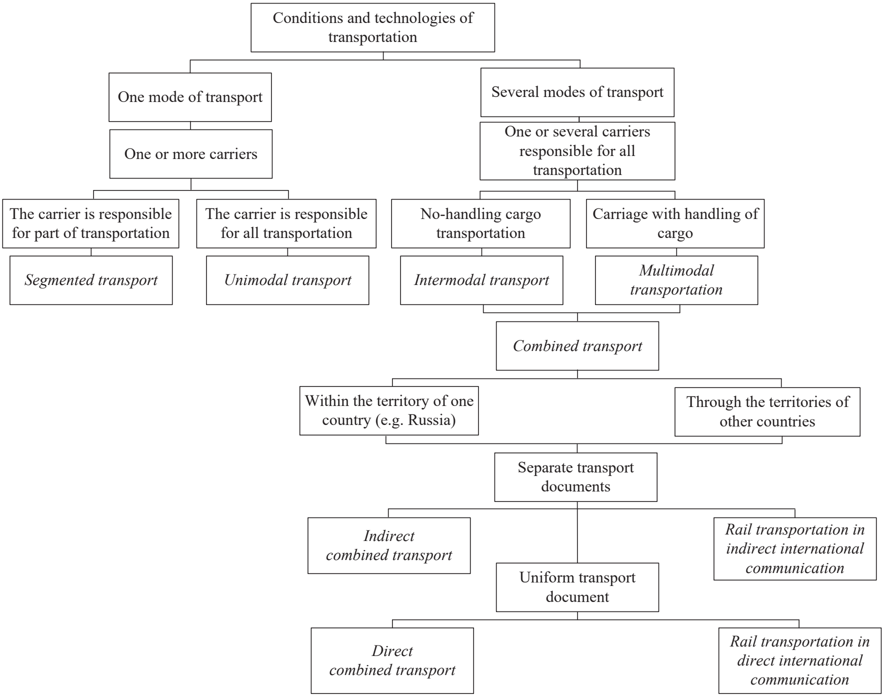

Figure 2-2. Classification of transport types. Source (modified): Panova (2016)

According to the State Duma (2002), combined transport is classified into four categories:

- *Direct combined transport* refers to the movement of goods within the territory of the Russian Federation by several modes of transport on the uniform transport document issued for the whole route.
- *Indirect combined transport* is transportation, carried out within the territory of the Russian Federation by several modes of transport with separate transport documents for each mode of transport.
- *Rail transportation in direct international communication* is transportation in international communication of passengers, baggage, and cargo; carried out between railway stations in different countries or by several modes of transport in different countries with a single transport document issued for the entire route.
- *Rail transport in indirect international communication* is transportation in international communication of passengers, cargo, and baggage,

> carried out through the railway stations and ports located within the border area with the use of transportation documents issued in the countries participating in the transportation, or the transportation by several modes of transport with separate transportation documents issued by each mode of transport.

According to Balalaev and Leontiev (2012), the prototype of *intermodal transport* is a *direct combined transport* (e.g., rail-water) and *rail transportation in direct international communication*. Telegina (2013) underlines that, in the Soviet Union, a large number of so-called direct combined transportations on a railway-water basis were carried out. Now they can be attributed solely to the carriage of goods by the Vanino–Kholmsk ferry (to the Russian island Sakhalin and back to the mainland) on a single waybill of the direct combined railway-water communication called GU-28.

Various legal procedures were simplified in order to increase intermodal traffic and its prototypes, such as direct combined railway-water transport and rail transport in direct international communications. So, to speed up the transfer of goods in border-crossing points of the Russian Federation and the countries of Western Europe, the following changes came into force. On 3 July 2009, the Law on Russia's accession to the Convention concerning international carriage by rail (COTIF) was passed by the Parliament (Cit-rail.org, 2009). According to the document, Russia's accession to COTIF, allowed Russian shipping companies to declare ferry lines between Russian and European sea ports on their initiative.

The Convention is mainly aimed at transportation by the Kaliningrad and October Railways located in Russia. It also allows for the carriage of goods by rail and ferry between Russia and Europe. The carriage is performed via Baltic-Sassnitz/Mukran (Germany) and Ust-Luga–Sassnitz/Mukran (Germany) as well as other European ports. It uses a single transport document (*CIM consignment note*), both on the railway section and on the sea. In addition, at the 34th session of the meeting of Ministers of the Organization for the Cooperation of Railways (OSJD), held on 13-15 June 2006 in Sofia, it was decided to introduce a single contract of carriage – the unified CIM+SMGS consignment note. With the help of CIM/SMGS, interoperability was achieved between different countries. CIM/SMGS combines two documents. One is the conventions on international rail transport, CIM, which is used in Western and Central Europe on rail freight. The second is the Agreement on international rail freight traffic, SMGS, which is applied in Eastern Europe, Russia, China and other parts of Asia. The unified CIM/SMGS consignment note found its application over a vast territory.

The CIM/SMGS consignment note was developed during the period 2003-2006 with specialists of the Railways of Ukraine, Germany, Poland, Belarus, Latvia, Russia and Lithuania, and with the support of the committees of the OSJD and the International Rail Transport Committee (CIT; Korovyakovskiy and Korovyakovskaya, 2011). The guide to the CIM/SMGS consignment note was published in Annex 22 to the SMGS with additions as of 1 July 2009. The CIM/SMGS consignment note consists of 6 sheets: 1 – the Original consignment note, 2 – the Road sheet, 3 – the Duplicate of the consignment note, 4 – the List of delivery, 5 – The List of the notification of arrival of the goods, and 6 – The List of the notification of shipment.

The participants of the CIM and SMGS that use the unified CIM/SMGS consignment note are presented in Figure 2-3.

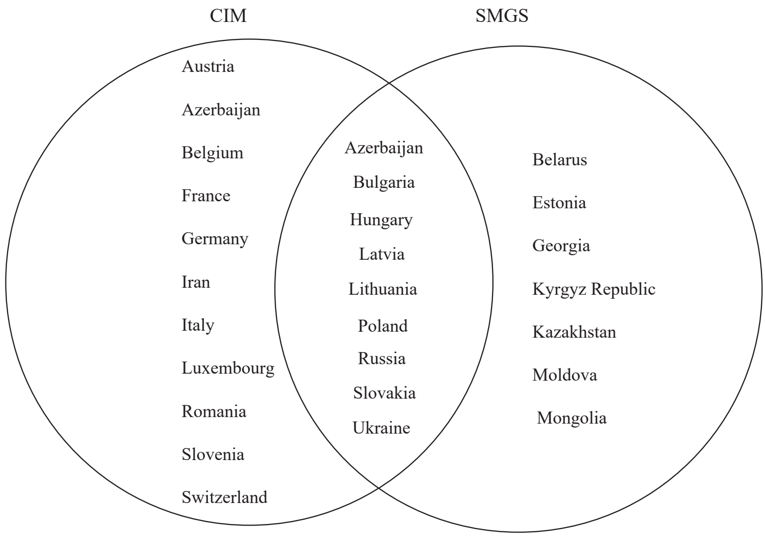

Figure 2-3. Countries-participants of the CIM/SMGS consignment note for freight transport as of 1 August 2016. Source (modified): Cit-rail.org (2016)

The CIM/SMGS consignment note greatly simplifies and speeds up transportation by rail. However, the CIM/SMGS manual applies only to the routes specified in the Relevant Annex of the document. It can be used on other routes, if agreed between CIM carriers, SMGS railways, consignors and consignees. The approval procedure is also set out in the relevant paragraph of the manual.

In Eurasian railway activity between Western Europe, Russia and China, an increasing number of transports are carried out using this modern approach. The CIM/SMGS unified consignment note has had significant success since it was used in rail freight traffic from Western China to Western Europe. The CIM/SMGS electronic consignment note should receive broader coverage, as it starts to have an advantage over the paper document.

2.3. Transmodal and intermodal technologies of transportation

The use of cargo modules, loading units and transport modules (Encyclopedia of Supply Chain Management, 2018) is essential in transmodal and intermodal technologies of transportation:

- *A cargo module* is any loading unit (box, bag, bale, barrel, and basket) designed specifically for transportation.
- *The enlarged cargo module* is a group of cargo modules included in a separate unit load (e.g., pallet) that are held together by various strapping materials.
- *A loading unit* is a transport unit designed for intermodal transport organized on the principle of door-to-door deliveries (container, swap body, trailer, bimodal semi-trailer, and road-railer trailer).
- *A transportation module* is any transport unit intended for the transportation of goods (in a car, plane, or ship).
- *An enlarged transportation module* is a group of transportation modules designed for mass-organized transportation (e.g. the entire train).

The *transmodal technology* of transportation refers to the connection of different segments of the same mode between an origin and a destination, while the *intermodal technology* of transportation involves the organization of a sequence of modes between an origin and a destination, including transfer between the modes (Rodrigue et al., 2013). Further on, both technologies will be regarded under the domain of the *no-handling cargo transportations*, in which the cargo at the points of transshipment is not overloaded itself; instead, only the loading unit or the entire transportation module, in which the cargo is placed, is subject to handling (Telegina, 2013; Korovyakovskiy and Korovyakovskaya, 2011). The organization of transshipments in no-handling cargo transportations would not be so effective without the use of different intermodal transport units and appropriate transportation modules (Figure 2-4).

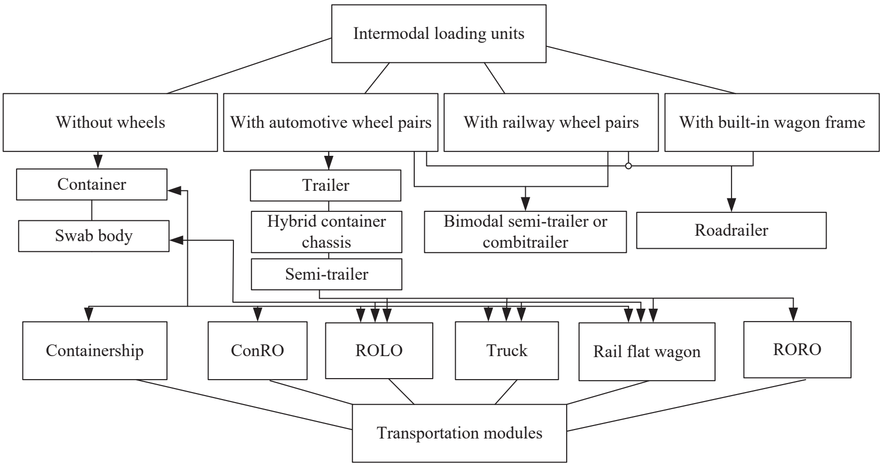

Figure 2-4. Classification of intermodal loading units. Source (modified): Panova (2016) and Transportgeography.org (2019)

The development of intermodal transport was partly due to the emergence of cargo units, also called management units. In the past, transport pallets were the main managed units. Later on, the development of the container system and the appearance of the first wooden container with dimensions of 5-10 feet, and after that, a metal container has reduced the amount of damage and the number of thefts, and, at the same time, expanded the range of intermodal transport units. The first wooden containers were standardized in the UK, in 1830, where the Liverpool–Manchester railway was used for carrying a container with a horizontal method of loading and unloading "boxes".

In 1839, the Birmingham and Derby Railway introduced an alternative form of intermodal transport, in which a container was overloaded from railway transport onto a horse-drawn carriage. However, the container standard adopted in the UK has not spread beyond its borders. This is why the first stage of intermodal transport development is associated with the beginning of the mass use of containers in maritime transport.

Containerization of transportation is one of the most effective methods of cargo transportation. It frees shippers from the need to pack cargo into transport containers, mechanize loading and unloading and warehousing. At the same time, it reduces the need for covered warehouses and covered wagons, and speeds up and minimizes the cost of cargo operations. The father of sea container transportation is considered to be an American entrepreneur who carried out a revolution in international trade (Containerpark.ru, 2018).

Malcolm Purcell McLean (Mr. McLean) re-branded his company Sea-Land Inc. USA, located in North Carolina, by converting the first series of vessels into specialized container ships that were capable of carrying containers on the lower and upper decks of the ship (ASEAN, 2014). To implement his idea, Malcolm McLean had to sell his trucking company, which had 1,770 trucks and 32 terminals. The reason for this was United States law, which at that time did not allow trucking companies to own ships and carry out sea transportation (Containerpark.ru, 2018).

Additionally, for the implementation of the planned idea, McLean challenged the American engineer Keith Tantlinger to be the first to design a transport container with a length of 33 feet and then 35 feet, following the length of the trailer of the truck (Yates and Murphy, 2019). It took several months to modify the ships, and develop containers and trailers for their transportation. On April 26, 1956, the SS Ideal X, a container ship converted from a tanker, sailed from Port Newark-Elizabeth, New Jersey, and headed for Houston, Texas. Fifty-eight brand-new 35-foot containers were placed on board (Containerpark.ru, 2018).

A year later, in April 1957, the first specialized ship for the transportation of containers, Gateway City, began regular calls between New York, Florida, and Texas. In the summer of 1958, McLean Industries, under the name Pan-Atlantic Steamship Corporation established regular routes for the container ship Fairland between the United States and San Juan, Puerto Rico. As a result, Malcolm McLean created a comprehensive and standardized system of container transport – not only the container itself and its processing technology but also road and sea transport, explicitly designed for the carriage of containers. The main elements of the system were patented.

McLean was confident that standardization was the key to the overall growth of the shipping industry. This is why he made its patents available to other carriers and granted their use free of charge to the International

Organization for Standardization (ISO). Since then, container transportation has become one of the most effective methods of cargo delivery. It has freed shippers from the need to use additional transport packaging to protect goods from damage. It has also helped to mechanize loading and unloading, and other warehousing operations, thus, leading to the speeding up of cargo processing and reductions in the cost of cargo handling. Also, the capital cost tends to decrease. This is partly because there is no need for covered warehouses and covered wagons. They are more expensive to construct compared to a simple container yard or platform wagon.

Thus, from the mid-1960s, the development began of the first stage of intermodal transport. It is associated with the standardization of container transportations by sea. The second stage was the distribution of container traffic on inland waterways and land routes (from the end of 1970). In the third stage, the development of intermodal transport was focused on the improvement of intermodal and transmodal operations. Predominantly, this was done by using specialized cargo or intermodal terminals (Rodrigue et al., 2013). The fourth stage of intermodal transport development is characterized by the formation of an integrated global supply chain. The evolution of this chain includes the development of the so-called "equatorial route", which became the primary basis for trade relations between Europe and Asia.

In the conditions for the implementation of the fourth phase of intermodal transport, there is a tendency to use specialized containers with a larger capacity. A container of high capacity (a *high cube container*) is standard in terms of the length and width of the ISO container, whose height is 9 feet and 6 inches (2.9 m, Table 2-3). A *super high cube* container is a container, whose dimensions exceed ISO standards. Its dimensions can vary, for example, over a length of 45 feet, 48 feet, or 53 feet.

Table 2-3. Main parameters of large-capacity containers. Source (modified): Yankovskaya and Panova (2014)

Technical characteristics	20 ft standard container (Twenty Equivalent Unit, TEU)	20 ft Hi Cube	40 ft standard container (Forty Equivalent Unit, FEU)	40 ft Hi Cube
External dimensions				
Length, mm	6060	6060	12200	12200
Width, mm	2450	2450	2450	2450
Height, mm	2400	2600	2600	2900
Internal dimensions				
Length, mm	5900	5867	12030	11988
Width, mm	2350	2330	2350	2330
Height, mm	2390	2350	2390	2700
Size of the doorway	2340x2280	2290x2260	2340x2280	2290x2560
Capacity				
Tare weight, kg	2300	2500	3750	3800
Max. payload, kg	25000	21800	27600	25600
Weight with max load, gross, kg	28000	24300	31350	29400
Internal volume, m3	33.2	32.14	67.7	75.43

Containers are divided into different types based on functional characteristics. The most popular types include the following:

– reefer container,
– tanktainer or tank container,
– general-purpose container,
– flat-rack container,
– open-top container.

Reefer or refrigerated containers are temperature-controlled and practically suitable for cargo that needs regulated and cool temperatures. These are delicate cargo and perishables, such as meat, fresh produce, seafood, dairy products, and chilled and frozen foodstuffs. A *tanktainer or tank container* is a standard container frame with a tank fitted inside. It is used for liquids. Non-perishable liquids are crude oil, alcohol, and harmful chemicals. Tank containers can also be offered with electric plugs in the case that cargo needs cooling or heating during transport. A *general-purpose container* is suitable for the transportation of dry cargo. It comes with a floor (e.g. timber or steel) and has various lashing devices to secure the load. A possible layout of enlarged cargo modules in general-purpose 20ft and 40ft containers is shown in Figure 2-5.

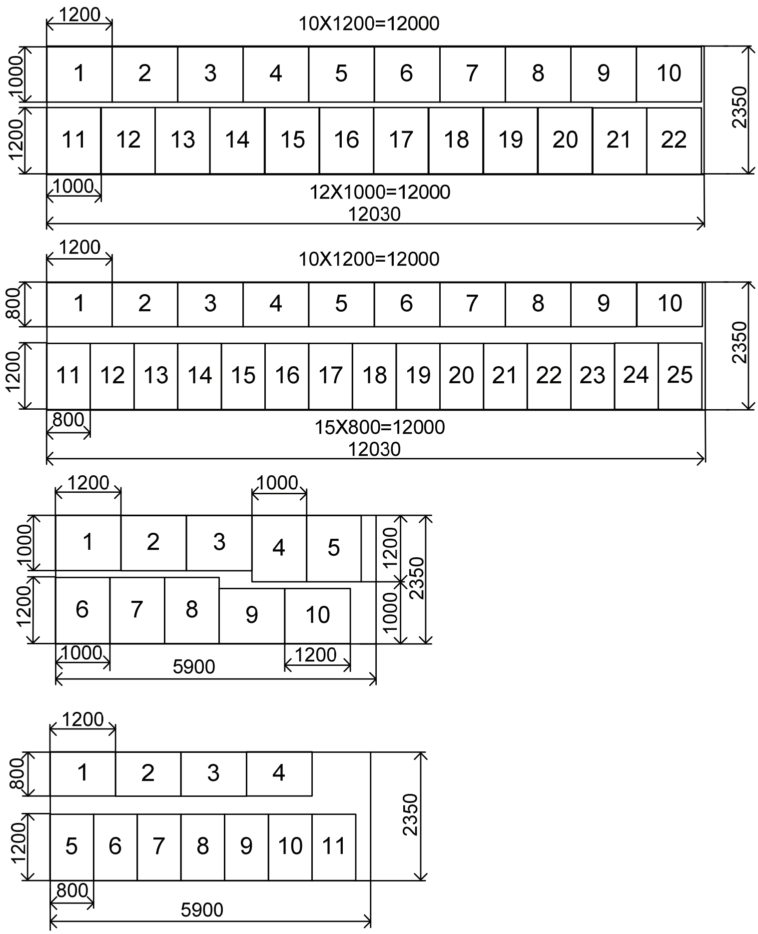

Figure 2-5. Schemes of placement of enlarged cargo modules in general-purpose 20ft and 40ft containers. Source (modified): Yankovskaya and Panova (2014)

For the transportation of oversized cargo, other specialized containers are used: open-top and flat-rack containers. *Open-top containers* are twenty- and forty-foot long with an open top, covered with a canvas tarpaulin. They also come with a PVC tarpaulin cover instead of a roof panel to allow loading from the top. Open-top containers are suitable for bulky cargo. *Flat-rack containers* are twenty- and forty-foot long and are platforms with end doors. The doors can be removed, thereby facilitating the process of loading and unloading.

Depending on the design features, there are several subtypes of flat-rack containers:

Flat-rack collapsible ends, equipment with folding end walls; and

Fixed ends flat-rack, equipment with fixed end walls.

These specialized containers are recommended for the transportation of heavy weights: over-width steel pipes, industrial boilers or tractors.

There is also a classification of containers by their mode of transport:

- *A maritime container* is a container that is strong enough for stacking in a cellular container ship and for lifting from above.
- *An air container* is a container that meets the standards of air transportation.
- *A land container* is a container that meets the technical requirements of the International Union of Railways (UIC) and is intended for use in rail and road combined transport.

Further on, it is reasonable to describe other intermodal loading units (Figure 2-4). Unlike the container, the *swap body* is equipped with loading and unloading devices designed to move it between different modes of transport, usually road and rail. Initially, such intermodal loading units were not suitable for stacking in the laden state or for lifting from above. However, at present, many such units can be stacked and lifted from above. Some swap bodies are equipped with hinged supports on which they rest when they are not on the vehicle.

A *trailer* is an unmotorized vehicle used for the transport of goods and intended for coupling with a motor vehicle, except for semi-trailers. The trailer has two axles so it can be treated as a separate vehicle. The other type is a *hybrid container chassis* that can also carry automobiles apart from containers (Transportgeography.org, 2019). A *semi-trailer* is a vehicle without an engine, which is used for the transportation of goods. It is intended for coupling with a vehicle. It allows a significant part of its weight and load to transfer to this vehicle. Semi-trailers can be specially equipped for combined transport. The semi-trailer has only one axle; in this connection, the load is distributed between the trailer and the tractor.

A motor vehicle with a semi-trailer is called an *articulated vehicle*, while a road train is a motor vehicle with a trailer. The bimodal semi-trailer (rail-road) is a vehicle semi-trailer, which, when equipped with rail bogies, can be used as a railway car. The transportation by rail of road semi-trailers is called *piggyback traffic*. This kind of traffic thus combines road and rail transport: entire motor lorries, trailers, or swap bodies are carried by rail. The concept of the organization of piggyback transportation on a 1,520 mm gauge gives a broader description of this phenomenon (JSC RZD, 2012):

- *Piggyback transportation* is the transportation on specific routes by rail of road trains, articulated vehicles, trailers, semi-trailers and swap bodies in a loaded or empty condition as part of the piggyback trains.
- *A Piggyback train* is a train of prescribed length, consisting of specialized platforms. They are designed for the transportation of loaded or empty road trains, articulated vehicles, trailers, semi-trailers, and swap bodies. This type of train is shipped by a single consignor at the station of origin to one consignee at one or more destination stations. During the journey, the train is not processed at the marshalling yards.

In turn, the piggyback train can be classified into two categories:

- *Accompanied,* when cargo in a vehicle or motor vehicle itself is accompanied by representatives of the owner of the cargo or the motor vehicle;
- *Unaccompanied*, when the goods in the vehicle or the vehicle itself are not accompanied by drivers/representatives of the owner of the cargo.

The first trial trips using piggyback technologies in Europe began in the 1960s. The regular route, Cologne (Germany) –Verona (Italy), was put into operation in 1972. Among the most successful projects is the organization of piggyback traffic since February 2003, on the route Illichivsk (Ukraine)–Minsk (Belarus)–Klaipeda (Lithuania). The train “Viking” was intended for the transportation of 20 ft. and 40 ft. containers, refrigerated and tank containers as well as semi-trailers and road trains. The route length is 1,700 km, the journey time is 52 hours, and the time at the border is 1.5 hours, with the frequency of carriage of once per week. In April 2003, the piggyback route Kyiv–Slavkov (Poland) was opened. The train “Yaroslav” consisting of 30 platforms was shipped weekly. The length of the route is about 1,000 km and the travel time is 39 hours, including 5 hours at the border-crossing points.

Bimodal semi-trailer transportation (or combi-trailer) is more technologically advanced. The combi-trailer is a bimodal transportation module having a road and railway-wheel pair, which is alternately lowered and raised depending on the mode of transport required (Figure 4). Combi-trailer transportation, as well as road-railer trailer transportation, belongs to the so-called “non-wagon” type of carriage. The *road-railer trailer* is a transportation module with a built-in frame of the car, which simultaneously performs the functions of the frame of the module itself. Road-railer trailers were developed in the USA in the late 1950s (Chesapeake & Ohio Railway).

The road-railer trailer is equipped with car wheel pairs and a device for lifting as well as a particular device for mounting railway wheel pairs. Thus, a conventional automotive semi-trailer equipped with a pair of steel railway wheels becomes a kind of wagon and moves on rails, when these wheels are lowered. When driving on the highway, it functions as a semi-trailer. Meanwhile, on the railway is the body of the car. In the other modification of a road-railer trailer, a pair of heavy railway wheels is not transported by a trailer. Therefore, its mass reduces by almost one ton, thus, increasing by the same mass the road-railer trailer payload (capacity).

Therefore, from a technical point of view, road-railer trailer technology is a combination of a road tyre-pneumatic trailer with a pair of railway trolleys equipped with a device for connecting such a bi-module to the system of auto-blocking and braking of the train. This bi-module moves by analogy with the wagons in the train. By leaving the bogies at the railway station, this bi-module continues its way along the highway behind the tractor (Scbist.com, 2014). Meanwhile, these technologies have some disadvantages:

1. Compared with cars, these technologies have more weight in the rolling stock and less payload.
2. The cost of transportation by road-railer trailers is 2-2.5 times higher than the carriage of conventional trailers or semi-trailers transported on railway platforms (piggyback traffic).

The development of intermodal units, as well as transportation modules, contributed to the growth of *no-handling cargo transportation*. As mentioned previously, on water transport, such a phenomenon started to spread with a decrease in the role of universal dry cargo ships. Instead of these, there was an increase in the importance of specialized vessels, such as container ships working on the principle of hub-and-spoke systems. Similar to container ships, the *lighter-lift vessels* provided the benefits of cargo handling minimization. They were created to reduce the volume of cargo work. Notably, they were used to deliver to the mouth of the river the lighter barges with a load of 1,000-1,100 tons. From there, they were further forwarded by river tugs up the river. A distinctive feature of lighter vessels is their ability to perform cargo operations in the roadstead. This is without the use of berths, which admitted them to service ports with a shallow depth of the water area. In recent years, the majority of lighter vessels have been operated as container ships (Telegina, 2013).

RORO (Roll-on/Roll-off) ships can be added to the category of vessels that facilitate no-handling cargo transportations. The principal difference between these types of vessels and others is horizontal loading (usually from the stern of the vessel) through the reclining nose or stern, which is called a "ramp". The ability of the goods to "enter" (or Roll-on) on board the vessel during the loading and "discharge" (or Roll-off) helps to eliminate the use of traditional crane mechanization for loading/unloading operations. More importantly, it allows an acceleration of the loading and unloading processes, reducing the downtime of ship and berth occupation time. It is quite clear that such vessels are intended for the transportation of wheeled vehicles (private cars, buses, trucks, and railway wagons). Most brand new vehicles are transported on the large RORO type vessels. On vessels of the *ROLO type (Roll-on/Lift-off)*, part of the cargo is accessible via the ramp. A crane unloads the rest of the goods. The other ships of the ConRO type are a hybrid of a RORO and a container ship. Transport vehicle are on the inner decks, while ISO containers are on the upper deck. Also, worth mentioning is a river-sea ship, which is a perfect solution for the problem of no-handling cargo transportations. The issue is solved through the creation of ships that can move along rivers and go to sea, usually for short sea shipping.

On the railways, no-handling cargo transportation has been enabled by a number of developments. Most of them belong to the framework of transmodal technologies. For example, when the particular passenger or freight wagons are transported by railways in international directions, the problem of the break-of-gauge is mitigated by three alternatives (Panova et al., 2018). The first option is the *reloading of containers* from wagons on one track to wagons on the other track. The two tracks are parallel with different track gauge standards and use different locomotives. This option is the most common at present, as it does not require high costs for the conversion of rolling stock and the construction of particular service points. However, it only provides the uninterrupted processing of wagons and trains, if the train-scheduling problem is well managed. It implies the arrangement of jointly processing trains at parallel railway tracks. This issue is typical for hub yards, which are used in the hub-and-spoke system.

On the whole, the overall scheduling problem is complicated and comprises five different tasks (Boysen and Pesch, 2008): "(1) Schedule the service slots of trains by assigning them to pulses; (2) Decide on the containers' positions on trains; (3) Assign each train to a railway track; (4) Assign container moves to cranes; and (5) Decide on the sequence of container moves per crane." These issues are broadly discussed in the scientific works devoted to the management of the three-generation hub yard types (Boysen et al., 2010; Boysen et al., 2013; Bostel and Dejax, 1998; Otto et al., 2016; Jiang and Jin, 2017; Kellner et al., 2012; Fedtke and Boysen, 2017; Cichenski, 2017; Dotoli et al., 2017). The mitigation of the break-of-gauge problem could be solved with the simple alternative; that is, *reloading containers between different wagons*. However, consideration of all components of the overall scheduling problem is required for this option to be fully economically viable.

Nowadays, the issue of technology improvement is acute for the third-generation modern rail-rail transshipment yards, since they can boost the growth of international trade on the principles of interoperability. Most of these terminals are still in the design phase in Europe and Asia (Boysen et al., 2010; Gombosed and Malikov 2013 a, b). However, a few of them are already built (Port-Bou at the border between France and Spain, as well as the German "Mega Hub" in Hannover–Lehrte; Boysen et al., 2010). Within these mega hubs, there are particular transshipment yards and warehouses, which are used for the rapid transshipment of containers from the wagons of one gauge to the other. The disadvantage of this alternative is the downtime of empty wagons, because of waiting for the loaded ones. The advantage is in the absence of a need to increase the size of the wagon fleet and their minimized empty haul (Kurilov, 2016).

The second alternative is based on the *replaceable coach bogies* that can be changed at the border-crossing points. This practice was broadly implemented from 1941 when the Leinkauf Firm organized transportations in 10 couches with replaceable wheel pairs (Sanchez-Conzalez, 1983). By the 1980s, the

Transfesa Company (Spain) had provided a large percentage of international freight transportations in 7,226 wagons with replaceable bogies. Meanwhile, today the technology is more frequently applied to passenger traffic rather than freight (Turnock, 2011; Islam et al., 2013; IRJ, 2007).

At that time (Sanchez-Conzalez, 1983), railways directed their efforts to reducing the time for the replacement of bogies. According to the author, previously, wheel pairs of one wagon could be replaced within 45 minutes. Later on, the time reduced to 8 minutes spent in the replacement of the wheel pairs of four wagons. For the replacement operations, there have been particular sites for changing the bogies. Such sites have been located at the border, within railway stations. As a rule, they are equipped with railways that have three rails. The technology is as follows: when special wagons arrive at the station, wagons with bogies adapted to the track width of 1,435 mm, roll along the inner and outer rails. Meanwhile, the wagons with bogies for the track width of 1,520 mm move over the outer rails. A train, which is located on the one gauge, is disengaged, and then the special jacks lift the coaches of the wagon to the height of 1.2 metres, afterwards, the bogies are replaced (Sanchez-Conzalez, 1983). Automatic couplers provide the fixing.

The disadvantage of this technology is the fact that at the transshipment point (e.g., an inland rail terminal) a stock of coach bogies is needed. It requires a considerable space, which, at the same time, is occupied by related lifting equipment. Sanchez-Conzalez (1983) also underlined high operating costs, as well as limited productivity.

He (2016) stresses that cargos are frequently delayed at bogie change stations (for example, Alashankou–Dostyk). Bogie change operations lead to an increase in not only the transportation time but also the operating costs, reducing the competitiveness of railway transport. Moreover, the limitations of this technology hinder the creation of a corridor with larger throughput capacity (He, 2016).

This is why many authors advocated the use of the more advanced, third technology, with variable *bogie axles*. This idea has already been stressed in earlier articles of Bogdanov and Naumov (1969). The technology with variable bogie axles could be preferable for several types of cargo (e.g., perishable goods) and provides several economic benefits (Bogdanov and Naumov, 1969): savings of working capital due to the short period of transportation and delivery of goods, a reduction in the number of costs and the uninterrupted processing of wagons with uneven arrivals at border railway stations. The same proposals were made by Tsyurenko (2003), who justified the application of wagons with variable bogie axles for the transportation of ore, metal from the European part of Russia to other countries.

The studies of Sanchez-Conzalez (1983) likewise underlined the benefits of the third technology (with variable bogie axles) compared to the option that required the change of coach bogies (the second technology). In particular, the costs related to the maintenance of the gauge change point equipped with the third technology are seven times lower than in the second technology. Moreover, labour-saving amounts to two person-hours per wagon. However, it is essential to bear in mind that the maintenance of wagons with variable bogie axles is ten times higher than for conventional wagons.

The third technology is grounded on the use of wagons with sliding wheel pairs. An example is the wagons of the leading European manufacturers Talgo, which started the development of continuous change of the gauge by the bogie (at the speed of 15 km/h) in1965 (Tsyurenko, 2003). In 1966, the Spanish Railways (RENFE) in co-operation with the International Union of Railways (UIC) set a tender for the development of a technical solution for wheelsets with variable bogie axles (RW, 2011a). On the grounds of several criteria, 15 proposals of systems were considered. The prizes were awarded to systems developed by Vevey (Switzerland) and Oficina General de Ingenieria (Ogi) from Seville (Spain). The other systems, due to the original approach to the problem, were also impressive. These are the projects of Talgo, Schindler, RAV and DR-4 (Sanchez-Conzalez, 1983). It should be noted that the cost of manufacturing and assembling wheelsets with variable bogie axles in comparison with the ordinary wheel pair (bogie) was ten times higher.

The particular system developed by Talgo between 1967 and 1969 went through considerable improvements and was endorsed by RENFE and SNCF (Sanchez-Conzalez, 1983). As a result, 48 years ago Talgo introduced the world’s first gauge-adjustable trainset-TEE Catalan Talgo, between Barcelona and Geneva via Port Bou (IRJ, 2009; EB, 1999; Tsyurenko, 2003; RW, 1995; RW, 2011a; Sanchez-Conzalez, 1983). In 1974, the Talgo-Lits trains were commissioned between Barcelona and Paris, and then on the route, the Madrid-Paris trains Talgo-Pendular with a bump of the body within curves, began to run (Sanchez-Conzalez, 1983; Tsyurenko, 2003).

Thus, in Europe, the pioneering gauge-changing devices were implemented in Port Bou and Irun, Spain's main border-crossing points with France (in 1969; IRJ, 2009; EB, 1999). To date, 14 facilities have been built (IRJ, 2009). Recently, a new gauge-changing facility in Zweizimmen (Switzerland) was justified by the TransGoldenPass project. According to the project, a regular service should be launched between Montreux and Interlaken in 2015-16. It had to eliminate the need for passengers to change trains at the break-of-gauge in Zweizimmen (Hughes, 2011).

Meanwhile, the works on the development of the gauge-changing bogie were started earlier (from 1951) in Germany (Bogdanov and Naumov, 1969), where types DR-III and DR-IV of replaceable coach bogies were designed. In Russia, the first samples of replaceable coach bogies (TG-1 and TG-2) were created in 1957. Later, in 1961, the new type of gauge-changing bogie (TG-6) was tested. These gauge-changing bogies could only be used under the passenger and freight wagons of USSR construction and were not suitable for use under wagons of the West European type (Bogdanov and Naumov, 1969). The change of rail gauge with replaceable coach bogies at the border-crossing point required 5-15 minutes. The technology was as follows: the broad gauge (1,520 mm) locomotive propels the train with a speed of 5-10 km/h through the gauge-changeable wheelset to the last rail car. Then, the train is attached to the locomotive of the narrow gauge (1,435 mm), which finishes the transfer to the narrow gauge of the last rail car (Bogdanov and Naumov, 1969). The technology was tested on the international traffic at the destination of the German Democratic Republic, Brest-Dnieper. The entire run of the train with the wagons fitted with the gauge-changing bogie, manufactured by the Bryansk machine-building plant was 160,000 km. The same technology (also named as the first generation; RW, 2011) was used for changing the railway gauge by passenger trains, at that time, between Barcelona and Geneva via Port Bou (RW, 2011). Technical and economic assessment of the technology by the USSR and GFR showed its sustainability compared to the transshipment of cargo from the broad to the narrow-gauge wagon (Bogdanov and Naumov, 1969).

However, by the end of the 1960s, all of the research and development activities in the USSR were halted. In the 1970s, Bulgarian inventor N. Gaydarov created variable gauge axles for refrigerated wagons. Later on, after the unification of the Federal Republic of Germany and the German Democratic Republic, the construction work on gauge-changing bogies was continued in Germany (in Delitzsch). The starting point was the level achieved by joint developments of the German Democratic Republic and the USSR (Tsyrenko, 2003). Gauge-changing technology was slowly developed in Japan (IRJ, 2009). In 1998, the gauge-adjustable prototype was initially sent for testing in the USA, and later on, it was extensively tested on narrow- (1,067 mm) and broad-gauge track (1,435 mm) in Japan (between 2001 and 2004).

Historical changes in the evolution of the technology of the gauge-changing bogie took place after 40 years of joint collaboration between Patens Talgo (Madrid) and Krauss-Maffei (since 1999, Siemens Krauss-Maffei Lokomotiven GmbH, München). They jointly developed a diesel locomotive with variable gauge axles (Talgo-Triebkopf BT). This is in composite with wagons on gauge-changing bogies which formed a unique train, Talgo XXI (EB, 1999). The train allowed the saving of expensive high-speed traffic minutes, which were previously spent at border railway stations. As a matter of fact, the train Talgo XXI, which required only 5 minutes of servicing at the border, became the main highlight of the exhibition in Madrid (RW, 2011). Thus, the so-called *second-generation technology of a gauge-changing bogie* appeared (RW, 2011).

Similar locomotives and related gauge-changing wheelsets were developed by the CAF Company. As a matter of fact, in the beginning, different gauge-changing wheelsets were required within the border-crossing point (one for the Talgo and another for the CAF trains; RW, 2011). In these circumstances, the border stations became overloaded with different equipment. As a result, the time for processing trains increased and so did the operative expenses. The incurred costs triggered the development of the *gauge-changing wheelset of the third generation*. It allows the processing of trains (wagons and locomotives with variable gauge axles) of different companies by one gauge-changing wheelset (CAF, Talgo; RW, 2011). This system was tested at the Roda de Bara bliz Tarragona in Spain (RW, 2010). It is a 12-metre-long assembly; thus, the passage time by one axle and the time spent in the wheelbase change operation are about 5 seconds. The train, with 12 wagons (13.14 m length) can be processed within one minute (Zander, 2000). The next step in the development of the Talgo gauge-changing wheelset was its further adjustment, allowing the processing of the variable gauge axles, designed in Poland and Russia (RW, 2010). Polish railways developed, and for five years tested their variable gauge axles. Principally, they had no have significant differences from the German type (at Polish railways, the German gauge-changing wheelset is used; Tsyurenko, 2003).

Some countries have moved forward and tailored their gauge-changing wheel technologies to the specific circumstances of their exploitation. For example, in 2015, the Japanese operating company JR West started the technological development of the gauge-changing wheelset (1,435/1,067), which can work in hazardous weather conditions (in snowdrifts; RW, 2015). Moreover, it is planned to equip the trains with variable gauge axles with the additional equipment. It had to prevent derailing during an earthquake (the same systems are already installed on the conventional trains, too).

It is expected that *the fourth-generation gauge-changing wheelset* will have extended functionality. It will allow the processing of passenger trains and freight trains from different countries and operated by various companies (RW, 2011). Nowadays, the Talgo system allows dynamic gauge change. It is applied to rail vehicles, which operate on rail lines of different countries. Such a system provides an interoperability of rolling stock across breaks in gauge throughout Europe (Yerpes et al., 2012; IRJ, 2009). In 2012, the Talgo Company tested diesel-electric trains with variable gauge axles between Madrid and La Coruña (RW, 2011b). Thus, the upgraded Talgo system was not only designed for passenger and freight wagons (RW, 1995; EB, 1999) but also for a locomotive of combined traction. It allowed trains to run on electrified and non-electrified tracks of different gauges: metric (1,000 mm), standard (1,435 mm), Russian (1,520 mm), and Spanish (1,668 mm). Besides the previously mentioned track gauges, Talgo's rolling stock also operates on the 1,676 mm gauge, as in India or Argentina, for example (Zembri and Libourel, 2017).

Reportedly, the analogue of the fourth-generation gauge-changing wheelset can appear in South Korea (Kang et al., 2014). According to the authors, the Korean gauge-changing wheelset (KGCW) can be a better solution than transshipment or bogie-changing by lifting coaches at the border of each country. It is expected that this system will improve the connection of the Trans-Korean railway with the Transcontinental railway. Further on, it will advance the gauge-changing process of all kinds of trains regardless of their gauges in the border areas in many countries worldwide.

2.4. Key components of intermodalism

The term intermodalism can, in a broad sense, be used to describe an approach to the organization of the supply chain. It consists of different modes of transport and warehouses, interacting based on agreed and compatible standard parameters. These are applicable to intermodal units and modules to ensure the implementation of a "seamless" combination of transport means. Such smooth communications are partly based on intermodal and transmodal technologies (Bovet and Martha, 2001; Levkin, 2014) that were broadly discussed in the previous sub-chapter.

In this sub-chapter, attention will be paid to the main components of intermodalism. They are: (1) transport operators, providing the coordination of transport modes; (2) critical nodal points of intermodal traffic (first and foremost, dry ports (Roso, 2009; Korol, 2015; Sherbakova-Slyusarenko, 2016; Henttu, 2015; Panova, 2012, 2016)). The latter, as a rule, are located along (3) international transport corridors (Monious and Lambert, 2013), which, in turn, are also an inevitable part of intermodal traffic.

The term coordination can be used in different contexts. Economists consider coordination mechanisms or governance structures that range from market-based management to hierarchical frameworks as intra-firm coordination. The "hybrid" forms include various schemes of partnership and joint ventures (Bask et al., 2001). In logistics and supply chain management, coordination, as a rule, refers to the planning and control of material and related information, financial flows as well as activities or concerted efforts within and between organizations. In the supply chain, coordination involves the concerted actions of the participants in the integrated processes at all stages, which ensure the growth of profits throughout the chain.

In transport, logistics and supply chain management help to coordinate goods (necessary products); their quantity (necessary and sufficient); the point of delivery (the right place); the level of customer service (the required quality of the product/service); the total delivery time (the specified time in the implementation of the "door-to-door" service); and the cost and tariff structure (in order to minimize them).

As a result of the complexity of transport processes and the transition from the principle of mode-based transport competition, there was an obvious need for a coordinator. Such a role is entrusted to transport operators. They can be represented by the logistics service provider or, for example, a railway undertaking in combined transport (Panova et al., 2017; Sondermann, 2013). The role depends on the modes participating in transportation and the specifics of rules and regulations, conditions and technologies used in transportation.

As previously described, combined transport involves different modes of transport, several carriers and different transport companies. Therefore, such transportation is difficult to perform. However, with the help of a combined transport operator or a multimodal transport operator, this type of delivery organization becomes simple. First and foremost, it benefits the customers, as, in this case, they need to deal with only one person. A multimodal/combined transport operator must be recognized as a provider of transport services. These are delivered to the customer in the form of a so-called specific single package, which includes value-added services. They are provided under the full responsibility of a principal (a person for whom another acts as an agent) along the entire route of international delivery. This approach significantly distinguishes the operator from the general service of companies that provide only individual transport services.

A multimodal or combined transport operator is a company that provides “just-in-time”, “door-to-door” delivery and has appropriate technologies and corporate connections (Sondermann, 2013). At the same time, the multimodal transport operator assumes full responsibility for transportation as it participates, not as an agent or intermediary, but as a party to the contract on behalf of the shipper, consignee or sender (Telegina, 2013).

On the whole, transport operators can be classified with regard to vehicles, modes of transportation and conditions of their performance. According to this classification, the following operators can be identified (Edu.dvgups.ru, 2016; Balalaev, 2008):

- *Non-vessel combined transport operator, NVCTO,* i.e., these do not own the sea tonnage and vehicles of other modes of transport; they organize delivery “door-to-door” assuming responsibility on a non-transshipment basis, using the consolidated load of goods in their own or rented loading units or transportation modules (containers, etc.), giving shippers forwarding documents for the goods. If the operator does not assume responsibility for the final delivery, he acts for the shippers and carriers as a freight forwarder.

A prerequisite for the emergence of these types of operator was the development of containerization in the transportation of general cargo. As a result, there was an occurrence on this basis of a new type of business. This is the provision of containers on a short- and long-term lease. For the first time, the concept of “non-owner operator” was introduced by large Japanese freight-forwarding companies, introducing the container transportation of goods in “peripheral” directions (to Latin America, Eastern Europe, Scandinavia, and Africa) under the “door-to-door” option. This approach has found an application in Europe, where there are many large freight forwarders. In no-handling cargo transportations, their legal relations with carriers of various modes of transport built through long-term agreements are allowed to have many preferences. They bargain tariff discounts, for the provision of the carriers, for the transportation of loaded containers belonging to other owners. On the other hand, it could be a certain number of containers owned by the carriers but loaded by the forwarders.

 Non-vessel owning common carrier, NVOCC. These are public carriers which operate either in their own interests by railway, automobile or air transport, or act based on agreements with their management. According to management agreements, the owners of vehicles impose the responsibility on the operators. They are responsible for the operation of vehicles, as well as for insuring their loading. Thus, they deliver goods “door-to-door” with full responsibility. The enormous spread of such types of operators is in the United States, where there are strict government restrictions on the activities of freight forwarders. Because of this, the activity of operators who are not operating tonnage has been regulated by law, since 1990.

 Vessel operator, VO. These include two types of shipping companies. Firstly, companies that do not own transport means of other modes of transport. Secondly, transport companies that own rolling stock of rail or road transport, ships, planes as well as transport terminals and a container fleet. These companies received the VOCC acronym (Vessel Operating Cargo Carriers), which means a voluntary carrier for general use, owning tonnage. It is the most common type of operator.

VOCC and NVOCC are often formed by combining two or more carrier companies or by establishing a subsidiary. Such companies operate as members of consortia of shipping companies or through joint ventures with them. Typically, VOCC operators provide the same range of services as the actual carriers. They also operate on popular cargo destinations (for example, North Atlantic, Pacific, or Indian destinations). As a rule, they provide their services based on the principle of delivering continuity of the transport process for the actual carriers.

NVCTO operators for the actual carriers at main transport destinations (not peripheral), are only regarded as shippers of goods. Due to this fact, NVCTOs receive commissions from transport operators for the provided volumes of cargo. As a rule, delivery of goods is carried out in any direction, as under the operation there are only transport cargo devices.

Therefore, the scope of services of a *non-vessel combined transport operator* may include the following:

- Advisory services to clients in transportation, cargo clearance, and compliance with the requirements of international and national legislation;
- Provision of containers and other transportation modules, their loading. Collecting loaded containers, trailers, etc. Such operators can arrange an exceptional transport service between the place of acceptance and the warehouse of the shipper;
- Weighing or measurement of the cargo by the shipper or his agent under the control of the operator or his representative;
- Organization of the export and transit customs clearance of goods;
- Registration of the contract for the carriage of goods with the use of different modes of transport;
- Contact and coordination with buyers, their agents and customs brokers;
- Providing notifications about changes in customer orders (purchase orders), allowing customers to control their inventory more effectively;
- Coordination of carriers' actions and control of cargo transportation;
- Advance notification of carriers (pre-advice) for the reservation of packages and shipment;
- Verification of documentation and its movement according to the customer's information or the buyer's letter of credit;
- Transfer of preliminary information, including details of the cargo, estimated time of its arrival;
- Providing accurate information about the time of arrival and many freight payments;
- Claim work;
- Implementation, and if necessary, distribution of the delivered products; and
- Provision of the necessary guarantees to the customs administrations of transit countries, control over compliance with the necessary formalities through their agents.

The non-owning vessel operators concentrate their activity in areas where they can bargain with the actual carriers for preferential rates. They also prefer spheres in which their agents are located or guarantees exist for loading containers on their return journey, thus eliminating empty runs.

Service schemes of operators in container shipments are as follows. If the customer provides a *Full Container Load* (FCL), the sender or his authorized representative (agent or freight forwarder) will load the container provided by the operator in the place agreed by the parties, seal by their seals, and then deliver the loaded container to the place of its transfer for transportation. After receiving the container, the NVCTO issues the contract to the sender. If representatives of the sender complete container shipments, they issue their document additionally to the sender (the warehouse receipt, certificate of receipt, and forwarding certificate).

In the case of a *Less than Container Load* (LCL), the operator combines the goods of several senders for a full container shipment under its seals. It also transfers the container to the actual carrier, taking responsibility for the safety of the LCL shipments until their delivery to the recipients. The operator issues on its behalf a transport document (bill of lading) to the consignor for the goods accepted for transportation. At the same time, it charges a fee for the agreed date at published tariff rates, the values of which are equal to or less than the actual carrier's rates for FCL transportation.

The income of operators that do not operate a ship is derived from the difference between the levels of the freight rates it pays to the actual carrier and the rates it assigns to senders. The difference should cover the direct and indirect costs of operators and be a source of profit. The income of the VOCC, in addition to sea carriage, can be supplemented with income from the organization of the land-based part of transportation.

If the operator cannot be independent in the performance of any services, it will engage relevant companies as subcontractors (contractors), which can be grouped as follows:

– *Transportation companies* that are attracted by NVCTO, NVOCC or VOCC as contractors for the implementation/performance of transportation in a particular part of the carriage (for example, land or air); and
– *Terminal companies* that are engaged in the warehousing and processing of goods, packaging, documentary and customs clearance, loading and unloading, leasing, survey operations with vehicles, devices, and which can be subsidiaries of the operators of any kind.

Whichever services are used, the operator enters into a separate agreement with each company, taking into account the applicable international conventions, national legislation, and common law. The operator acts as principal. This is why such contracts for the operator are of the "contract out" type. The terms of these contracts do not affect the obligations of the operator to its customers. However, the receipt of agreed services is only possible on the agreed terms with the subcontractor. Contracts may also specify an additional fee for operators for the scope of work provided to subcontractors for specific types of services.

Sometimes, operators are forced to provide financial coverage of transactions and pay the price deviations that occur in the progress of the delivery and may not be included in the contract. This is the case when deferred payment is used. The operator receives from the customer at the agreed time the payment for the delivery of the goods. As a rule, this is done at the destination based on the pre-agreed rate. Therefore, operators need to have sufficient and reliable financial resources and the capacity to support operations. These are the necessary minimum capital and a strong business reputation and financial "history", allowing good relations with financial institutions, insurance companies, subcontractors and other operators. By receiving delayed payments for the services of its contractors and providing its customers with a short-term loan to pay under the contract of transportation, operators freeze funds from their debtors. Therefore, operators should have financial flexibility, and it is crucial to have a well-established system of cash flow management. For example, by providing customers with a deferred payment option, they can apply for bank guarantees to cover the debt owed to subcontractors. They can do this using a specific part of their assets that is sufficient to cover the guarantee to the bank.

Despite the critical role of operators in national and international shipments, some countries still do not use the related benefits. For example, Russia has sufficient experience in managing cargo delivery operations with the use of different modes of transport. At the same time, there is the strong financial position of individual companies. Therefore, the creation of operators and the licensing of their activities can provide a sufficiently effective system of management of maritime activities in Russia. This would facilitate the transformation of marine resources through political will and power into real national wealth. However, so far, the primary attention in the country is paid to the implementation of transit transport projects in which railway transport is a priority (Panova, 2016).

The railway complex of Russia, organizationally registered in the form of the company "Russian Railways", took sixth place in the list of global transportation and logistics companies (Kiryanov, 2016), and thus has the opportunity to become a significant Eurasian transport operator. In this regard, in 2014, on the initiative of the Railways of Russia, Kazakhstan and Belarus within the integration of the three countries on the basis of the Common Economic Space (CES) and the Customs Union (CU), the JSC "United Transport and Logistics Company" (OTLK, Moscow) was established. The updated operating model of JSC "OTLK" also allows for the possibility of attracting third-party operators of rolling stock and logistics companies on market terms to optimize the cost of services and improve their quality. Thus, it will be possible to provide not only basic services to customers, but comprehensive services by the "terminal-to-terminal" principle at the initial phases, and then with the use of the "port-to-door" principle, i.e., from the warehouse of the sender in the port to the warehouse of the recipient under the full responsibility of a single transport operator. The creation of such a single coordinating operator will allow the most efficient transportation to international destinations. They will be able to use both: rolling stock and leased ships. Additionally, other components adhered to the phenomenon of intermodalism will be at their disposal. These are a network of dry ports, transport corridors, and other transport infrastructure.

The system of international transport corridors is an integral attribute of modern globalization processes that integrates the vital interests of the three leading world centres of Europe-America-Asia, which account for 90% of world trade. Within a transport corridor, one or several modes of transport can be used to move stable cargo flows in a given direction (Shabarova, 2002; Gombosed, 2013). Morozov (2009) proposes to consider the transport corridor as a set of industrial transport areas (clusters) through which the transport corridor passes. The essential Eurasian transport corridors are summarized by Hilletofth et al. (2007):

The Northern Corridor, also known as the "Tran-Siberian land bridge", connecting the Netherlands (mainly the sea port of Rotterdam), Germany, Poland, Belarus, Finland, Sweden, Russia and passing directly through the territory of Kazakhstan to China (the sea port of Lianyungang) has a total length of 11 thousand kilometres. The corridor was formed in 1990. Most of it (9.2 thousand kilometres) is the Trans-Siberian railway (TSR). A change of railway gauge takes place on the Polish-Belarusian border (1,435-1,520 mm) and the borders of Russia-China and Kazakhstan-China (1,520-1,435). It is also called the "West-East" corridor in the literature because the corridor is vital for the commercial relations of Europe and Asia. It has the largest capacity and the shortest delivery time for goods compared to other corridors in the Eurasian direction.

The TRACECA corridor (Europe–Caucasus–Asia) goes from Western Europe to Central Asia, connecting the Netherlands, Germany, Austria, Hungary, Romania, Ukraine, Moldova, Russia, Bulgaria, Georgia, Azerbaijan, Turkmenistan, Uzbekistan, Tajikistan, Kyrgyzstan, Kazakhstan and China. The progressive elaboration of the TRACECA project began in 1995 at the suggestion of the European Union. The disadvantage of this transport corridor is that the rolling stock has to move twice from one gauge to another. Additionally, the mode of transport changes four times: from rail to water, and vice versa, in the ports of the Caspian Sea and the Black Sea. Besides, the corridor crosses more than a dozen countries, each of which has its own laws and customs regulations. Calculations show that although the TRACECA route is shorter than the previous one, cargo delivery will take longer due to these circumstances (Gombosed, 2013).

The *"North-South"* corridor passes from Northern Europe to the Persian Gulf. The main route starts in Helsinki, Finland, continues through the territory of Russia and is divided in three directions on the approach to the Caspian Sea:

1) Western – via Azerbaijan, Armenia and Western Iran;
2) Central – from the Russian port of Olya, Caspian Sea, to Iran. The ferry service from the port of Olya (Astrakhan region)–Enzeli (Iran)–Turkmenbashi (Turkmenistan) was opened in 1999. In this direction, there are vessels of the RoRo type, which can carry up to 33 heavy-duty trailers; and
3) East – through the territory of Kazakhstan, Uzbekistan and Turkmenistan to Eastern Iran.

The western and central directions both converge on the Iranian capital of Tehran and continue to the Iranian sea port of Bandar Abbas. The North-South corridor also provides access from the sea to Central Asia through Iran.

The Southern corridor runs from Western Europe to South-East Asia and connects Germany, Austria, Hungary, Croatia, Serbia, Romania, Turkey, Iran, Pakistan, India, Bangladesh, Myanmar and Thailand, with branches going to the Chinese province of Yunnan, and through Malaysia to Singapore. A change of railway gauge occurs on the borders between Iran and Pakistan (1,435-1,676 mm), India and Myanmar (1,676-1,000 mm) and Myanmar and China (1,000-1,435).

Despite the existence of land transport corridors, goods are currently transported mainly by sea through the Indian Ocean, the Suez Canal and the Mediterranean Sea. Only a small portion (not more than 5%) is transported by rail across the continent of Eurasia. Rates of tariffs for transportation are of great importance for attracting cargo flows to the transport corridor (Panova, 2016). Even the development of the shortest sea route between Asia and Europe – the *Northern Sea Route* (NSR), will not replace the alternative route using the Suez Canal for the transport of goods.

At the same time, high rates of economic growth in Asia continue to contribute to the formation of a system of transcontinental transport systems through Russia with access to European markets (Panova and Hilmola, 2016). In turn, the corridor system of Europe, which is the base, not only of European but also of Russian intermodal transport, has been formed in a more or less rigid structure. Of the nine priority international transport corridors, three pass partially through the territory of Russia, with further access to Asia:

Pan-European transport corridor No. 1. There is a branch on the territory of the Russian Federation which goes from the main corridor in the direction of the Riga-Kaliningrad border with Poland.

Pan-European transport corridor No. 2 goes in the direction of Berlin–Warsaw–Minsk–Smolensk–Moscow–Nizhny Novgorod, Yekaterinburg. The corridor connects with the Trans-Siberian railway on the territory of Russia.

Pan-European transport corridor No. 9 has the following directions: the border of Finland-St. Petersburg–the Moscow border with Ukraine, as well as branches: St. Petersburg–the border with Belarus and the border with Lithuania-Kaliningrad.

After Russia's accession to the WTO, the development of the transport infrastructure of the Baltic region, namely the *Barents corridor* and the *Klaipeda-Moscow corridor*, became of great importance (Bentzen et al., 2008). The regional development programme envisages the development of transport links in these transit corridors, focusing on increasing investment in infrastructure and increasing corridor capacity.

Soon, the role of the North-Western region of Russia will also increase. The reason for this is in the implementation of the *Rail Baltica Growth Corridor (RBGC)* project by RB Rail AS Company (Bloomberg.com, 2014). It aims to improve the competitiveness and accessibility of cities and regions of the Eastern Baltic. Russia was also a member of the RBGC development project. The objective of the RBGC Russia project programme was to expand the geography of the project beyond the EU. Besides, it aims to involve the North-West of Russia in the mutually beneficial process of development of the transport infrastructure of the Baltic region. RBGC pursues more global goals of the *Rail Baltica (RB) concept*. Specifically, the railway route of the same name will connect the regions of the Eastern coast of the Baltic Sea. It will stretch from North to South; that is, from St. Petersburg (Russia), then Helsinki (Finland)–Tallinn (Estonia)–Riga (Latvia)–Kaunas (Lithuania)–Warsaw (Poland) to Berlin (Germany). From a technical point of view, the main objective of the Rail Baltica project is the unification of the railway track. To date, Finland and the Baltic States, as well as Russia, use a wide railway track of 1,520 mm (in Finland 1,524 mm), while Poland uses European track (1,435 mm). Taking into account the complexity of the issues related to the development of the new Rail Baltica corridor, in fact, the final planning stage should be during 2018-2019. Following this schedule, the Rail Baltica route with the European gauge standard will be put into operation no earlier than 2025.

The second and more large-scale developing project, which is in the interests of all the states of the Eurasia continent, became the Silk Road Economic Belt. This will be more specifically discussed in the next chapter. The project will use the benefits of the Eurasian Economic Union, and the signing of 37 Russian-Chinese documents has already triggered the start of this initiative (in the Kremlin on May 8, 2015; Vestifinance.ru, 2016).

Border-crossing points and *dry ports* located in the direction of one of the corridors of the *Silk Road Economic Belt* play a role of international importance. They are essential components of an effective and efficient integrated intermodal transport and logistics system. Dry ports, also called *inland terminals*, have become widespread in recent years. The movement of block trains, which take goods from ports to inland areas, is carried out on a regular schedule. A single consignor uses the whole train, which is run directly from the loading point to the destination. No assembling and dissembling are required. A block train can be opposed to a *single wagon* option, when the train is formed out of individual wagons or a set of wagons, which have different origins and different destinations.

The presence of a developed network of inland terminals with a stable rail connection is a sign of the effective functioning of a large sea port. The use of the dry port concept has led to a rapid increase in the rail transport share in the throughput of ports. So, for the leading port of Sweden, Gothenburg, the share of railways in cargo delivery from/to the sea port has increased from 28% in 2005 to 46% in 2013. Such practices may indicate the hidden potential for railways of other countries, in terms of a possible share increase in the freight turnover of sea ports employing dry ports. Moreover, a transport company which has its own warehouses and container terminals is able to receive large cargo flows for its transportation. In particular, these are cargo flows that require changes in the process of delivery of the parameters of transport parties. This approach holds value especially for transportation involving several modes of transport (Malikov, 2003, 2005; Panova and Hilmola, 2016). Moreover, companies/transport operators that own dry ports or container terminals can dramatically improve the service for customers (Panova, 2016). Otherwise, a company would hardly be able to positively influence or improve the service in the warehouses that the company uses.

Meanwhile, the productivity enhancement of large container terminals (either inland or maritime) in logistics networks is chased by many participants of the supply chains. This is logical when looking at broader trends in supply chain competition. Many shipping trade routes nowadays are dependent on the competitiveness of hinterland connections and container terminal performance (Felício et al., 2015). This is because of the tremendous and positive effect that port and inland container terminal characteristics can have on time savings. Therefore, they can unlock the potential for cost benefits of entire transportation chains.

In light of such trends, about 10 years ago there were more than 570 dry ports developed in the USA and more than 200 in Europe. In India, by the beginning of 2009, the number also approached two hundred. Three years later, more than 50 dry ports were registered in China. In 2012, in ten European countries (Denmark, France, Germany, Greece, Hungary, Italy, Luxembourg, Portugal, Spain and Ukraine), the number of dry ports was equal to 60. As a rule, dry ports help to ease the processing of cargo in loading units, such as containers, trailers, and semi-trailers that are forwarded through the sea ports (United Nations, 2013; Roso, 2009). These ideas are identified in the intergovernmental agreement on "dry ports", available in the Chinese, English and Russian languages. It was opened for signature in Bangkok, on 7-8 November 2013, and then remained open for signature at the United Nations headquarters in New York until 31

December 2014. On 23 April 2016, it was ratified by eight out of 17 countries (Russia, Bangladesh, India, Kazakhstan, Republic of Korea, Tajikistan, Thailand, and China).

With the ratification of the Agreement, the dry port definition was fixed at the level of a normative legal act. In particular, the Agreement (Article 1) defines a dry port as “the site located on the inland territory of the country”. It includes a logistics centre connected to one or more modes of transport. Besides, such a site is intended to provide processing, temporary storage, and the lawful inspection of goods. Particularly, these services are directed to goods that are carried in the course of international trade. Therefore, the fulfilment of applicable customs control functions and formalities is the inevitable function of the dry port. According to the document, each country provided a list of dry ports that can be used for handling cargo. Russia offered 15 dry ports, including those existing and projected, China offered in turn 18, and Kazakhstan proposed five.

Most of the Russian dry ports are concentrated near the northern capital of Russia (St. Petersburg; Korovyakovskiy and Panova, 2011). However, these examples of inland terminals do not have the full range of characteristics of the “dry” port. The main barriers to their development in Russia are the poorly developed infrastructure of cities, primarily railway, as well as the uncoordinated work of customs, transport companies and terminal owners.

In Russia, in order to reduce the investment burden and provide a faster commissioning of dry port projects, the public-private partnership (PPP) scheme of investments has been used in recent years. An example would be the “Hovrino” inland terminal that is connected with the port of Ust-Luga, which demonstrates the successful development of infrastructure through a public-private partnership, involving JSC “Russian Railways”. This project was put in operation in 2014 and was apparently initiated inland, by Russian Railways, which plans to increase its throughput in the sea port, in which it already owns shares. Therefore, the PPP project is related to the scheme, “inside-out” (Roso, 2013; Wilmsmeier et al., 2011), which indicates the origin of interest, from representatives of the inland side, e.g. Russian Railway subsidiaries moving forward to enlarge their share in sea port throughput.

On the contrary, another example is the “Predportovy” project that was presumably initiated by the sea port and belongs to the scheme “outside-in”. The model’s name is given in compliance with the cooperation of the interests of sea port actors willing to expand in the hinterland. The inland container terminal “Predportovy” of the logistics company “Eurosib” was developed in cooperation with Russian Railways (JSC RZD) and connected with the St. Petersburg sea port. It was commissioned in 2006 (Panova and Hilmola, 2015).

One of the first privately owned inland terminals became the “Logistics-Terminal”. The geography of customs was changed for this terminal. The port and the terminal were both included in the service area of one, Baltic, customs area. It provided the smooth technology of customs clearance. The work of most Russian dry ports is oriented on the processing of import flows because import flows are delivered to Russia in containers.

Meanwhile, exported cargo from Russia is not suitable for delivery in containers. Exports are represented by raw materials, i.e., oil, gas, and coal. However, the situation may change if dry ports are equipped with appropriate technologies (such as flexible polymer tanks: flexitanks and dry-liners, installed in large-capacity containers for the transport of petrochemicals, agricultural and food products, etc.; Panova et al., 2012). Then, the dry ports can be located close to the industrial enterprises. This will provide regular shipments of goods for export. At the same time, the nomenclature of goods can be broad.

In this regard, the work of dry ports will not be solely limited to the service of the sea port, according to the global concept of dry ports. The dry port can also facilitate the work of inland border-crossing points, if located close to the borders. There are several dry ports in Russia, close to the border with China. They have already been opened but are still under expansion and construction. Most of them are co-located with railway stations. The Yuzhny dry port, which was put in operation in 2014 is situated close to the train station of Nadezgdinskaya. The next dry port Primorsky, which is also on the way to the border-crossing point of Grodekovo, is expected to be fully functional near the railway station of Ussuriysk. Beside the Khasan border-crossing point with North Korea, a dry port will be settled near the train station of Malakhino (Panova, 2011; United Nations, 2013).

In China, one of the largest dry ports is Shijiazhuang dry port (design capacity of 205,000 TEU). Direct links connect it with the Tianjin sea port. The second largest is the Alashankou dry port. International cargo to and from the Lianyungang sea port to Alashankou normally bypasses Urumqi West Railway Station (Hanaoka and Regmi, 2011). Near Urumqi railway station, the Xinjiang Rail International Logistics Park, named as a dry port (United Nations, 2013), was opened in 2016 (Chinadaily.com.cn, 2018).

Since then, a weekly cargo train service has been started between this dry port and the port of Duisburg, considered the world's largest inland port (Xinhua, 2016). The new route, which starts in Duisburg (Germany) or Rotterdam (Netherlands), goes through Poland, Belarus, Russia, and Kazakhstan to China (the sea port of Huanghua in Bohai Rim; Russian news.cn, 2016).

Dry ports were also developed near the border-crossing points of China with Mongolia, e.g., Erenhot and Manzhouli (United Nations, 2013). The Erenhot dry port, which is close to the border with Zammin-Uud in Mongolia, handles containerized and bulk cargo (Hanaoka and Regmi, 2011).

Nevertheless, critical attention in China is paid to the promotion of the Xinjiang Region rather than Inner Mongolia, since Xinjiang has been designated as the "core area" of the Silk Road Economic Belt, because it shares borders with eight countries: Afghanistan, India, Kazakhstan, Kyrgyzstan, Mongolia, Pakistan, Russia and Tajikistan (Cbbc.org, 2016). This is why the development of dry ports (especially, Alashankou dry port, and the Xinjiang Rail International Logistics Park) will be further continued. At the same time, co-located border-crossing points with Alashankou railway station and Urumqi West Railway Station will be improved. This will facilitate the promotion of trade and connectivity between China and Kazakhstan.

Kazakhstan has seven border-crossing points with China. Not all of them are operational, though (e.g., Narynkol–Muzart in the south-east, and Alekseevka–Aheytubiek in the north-east; Caravanistan.com, 2016). Until 2012, the only railroad border crossing between Kazakhstan and China was between Dostyk railway station in Kazakhstan and Alashankou in China. Meanwhile, the most essential road link from Kazakhstan to China was via the Khorgas border-crossing point. In December 2011, a 293-km railway was completed from the Khorgas border crossing to the Zhetygen terminal (near Almaty), and on December 22, 2012, the first regular trains from the two countries crossed the border at Khorgas. A railroad now connects Khorgas with Jinghe via Yining (Gulja), where it connects to Urumqi. The Khorgas "dry port" on the Kazakh-Chinese border is planning to increase trade across Central Asia (Farchy, 2016). The railway border crossing is expected to handle up to 15 million tonnes of freight per year initially, the volume rising to 30 million tonnes per year in the long run (News.huochepiao.com, 2012).

The development of dry ports along the Silk Road Economic Belt can stimulate the realization of the initiative concerning the possibility of a transit customs policy. It implies the performance of customs procedures only at the countries of origin and destination of the shipments. Most of the dry ports of China are connected with the central train stations in Kazakhstan. In particular, both border-crossing points of China (Alashankou and Khorgas) are linked to the Dostyk railway station in Kazakhstan. Despite the real potential of simplifying institutional procedures between the countries based on the network of dry ports co-located with border rail stations, one of the challenging obstacles that remains is the barriers of technological connectivity between different railway systems. First and foremost, these would be difficulties that occur during the break-of-gauge problem (Panova et al., 2018).

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CHAPTER THREE

TRANSPORT INFRASTRUCTURE MEGA PROJECTS

YULIA PANOVA & OLLI-PEKKA HILMOLA

3.1. Eurasian logistics infrastructure performance

Nowadays, in Eurasian logistics, the all-water route which goes through the Suez Canal is of critical importance (Lunxiao, 2016). Along with this, new routes via Russia have been identified by local companies. It is not only serving as the transit territory for European based cargo, but also collaboration among Eurasian countries is increasing. Examples are the *"Primorye-1"* (Vscport.ru, 2016) and *"Primorye-2"* projects, which both intend to integrate the Asian-side sea ports of Russia to serve, e.g., very Northern Chinese logistics sector needs by intermodal transport solutions (Otvprim, 2015). These have also increased the use of the Russian railway network (Russiachina-eastcargo.com, 2018).

Critical reasons for the recent development of these routes are the vast and expanding trade growth with China. Primarily, this concerns the northern provinces where Far Eastern sea ports have mushroomed. Container turnover of Far Eastern sea ports is growing faster than that in the rest of the Russian ports (+26.7% in 2016 and +23.9% in 2017 to 1.48 Ml TEU; Morvesti.ru, 2017a; Morvesti.ru, 2018). The leading pace of throughput enlargement is demonstrated in the Vladivostok sea port, which is accountable for 56% of total cargo turnover of sea ports of the Far East oceanic basin. Its handling volumes, mainly cargo in containers, have experienced growth. In particular, the stevedoring company in the port, OJSC "Vladivostok MTP", has risen on the list of the biggest maritime stevedoring companies in Russia. In terms of container handling, it moved from fifth position in 2015 to third position in 2016, remaining in the same place in 2017 (Morvesti.ru, 2017b; 2017c).

Apart from the routes “Primorye-1” and “Primorye-2” that utilize Far Eastern sea ports and adjacent railways in Russia to deliver cargo in connection with China-EU, there is potential gain from the route between the two Koreas. Recently, South Korea announced plans for building a $35 billion high-speed railway to connect North Korea with the world (Businessinsider.com.au, 2018). With the possible future resolution of disputes between North and South Korea, the route is considered to be the most competitive between Korea and the EU (Moon et al., 2015). It lies via the Trans-Korean Railway (TKR) and is also connected with the Trans-Siberian Railway (Russia). Therefore, it can also be favourable for Chinese trade companies, if the origin point of cargo flows is in the northeastern regions of China.

In order to maintain traffic growth, Far Eastern Russian sea ports are enlarging their capacity by acquiring new equipment and strengthening their cooperation with railways (Vscport.ru, 2017). Many stevedoring companies in the sea ports (more than 50% of respondents, according to the survey from Ernst & Young Global Limited, 2016) highlighted exciting outcomes. The insufficient development of rail infrastructure is among the main factors which hinder an increase in the volume of cargo transshipment through terminals. Additionally, they mentioned the inadequate depth of canals in the marine waters of ports. In some estimations, by 2020, the length of “bottlenecks” on railways will reach the point of 20,000 km (Ernst & Young Global Limited, 2016). In order to reduce the workload on Russian railways, which provide approximately 50% of transportation to sea ports, stevedoring companies use alternative options via roads for deliveries of cargo (Vscport.ru, 2017). However, respondents, likewise, identified the insufficient development of automobile infrastructure as the third drawback factor for the growth of sea port throughput (Ernst & Young Global Limited, 2016).

Currently, companies have also started to employ intermodal air transport for shipping cargo from China (Peyrouse, 2008). In particular, from Chongqing (China) to Amsterdam (Netherlands): JSC’s “KTZ Express” together with logistics partner DB Schenker and flights scheduled by Dutch KLM organized the transportation of cargo. Part of the route, from China (Chongqing) to Almaty (Kazakhstan), was provided by railway transportation with transshipment at Dostyk (a border-crossing point between Kazakhstan and China). Air transport services covered the second part of this route with a total shipping time of around seven days (Gudok, 2016).

In light of this situation, the populated regions of Russia also experience new air transport infrastructure development. The outstanding national project is the Ust-Luga multimodal hub (located in the western end of Russia, near St. Petersburg). The idea is to bring together four modes of transport in one place. Meanwhile, the sea port of Ust-Luga, with federal highway and railway approaches, including the railway junction in the port area, has been in operation since 2001 and has exhibited a fast pace of cargo traffic growth since then. In 2013, the sea port became the third-largest in Russia and it was the second-largest in 2015. The air mode of transport will soon be added to this hub (with the services of building and maintaining planes in the hub).

The need for this project is high for many companies and state structures. Some companies wanted to attract smaller planes relating to business aviation, similar to the airport in Hamburg. Particularly, Airbus assembles and tests its aircraft there, and clients accept aircraft directly at the port, from which they are forwarded to the required destinations. At the same time, companies such as Express Mail, DHL, EMS, and other operators of e-commerce (or electronic trade, which is popular in China) are also interested in this site. Logistics companies and operators with the use of Ust-Luga's multimodal capabilities will be able to optimize their business processes (Vlasova, 2016).

The cargo airport will be built in Ust-Luga to provide a supportive role to the existing airport of Pulkovo (St. Petersburg), as well as airports of the Central and North-West Regions of Russia. Meanwhile, air transport for freight traffic applicability is limited. In this regard, the competitiveness of the overland transport infrastructure is higher due to a broader nomenclature of goods feasible for transportation by land modes of transport. Specifically, Gudok (2016) advocates for SREB (Silk Road Economic Belt). This is grounded in the development of links used by traders, many centuries ago. At that time, the Chinese city of Xi'an was the starting point of the Silk Road. In Russia, this is the modernization of the Trans-Siberian Railway and its parallel paths, e.g. Baikal-Amur Railway during the period 2017 to 2019 (330.8 billion rubles; 231 billion rubles were already invested; Press.rzd.ru, 2017).

With the initiated developments on the SREB, it is expected that about 40% of the transportation flows will be redirected from all-water routes to overland transportation corridors by 2030 (Ergashev, 2015). The realization of projects of the overland transportation corridors included in the SREB can reduce the cargo delivery time from China to Europe to 15 days. It is considerably lower than that provided by the all-water routes via the Suez Canal (roughly 45 days). It has been argued that there are up to 40 different transportation corridors linking China and Europe together (Sheu and Kundu, 2018; Shepard, 2016, 2017a; Dong et al., 2018; Contessi, 2016; Rodemann and Templar, 2014). Therefore, the SREB could potentially include numerous transportation corridors. Several countries can provide the freight cargo basis for backward traffic to China along the routes of the SREB. These are mainly economies that supply Chinese industries with fuel and energy resources. They are mainly in demand in the newly developed Central and Western regions (Kibalov and Bykadorov, 2016; Schneider et al., 2015; Notteboom and Yang, 2017; Rodrigue, 2015).

The use of the corridors that lie between Europe (e.g. Finland or Poland) and China via Central Asia-Russia will be preferable in terms of time and customs (Yang and McCarthy, 2013). The government of China had already made a milestone step in simplifying customs procedures by signing the agreement on the strategy for linking the SREB and the Eurasian Economic Union (EAEU; Korostikov, 2016). Specifically, the EAEU provides one customs tariff, removing customs borders between Belarus, Kazakhstan, Russia, Armenia, and Kyrgyzstan, which are passed through along the routes (e.g. 0% VAT; Yang and McCarthy, 2013; Islam et al., 2013).

It should be noted that the transportation of cargo in connection with China is increasing via overland routes through Kazakhstan, Mongolia, and Russia. The Trans-Kazakhstan and Trans-Mongolia transportation corridors utilize the Trans-Siberian Railway. Over the TSR, the cargo in containers is mainly forwarded by PJSC “TransContainer”, the subsidiary of JSC “Russian Railways”, and the national leader in container transportation, which manages the largest fleet of containers and flatcars in Russia (Trcont.com, 2018a). TransContainer is an international company which transports significant volumes of cargo in containers from China to Russia or in transit directions through Russia to Europe.

PJSC “TransContainer” organizes the forwarding of fast trains in the directions of stable cargo flows, such as the TSR. The company’s main routes for container transportation from China are provided via the Vostochny sea port and the Zabaikalsk border-crossing point (Russia) located inland in the vicinity of the Inner Mongolia province (China). The advantage of delivering a container (e.g., from Shanghai) through the port of Vostochny is the cost (Perminova, 2016), which is mostly down to the transportation of containers from the ports of China to the port of Vostochny. This route implies lower sea freight costs.

The shipping of cargo via the Zabaikalsk (Russia)–Manzhouli (China) border-crossing point is provided by two alternatives. The first scheme implies the direct railway delivery of the container from ports in China to Manzhouli. Then, the container is transshipped from the Chinese railway (with a gauge of 1,435 mm) to the Russian railway (with a gauge of 1,520 mm). The second scheme involves combined transportation – the delivery of containers from Chinese ports, such as Shanghai, Ningbo, Guangzhou, Shenzhen, and Yantian by sea to the port of Tianjin, at which the container is loaded onto the railway and delivered to Manzhouli. This combined transportation allows a saving on the cost of transportation through the territory of China since sea freight is cheaper than the railway tariff. Nevertheless, it is still higher than the cost of delivery through the Vostochny sea port (Perminova, 2016).

The recent development of new schemes for the delivery of containers from China by the company PJSC "TransContainer" and other competing companies has had a favourable influence on container traffic on the Trans-Siberian Railway. It should be noted that the volume of international container traffic, using the TransContainer assets (Figure 3-1), replicates the international container traffic via the TSR (Figure 3-2). Since 2007, there has been a positive development of containerized cargo via the TSR (except for the economic crisis and sanctions during the years 2009, 2015, and 2016). The same applies to the transportation of containers by TransContainer: at the end of 2008, volumes reached 1.502 Ml TEU from 1.310 Ml TEU in 2007, while in 2009, the decrease was close to 19%, reducing the traffic to 1.221 Ml TEU (Trcont.ru, 2018b).

Figure 3-1. The volume of container traffic at railways, using the TransContainer assets, in TEU ('000s). Sources: Trcont.com (2018a), Trcont.com (2018c)

Import-export shipments mainly provide an increase in container traffic over the TSR and Russian Railways as a whole. As a result of the development of car assembly plants, transportation volumes of imported car parts in Russia have been stimulating imports. However, the preservation of a weak currency (ruble) against significant world currencies may have a deterrent effect on container imports, while, on the other hand, remaining a facilitating factor for the increase of exports.

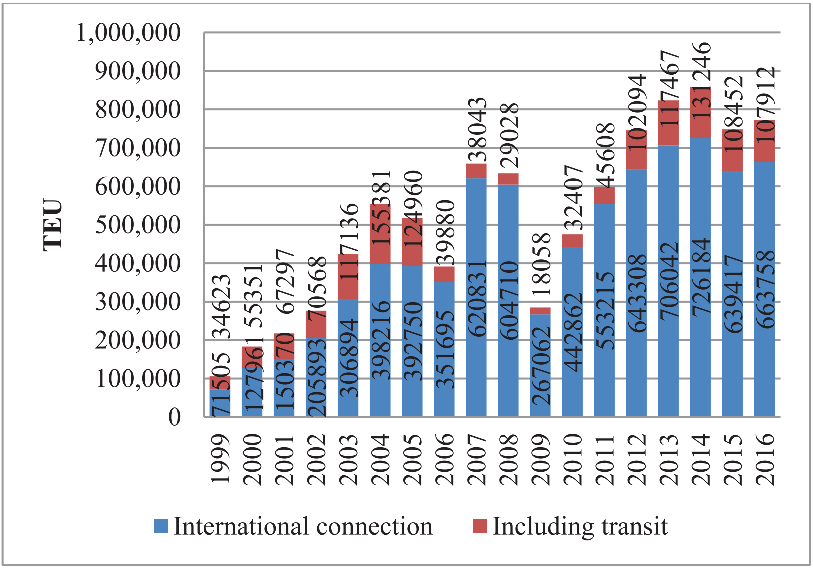

Figure 3-2. Dynamics of international container traffic via the TSR (in TEUs). Source: Coordinating Council on Trans-Siberian Transportation (2018)

In the long term, import-export shipments will continue to trigger the growth of container traffic via the TSR, especially with the more active involvement of Russia in the international trade system (due to Russia's accession to the WTO in 2012). Since the year 2012, the structure of container traffic (i.e., the proposition of export, import, transit, and domestic traffic of total container flows) using the TransContainer assets and via Russian Railways to a more considerable extent, did not change significantly (Figures 3-1 and 3-3), if the year 2017 is not taken into account.

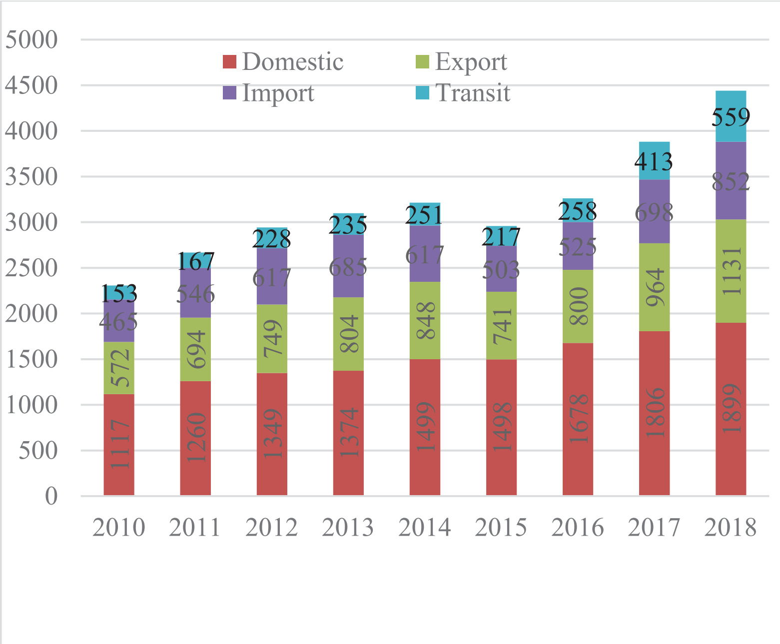

Figure 3-3. Russian market of railway container transportation (in '000 TEUs). Sources: Trcont.com (2018a), Trcont.com (2018c)

In the year 2017, transit traffic grew to a record 11% share on Russian Railways from an average of 8%. Meanwhile, the domestic container flows remained more or less stable over the years. They comprise a significant share of all container traffic (approximately 48-53%). At the same time, their share in export and import directions was accordingly, 24-25% and 16-19%.

In the first eight months of 2017, more than 482 thousand TEU were transported along the Trans-Siberian railway, which is 1.5 times more than in the same period of the previous year (Figure 3-2). At the same time, transit traffic increased by 78% to 113 thousand TEU (Rns.online, 2017). In 2018, Trans-Siberian container transportation in international traffic continued to grow by 23% to about 950 thousand TEU (a quarter was in the transit direction; Morvesti.ru, 2019).

By the estimations of the Coordinating Council on Trans-Siberian Transportation (CCTT), the volume of international container traffic via the

TSR could soon (e.g., by 2020) grow to one million units per year. This is from current volumes, which during the period January-August 2019 increased by 25% compared to the same period of 2018, to 727 thousand TEU (Morvesti.ru, 2019). The total container volume over the Russian Railway (including the TSR) could increase to more than 4.5 Ml TEU in the coming years. This is especially true if taking into account the growth of export-import shipments and transit traffic.

On the whole, such indicators were largely achieved due to tariff regulation. In particular, on the initiative of the CCTT, rates for the transportation of goods in 40-foot containers changed in 2014. They were reduced by 42% for containers in container trains forwarded to China. The same rule was applied to the opposite direction through the Brest border-crossing point. These conditions were also preserved in 2015 (Rzd-partner.ru, 2015).

Additionally, new services have been introduced on the route. For example, in 2016, a pilot joint project of JSC "Russian Railways", TransContainer, Chinese Railways, the Container Corporation of the Chinese Railways, and Dalian port started the implementation of the transportation of goods for Samsung in container trains from Dalian to the Kaluga Region (near Moscow) through the Zabaikalsk (Russia)–Manzhouli (China) border-crossing point. Since the beginning of the service, in the year 2016 alone, this new route attracted some thousand(s) of TEUs (Rzd-partner.ru, 2016; a mid-October 2016 article mentions that 944 TEUs had already been transported). On average, up to the present day, more than 30 routes of container trains for domestic and international destinations have been laid through the TSR. This has led to a constant increase in traffic (Coordinating Council on Trans-Siberian Transportation, 2018).

Many authors have studied the competitiveness of the overland routes on the grounds of transportation costs (Hilletofth et al., 2007, Panova, 2011; Verny and Grigentin, 2009; Rodemann and Templar, 2014). In addition to previous research, it is essential to conduct an analysis of several key performance indicators. At the same time, financial benefits have an interest, primarily, those that can be attributed to the whole logistics network and its parties (e.g., customers, shippers, terminal operators and other companies, as well as countries, to a broader extent).

Nowadays, shipping container businesses are striving for the minimization of non-value-added time at the network nodes. These are border-crossing points, railway stations and co-located maritime and inland container terminals. The minimization of processing time at these nodes can provide a reduction of the vessel, train or wagon turnaround time (the round-trip time between two loadings). This, in turn, can help to improve the operation of the assets and reduce logistics costs (Figure 3-4).

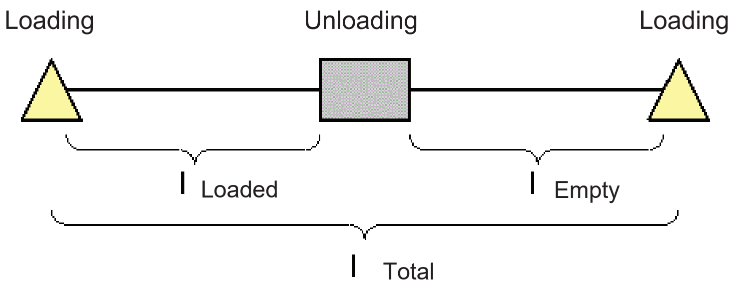

Figure 3-4. Turnaround time

On the whole, the turnaround time includes two parts: the time spent on the voyage and at the nodal point under initial or final operations. The second element of turnaround time should be reduced. The reason for this is that, for water transport, rates for initial-final operations at the terminals are highest in comparison with other modes of transport. A minimum rate for initial-final operations exists for road transport (Panova and Isaeva, 2016; Xukuo and Qiong, 2013). However, road transport has the highest rates for the voyage part or transportation cost component alone (because of low capacity and high fuel expenses). On the contrary, in maritime transportation the freight rates are the lowest due to the economy of scale.

The share of costs related to the voyage and operations in nodal points is also determined by the specification of the route and used transport modes. In Russia, for example, when taking into account the structure of exports and shipping locations, the loading and unloading rates at the sea port have a much lower proportion than the tariffs for rail transportation and sea freight, and account for 10-12% of the through (total) rate for the transportation of cargo from the origin to the destination point (Association "Union of port operators", 2010). However, if the distance to the sea port is, for example, 100 km, then the railway tariff can be comparable with the cost of transshipment at the sea port.

Meanwhile, regardless of transport combinations, the reduction of turnaround time can lead to the growth of productivity and the minimization of associated expenses. Kovalev and Osminin (2011) highlighted that the wagon turnaround time (WTT) reflects the performance outcome of many production processes. Specifically, the main factors affecting the WTT are not only the technical condition of the infrastructure and rolling stock but also the quality of the organization of the operational work, the level of discipline and coherence in the actions of all involved departments and organizations and their employees. The WTT is also known as wagon rotation, i.e., the "time from when they receive a load and deliver it to a plant to the time when they return to the point of loading" (Palander, 2015, Figure 4). This time consists of three main components, according to its formula (Table 3-1; Kovalev and Osminin, 2011).

The first part of the WTT formula (Table 3-1) shows the wagon's proportion of the WTT on the voyage (in its movement, including stops at intermediate stations). The second part of the WTT formula represents the time that a wagon spends at technical stations during the turnover. Finally, the third part describes the wagon's time at the loading and unloading stations.

Table 3-1. Key performance indicators of a transport infrastructure operation. Source (original; modified with wagon working fleet): Panova et al. (2018)

Indicator	Description	Formula
Wagon turnaround time	The round-trip time between two loadings, which is comprised of three time components (i.e. three terms in the formula).	$\theta = \frac{\left(\frac{l_{loaded}(1+\alpha)}{V} + \frac{l_{loaded}(1+\alpha)}{L} \cdot t_{tech} + K_{loc} \cdot t_{loc} \right)}{24}$, where l_{loaded} – voyage in the loaded state, i.e., the distance that the wagon travels during the turnaround time, km, α – empty run ratio, V – "precision" speed (or the average speed of the train along the section, taking into account the time of stops at the intermediate stations, acceleration, deceleration and delay of the train on the stretches), km/h, L – "wagon shoulder", which means the weighted average distance between technical rail stations, km, t_{tech} – the average time that wagon spends at technical stations, h,

		K_{loc} – the coefficient of local work for the general working fleet of wagons, t_{loc} – the average time that a wagon spends at the loading and unloading stations.
Wagon working fleet	Number of wagons participating in the performance of a specific transportation operation.	$N = \theta \cdot U$, units U – for the rail network, the number of loaded wagons, N – the number of wagons.
Inventory cost	The cost related to storing and maintaining inventory over a certain time.	$S = (C \times I \times \Delta D) / 365$, where S – savings on inventory costs, C – the cost of goods, I – a percentage of the inventory cost in the price of the goods, ΔD – the difference in the timing of delivery, days, 365 – days in a year.
Opportunity cost	The cost related to a benefit that a person/company could have received, but gave up, to take another course of action.	$\mathrm{R} = (\mathrm{C} \times \mathrm{E} \times \Delta D) / 365$, where R – reduction of opportunity cost, C – the cost of goods, E – a percentage of the annual price reduction, ΔD – the difference in the timing of delivery, months, 365 – days in a year.

Davydov and Kotlyarova (2008) stress that up to 70% of the WTT is the time the wagon spends at the stations and only 30% is the time on the voyage. Sharma and Manimala (2007) consider that actions for reducing turnaround time mainly concern the terminals (better loading, unloading facilities, reduction of detention times as well as de-bottling infrastructure constraints). Therefore, the minimization of time-related to the second and third components of the WTT formula can provide tremendous benefits for different participants of the supply chain.

At the same time, Eremenko and Shirokov (2015) underline the detention of the wagon at the (un)loading stations. This is the last component of the WTT formula, which is an essential operational indicator of the station's operation. Its excess leads to difficulties in the regular operation of the station and reduction of its capacity, and naturally contributes to the growth of the WTT, and, therefore, to the working fleet of wagons and containers (Eremenko and Shirokov, 2015; Panova et al., 2012; Eitatus and Zits, 2016).

From the formula of the working fleet (Table 3-1), it is easy to see the dependence between two parameters. The larger the WTT, the more wagons (N) are required to carry a particular volume of traffic. The working fleet is expressed in terms of the number of wagons loaded in a day. The shorter the turnover time of the wagon, or the faster the turn of each wagon, the more cargo can be transported by the number of wagons in the working park. Thus, the turnover of the car determines the possibility of carrying out a particular volume of loading, and consequently, the acceleration of the turnover of the wagon is the most crucial task in the transportation process.

For example, the commercial policy for freight services of “Bulgarian State Railways Inc” envisaged the utilization of companies’ resources. It was found that the acceleration of freight wagon turnover by half a day will enable the company to operate about 200 freight wagons more per day. It allowed the projected freight volumes of 21 million tons to be covered (Holding BZD, 2006). Similar benefits (higher utilization of assets and reducing the revenue leakages) have been experienced on Indian railways (Ravindra, 2008). The need for the WTT reduction is acuter for private companies. The reason is that public organizations, in the case of financial losses related to the turnaround time, can survive on budget support. However, this support can scarcely be possible for private companies (Sharma and Manimala, 2007).

During the last four decades, wagon turnaround time has been of particular interest to Indian research studies. Attention to this indicator was not only raised by researchers but also by practitioners and policy-makers (Sharma and Manimala, 2007). The potential of WTT can be used by representatives of private railways that are considered to be efficient. Reportedly, the public sector, by its nature, can hardly be productive and effective (Sharma and Manimala, 2007). Nowadays, many railways transform from the stance of public ownership to private companies. They confront liberalization and deregulation (Laisi and Panova, 2013). Therefore, the WTT management holds its usefulness for newly established companies.

In this regard, the low average wagon turnaround time is one of the primary concerns for the logisticians in the country (Sahay and Mohan, 2003). An understanding of the phenomenon of WTT can help managers make strategic decisions. Moreover, many parties can be interested in the reduction of WTT. The reason for this is that the WTT of ships, wagons and trains is closely related to the productivity gains that are often shared with customer satisfaction (Mabhena et al., 2016; Mutambatsere et al., 2013; Haralambides and Gujar, 2011). At the same time, not only policymakers but also other vital parties (ship/carriers and terminal operators) may consider WTT reduction.

The third indicator, inventory cost, is also related to productivity, as it depends on the reduction of the delivery time (Lukinskiy et al., 2016). The shorter the delivery time, the lower is the inventory cost (Table 3-1). This effect is essential for terminal operators and shipping lines. Finally, the opportunity cost indicator, which is expressed in financial terms is of critical importance to the cargo owners (Hilletofth et al., 2007). The criterion can be used for the comparison of the transportation routes in terms of their efficiency if the formula includes the difference in the timing of delivery (Table 3-1).

To compare alternative transportations, one of the popular destinations from China will be considered below that goes via Kazakhstan or Mongolia and then through Russia and Belarus (Table 3-2). Reportedly, the route via Mongolia is 30 to 50% cheaper than the alternative railway option via Kazakhstan (Joc.com, 2017). On the whole, both routes can be attractive to electronics companies like HP; a shorter transit time compared with shipping by sea is worth paying for (Farchy, 2016).

The following assumptions have been made in order to compare the four transportation options. Assuming that transportation by railway is almost twice as fast as by sea (Rodemann and Templar, 2014), the savings on the inventory costs would be 7,192 USD ($1{,}250{,}000 \times 0.35 \times 6/365$). For the alternative via Kazakhstan, the savings on the inventory costs compared to the sea transportation alternative are more noticeable ($1{,}250{,}000 \times 0.35 \times 11/365 = 13{,}185$ USD, Table 2) than for the route via Mongolia ($1{,}250{,}000 \times 0.35 \times 8/365 = 9{,}958$ USD, Table 2).

Table 3-2. Comparison of alternative delivery options. Source (original; modified with Mongolian option): Panova et al. (2018)

Indicator	Transportation by sea (USD/TEU)	Combined transportation (USD/TEU for rail and USD/load for air)		Transportation via Kazakhstan (USD/TEU)	Transportation via Mongolia (USD/TEU)
		Rail	Air	Rail	Rail
Tariff	2,000	2,000	14,000	4,000	2,800
Price of the product	1,250,000				
Delivery time	24	7		13	16
Savings	On sea transportation (when compared to the railway option)	On the combined option of transportation (when compared to the rail option)		On railway transportation (when compared to the sea option)	On railway transportation (when compared to the sea option)
Inventory costs	-	7,192		13,185	9,589
Alternative costs	-	4,931		9,041	6,575
Tariff	2,000	-		-	-
Total savings	2,000	12,123		22,246	16,164

The next criterion evaluated in the comparative analysis is alternative costs (Hilletofth et al., 2007). It is assumed that the annual price reduction of goods in containers (e.g., electronics due to the development of new models) can be as high as 24%. Therefore, longer transportation leads to a higher reduction in the price of goods, lowering their competitiveness at the point of destination. In other words, it causes the enhancement of alternative costs. In order to prevent the growth of these costs, the goods should be transported faster. The value of the cargo in the container can decrease less if it is carried by the mode of air transport. Then, the savings on alternative costs compared to the railway option would be 4,931 USD (1,250,000 × 0.24 × 6/365). However, such a conclusion is only essential for expensive cargo.

The analysis in Table 3-2 shows that it is worth paying much more attention to transportation by railway. The reason behind this is the expected counterbalance. In the case of using the route via Kazakhstan, there is a twofold difference in tariffs compared to delivery by sea (4,000 USD and 2,000 USD). This difference can be fully covered by savings on the alternative costs (9,041 USD). The same can be said about the option of cargo transportation by railway via Mongolia (1,200 USD vs 6,575 USD). Furthermore, the shorter delivery time by railway, compared to sea transportation, provides savings on inventory costs (13,185 USD and 9,589 USD for each railway option, respectively, Table 2). Hence, the total maximum savings on the railway (22,246 USD) are significantly higher than the additional tariff rates paid by them for a quick delivery (4000 – 2000 = 2,000 USD).

The next comparison concerns the railway option and combined transportation (Table 2). The savings on alternative costs due to a quick delivery by air transport compared to the railway option equal 4,931 USD. The potential benefits gained from savings on inventory costs due to faster transportation are 7,192 USD, which the railway option cannot provide. The total sum of both types of savings is 12,123 USD, which is not sufficiently covered by the difference in tariffs (16,000 – 4,000 = 12,000 USD). In other words, in the given case, such a quick delivery by the combined option with the mode of air transport requires higher payments for the tariff (12,000 USD). However, it is comparable to the potential savings on inventory and alternative costs (12,123 USD).

In conclusion, it can be said that the transportation of goods by railway is the best option, compared to others provided in Table 2. There is an economic advantage for shipping some products in containers by railway, especially if the price of the goods is not low. Otherwise, sea transport is a more suitable option. On the contrary, if the price of goods is significantly higher than the given example from Table 2, the use of the mode of air transport can be justified. This is due to the savings on alternative and inventory costs. They cover the additional payments in the tariff, compared to the railway option.

3.2. Eurasian transport infrastructure development

Europe has a long coastline, and numerous countries have had the improvement of sea port infrastructure on their development agenda, eventually adding more capacity. The implication of this sort of behaviour is apparent in current transportation statistics, where sea transports have a one-third share from intra-EU trade, and three-quarters from external trade (European Commission, 2017). The situation does not change if it is examined through more distant and smaller European countries. In Sweden and Finland, the total number of sea ports is around 45-50 (in each of these countries), and approximately half of these sea ports are open throughout the year (Trafa, 2017; Finnish Transport Agency, 2017). It should be noted that both countries have hinterland access by road and rail to achieve intra-EU transport needs. Of course, in the case of Finland, it is rather limited as a country as most of its hinterland connections are in the north.

There are numerous reasons why Europe has not had a railway connection to Asia before. Due to the history, wars and politics of the last century, railway development did not catch on in a cross-border setting. Also, the higher costs of railways, differences in technology and standards as well as a lack of multinational railway companies have inhibited development. However, the potential of Eurasian hinterland transports by rail is apparent for Europe – it is very natural if examining maps alone. As concluded earlier in this book, railways still have a marginal role as deep-sea transports between Asia and Europe have volumes of 23.1 m TEU containers (the year 2017; United Nations, 2017).

In comparison, the Eurasian route (Trans-Siberian Railway) is attracting a few hundred thousand TEUs as transit traffic, and the overall international volumes on the TSR are below 0.8 m TEU (Coordinating Council on Trans-Siberian Transportation, 2018). North America could act as a positive comparison point. Asian containers are mostly served by west coast sea ports. Then, the final delivery is made through the hinterland using road or rail (US Department of Transport, 2017). There is no reason why Eurasia could not achieve the same situation. If economies are more integrated and peaceful, the railway sector can achieve similar efficiencies to North America. This change will not mean that sea ports are not needed or irrelevant. Transportation corridors and mode shares will change, having impacts on the overall transportation system.

Their further development has been taken under a so-called "umbrella initiative" on the implementation of the "One Belt and One Road" programme. It is a plan to build projects across approximately 60 countries, from the South Pacific through Asia to Europe and Africa (Cheng, 2016; Huang, 2016). Infrastructure investments across Asia, Africa and the Middle East within the framework of all Belt and Road projects are worth $1.8 trillion, including such projects as oil drilling in Siberia, new ports in

Southeast Asia, railways in Eastern Europe and power plants in the Middle East (51voa.com, 2018; Seo et al., 2017).

As journal analyses and their publication mount, it becomes apparent that the One Belt and One Road (OBOR) programme is not only in the interests of transportation. Logistics and supply chain management, as well as general macro-economic issues, energy, environment and finance have received substantial interest (Table 3-3).

The literature review concerning the OBOR programme was completed by searching articles from the databases of Elsevier ScienceDirect and Emerald publishers in early August 2018 and late November 2018. Both times, the search was done with the words, “belt” and “road”. Searches for these words related to titles, abstracts and keywords. In both cases, the resulting articles were high in number (in the case of Elsevier, many hundreds). All of these research works were checked for the inclusion of the OBOR programme. At the same time, they were checked for traffic safety and the use of seat belts in road vehicles (in some cities or countries). In total, 66 valid articles were gathered from two leading publication databases. This is not much when considering the scale of the OBOR programme.

However, it should be remembered that scientific publishing always suffers a considerable delay. Sometimes years, as the actual research takes typically from half a year to one year. Moreover, reviews of peer-reviewed journals also take time. And the same goes for editing and waiting in the publishing pipeline. All in all, it could easily take two years. Therefore, possibly a higher publishing volume is yet to come. The OBOR programme was initiated in Xi Jinping’s speeches in late 2013 (“Silk Road Economic Belt” in September 2013 during his Kazakhstan visit, and “21st Century Maritime Silk Road” in October 2013 during the visit to Indonesia). It makes the entire research execution and publishing period before this completed literature survey to be around four to five years. Actually, four years is the more accurate number as publications always have a waiting delay before actual publishing. Searched articles were all published, or at least the final form was edited (in the early view as final proofs). It is also worth noting that the OBOR programme was not executed right away after the announcements of 2013. The delay consisted of the development of the finance mechanism through the newly established Asian Infrastructure Investment Bank (AIIB). The AIIB became operational in early 2016. In the following analysis,

Table 3-3. OBOR publication numbers in different scientific journals (n=66).

Journal	# of publications
Transportation Research Part E	8
China Economic Review	5
Journal of Eurasian Studies	5
Applied Energy	3
Journal of Cleaner Production	3
Physica A	3
Science of the Total Environment	3
Journal of Chinese Economic and Foreign Trade Studies	2
Journal of Korea Trade	2
Renewable and Sustainable Energy Reviews	2
Advances in Climate Change Research	1
Business Process Management Journal	1
Chemosphere	1
China Agricultural Economic Review	1
China Political Economy	1
Cities	1
Energy	1
Energy Policy	1
Foreign Policy Research Institute	1
Forest Policy and Economics	1
International Journal of Development Issues	1
International Journal of e-Navigation and Maritime Economy	1
International Journal of Industrial Ergonomics	1
International Journal of Social Economics	1
Journal of Asian Economics	1
Journal of Ocean Engineering and Science	1
Journal of Science and Technology Policy Management	1
Journal of Transport Geography	1
Management of Environmental Quality: An International Journal	1
Marine Policy	1
Natural Gas Industry	1
Omega	1
Procedia Engineering	1
Research in Transportation Business & Management	1
Resources Policy	1
Structural Change and Economic Dynamics	1
The Journal of Finance and Data Science	1
Transport Policy	1
Transportation Research Part A	1
Transportation Research Part B	1

scientific OBOR publications have appeared since the year 2016 (nine articles out of 66), and this number increases to 39 in 2018.

As the programme is very large-scale, it is understandable that research journals typically also deal with policies (or politics). There exist ten journals, which have published two or more research articles on the OBOR topic. Only the *"Journal of Eurasian Studies*" and the *"Journal of Chinese Economic and Foreign Trade Studies*" do not have an impact factor in the Thomson-Reuters 2017 evaluations. A group of ten journals is led by an impact factor of somewhat above nine, which was granted to *"Renewable and Sustainable Energy Reviews",* which is followed by *"Applied Energy*" (impact factor of 7.9) and "*Journal of Cleaner Production*" (impact factor of 5.651). It could be concluded that OBOR has been of interest to rather prolific journals.

One way of examining the content of articles is to use the tag cloud technique for analysis. Included in Figure 3-5 are all of the written words of abstracts from the group of OBOR articles – it was produced using the Wordle (2018) application. It reveals that OBOR research is still taking its early steps, as from countries it is China, which is dominating the most common word of countries, but also in general all words (if summing together word frequencies of "China", "Chinese", and "China's"). From other countries or continents, Asia, Russia, Europe, the US, and Pakistan are mentioned. It is rather interesting as the central area of the OBOR programme is in Asia, the Middle East and Africa.

Figure 3-5. Tag cloud analysis of abstract words in OBOR articles (n=66).

Of course, the success of this programme much depends on Europe, Russia and the USA. Europe is an important consumer market, and it is the western end of the OBOR. European manufacturing's significant stronghold in Asia and China should not be underestimated. Russia, in turn, is pivotal for the OBOR programme in numerous ways.

Russia plays an increasingly important role as an energy and raw material supplier to China (Duan et al., 2018; Sheu and Kundu, 2018). Interestingly, abstracts also mention the USA several times. It has been known from the beginning of the OBOR programme and the establishment of the AIIB, that the USA's opinion of the development of Eurasia has been ranging from neutral to negative (Clarke, 2016; Kuchins, 2018). This changing attitude has been a problematic issue for Japan to handle and eventually participate in the programme (Paramonov and Puzanova, 2018). The USA is still neither part of the programme, nor a member of AIIB.

However, in the distant future, China can extend railways to the US and Japan through Russia. Nowadays, it is all-dominating as the transportation route to Europe, whether railway or road transport is concerned (Lukin and Yakunin, 2018; Wang and Yau, 2018).

With the development of railways and roads in Russia, the environment for the realization of the OBOR initiative will be even more favourable. In particular, to follow the current global trends of unmanned vehicle development, in 2018 the Federal Road Agency of Russia (Rosavtodor) started to form the regulatory and technical base in the field of uncrewed vehicles. Their number will reach 10 million by 2020. It is necessary for the implementation of the project "Caravan", aimed at the development of unmanned transport, which the agency has had in operation since 2016 (Comnews.ru, 2017).

In terms of railway project development, Russia pays attention to the Far Eastern Region. The reason is that Russia has a vital role in Northern China, as it often enables transportation to other economically essential countries, such as South Korea and Japan (Lee et al., 2018). In this regard, for the first time in 2018, possible dates for the realization of the project of land crossing, connecting Russia with Sakhalin island (located on the east coast of Asia) and its future extension to the Japanese island of Hokkaido, have been outlined (Russian.rt.com, 2018). With the realization of this project, Japan can become a "continental" country, having a leading position among maritime economies. According to preliminary data on the current project, the period of realization is set for five years (1tv.ru, 2018).

Among other ambitious projects, which fall under the interest of Asian countries with the involvement of Russia, is the construction of the land connection across the Bering Strait. China is considering the possibility of building a high-speed railway towards the US, through Eastern Siberia (Russia), the Bering Strait, Alaska and Canada, reports China Daily (News.ykt.ru, 2014). The total length of the route will be almost 13,000 km – almost 3,000 km longer than the Trans-Siberian Railway. The most challenging part of the project is the tunnel under the Bering Strait of 86 km (Kp.ru, 2017). Similar long tunnels exist between the islands of Hokkaido and Honshu in Japan (53.8 km, they built 40 years) and under the English Channel (50.5 km, designed and erected for 30 years).

However, this project is not mentioned in the Strategy of Railway Transport Development in Russia until 2030. There is only information about the construction of the railway to Yakutsk (this is being built). Further, it is being extended to Uelen, which is a Chukchi town located on the coast of the Bering Strait. This is why the connection of continents will not start before 2030. So, this is a project of the distant future, after 2050, according to some estimations (Kp.ru, 2017). Despite the scepticism of many experts for this project, China claims that it is fully capable of implementing it using its cutting-edge technologies.

The China–Russia–Alaska–Canada–USA railway project is just one of four international projects that are already in some stage of development. The first project is a railway, which goes from London to Beijing through France, Belgium, Germany, Poland, Belarus, Russia, and Kazakhstan that was launched in 2017 (Bbc.co.uk, 2017). The railway is a significant strategic development to assist Xi Jinping's OBOR programme. The second project should connect the west of China with Germany through Kazakhstan, Uzbekistan, Turkmenistan, Iran and Turkey. The third railway will connect the southwest of China with Singapore through Vietnam, Cambodia, Thailand and Malaysia (News.ykt.ru, 2014).

The ambitions of China do not end with these railway projects. The mentioning of Pakistan in the OBOR abstracts (yet not as the primary research subject, like in Malle, 2017; Kuchins, 2018) has been noticed. This is not a coincidence. Pakistan holds a critical geopolitical position for China. It could offer proper hinterland transports together with sea port services through the port of Gwadar (Shaikh et al., 2016; Ahmed et al., 2017). This could happen after the OBOR investments are completed; currently, the initial flow has started (Naz et al., 2018; Kousar et al., 2018). The Pakistani route would offer cost, distance and lead time advantages not only for

Chinese oil imports (a sea transport and intermodal pipeline solution in Shaikh et al., 2016), but also for exports to the Middle East, Africa and Europe.

Ahmed et al. (2017) and Shaikh et al. (2016) estimated that the amount of Chinese investments and loans just to the port of Gwadar centric supply chain is 46 bill. USD. Sea routes through Malacca Strait do take time (Shaikh et al., 2016; Zeng et al., 2017), and are also dangerous (due to pirates, local conflicts and high frequency as well as the volume of shipping traffic). The role of Pakistan in the future of global supply chains cannot be underestimated as current flows of containers through the Singapore transshipment port alone are 30+ million TEU (Twenty-foot Equivalent Units) containers. Besides, its domestic markets are enormous for Chinese products due to a significant (200+ m) and young population. However, one alternative for solving the Malacca Strait challenge is to build the Carat Canal (Zeng et al., 2017) through southern parts of Thailand (this is not at any implementation stage yet). It would not, however, decrease the future role of Pakistan as an essential transit route. Pakistan is also evaluated as a critical partner in bilateral energy trade between China and Pakistan (Duan et al., 2018).

Pakistan, Russia, Germany, Poland, Kazakhstan, Uzbekistan, and other countries, of course, represent the more conventional terms of the tag cloud analysis, e.g., “countries”, “development”, “economic” or “trade” (Figure 5). It should be noted that “trading with the rest of the world” is also the common theme of OBOR research, which has been covered regarding the supply chain development. From this point of view, the analysis could be started from Europe, wherein the research works’ OBOR interest has been twofold.

From the first (Yang et al., 2018b; Schinas and von Westarp, 2017), research has been interested in the continued growth and investments in the Chinese operated part of the port of Piraeus (in Greece). This sea port arguably has its benefits, with the most important being the shorter lead time connection from Asia to Europe, and its related savings. These not only concern operative savings, but also the fleet size could decrease. At the same time, ship investments would be smaller than in North European sea port dominated chains. However, a constraint for all of these lucrative benefits is the low population in, e.g. Greece, which results in small domestic markets. The situation is also the same in nearby European Union countries. Therefore, a railway connection to Budapest (Hungary) is planned and evaluated. However, in some research works, this railway connection reaches Prague in the Czech Republic, and Hamburg in Germany (Yang et al., 2018b; Yang et al., 2018a).

The second direction in OBOR research concerning Europe is China's railway land bridge connection to Poland/Germany, and other European countries (Yang et al., 2018b; Wang and Yau, 2018; Jiang et al., 2018; Yang et al., 2018a). It is considered as a short-term success; however, its more significant role concerning volumes is doubted, and also cost efficiency is considered to need subsidiaries (Jiang et al., 2018). However, as Wang and Yau (2018) highlight, the land bridge development was due to a manufacturing export requirement of Chongqing for such well-known and high-volume manufacturing companies as Hewlett Packard and Foxconn. Similar information is provided in Kuzmicz and Pesch's (2018) research. It argues that Samsung has started to favour the railway land bridge increasingly from China to Europe. Also, Jiang et al. (2018) emphasize the role of high-technology product exports from hinterland areas of China to Europe.

One priority of the Made in China 2025 programme is spreading the success of the Shenzhen area around China in innovation within high technology (Al-Sayed & Yang, 2019). Kuzmicz and Pesch (2018) identify the problem of empty containers as a challenge for railway land bridge development. It was also partly mentioned in Jiang et al. (2018). Transportation is typically unbalanced, with a higher container volume in one direction than the other. For example, Chinese trains heading to Central Europe are typically fully loaded, but from west to east (eastbound), nearly half of the containers are empty. The situation is challenging to manage in hinterland transports as it is based on providing a service between a few points. In comparison, sea transportation has more opportunities as container handling is centralized in sea ports. At the same time, sea vessels visit numerous sea ports during their journeys. They proceed based on planned routes and schedules to have the highest possible fill-rates, revenues and low costs. From a totally different angle, Alon et al. (2018) argue that transportation infrastructure and connectivity are instead well-developed between Europe and China. However, as most of the European companies are small and medium-sized enterprises (SMEs), they need to know more about Chinese markets. Besides, they do need local partners with good relationships with China Railway Express.

Together with European connectivity at the OBOR, supply chain research works often deal with the already reviewed future role of Pakistan to connect the north-west of China to the world (Shaikh et al., 2016; Sheu and

Kundu, 2018; Wang and Yau, 2018). Research is often concerned with new routes for oil imports to China (Shaikh et al., 2016; Sheu and Kundu, 2018); however, the situation in Pakistan is not without its troubles. The country lacks oil pipelines serving the Chinese market, and building these would require significant effort due to high altitude (Sheu and Kundu, 2018). All research works agree that the Pakistani route would indeed offer a lucrative lead time advantage. Additionally, its provision of economic spill-over effects to numerous countries other than China and Pakistan, would be remarkable (Wang and Yau, 2018). Also, the current sea route using the Strait of Malacca is considered troublesome (Shaikh et al., 2016; Sheu and Kundu, 2018). In research works, investments and plans are Gwadar centric (a sea port, where the Chinese have a long-term concession contract). Investment plans also include several railway lines, and a number of road network parts, which also serve Karachi and other cities (Wang and Yau, 2018). However, it should be highlighted that investing in emerging, but under-developed, Asian economies is risky as illustrated by the case of the Barapukuria coal mine in Bangladesh (Li et al., 2019).

Another point of interest in the OBOR supply chains is the region of the Association of Southeast Asian Nations (ASEAN), and logistics routes and infrastructure projects related to serving China (Zeng et al., 2017; Chen and Yang, 2018; Dong and He, 2018; Wang and Yau, 2018). One of the main questions in this territory has been the construction of several modern railway lines to form a network to serve cross-border traffic between ASEAN countries and China (Wang and Yau, 2018). Realization of this is still somewhat uncertain; however, the Laotian government has decided to build a railway connection with the Chinese between Kunming (China) and Vientiane (Laos). The project itself is already ambitious as its budget is more than half of Laotian annual GDP (and most of the construction is on Laotian soil).

From Vientiane, it would be logical to continue a railway route to Bangkok and from there to Kuala Lumpur, eventually reaching Singapore (as shown in Wang and Yau, 2018). Other points of interests within the OBOR in ASEAN countries have been the effects of the possible construction of the Carat Canal on Thai territory (to avoid Malacca Strait challenges; Zeng et al., 2017). Also, there is the evolution of ASEAN and Indian sea ports to serve the future export markets of Europe, Africa, Australia, China and the Americas (Chen and Yang, 2018). In both of these studies, future scenarios contain a loss of volume for the transshipment hub, the sea port of Singapore (and also in part the ports of Klang and Tanjung Pelepas in Zeng et al., 2017), and correspondingly, growth for Chinese sea ports and Thailand's Newport

(Zeng et al., 2017), or growth for Sri Lankan sea ports (Chen and Yang, 2018). It should be noted that China holds a long-term concession contract in Sri Lanka's sea port. As a strength of Singapore, Huang (2019) identifies that it holds the highest performing environmental conditions (low environmental risks with huge opportunities) for investments from all OBOR countries.

ASEAN countries are also important trade partners with China, as illustrated in the longitudinal wood import study of Dong and He (2018) from Myanmar (Burma). Research showed that the volumes in this particular trade pair have been growing since the Chinese own wood harvesting legislation changed in 1998. However, volumes are greater for logs and raw wood than for processed wood. Besides, intermediaries hold a significant role in trade. These could lead to unwanted consequences and less successful development in the long-term. Dong and He (2018) recommend that the OBOR programme needs to take on the learning curve to further develop imports from raw materials into more processed products. Additionally, it is to make import processes themselves more transparent.

Chen et al.'s (2018) research, in turn, is without any geographical region of the OBOR. However, it is a domestic sea port and hinterland terminal simulation study from China (the sea port of Ningbo and its vast hinterland). It recommends the future taking into account of sea port investments abroad and the uncertainty of sea port-centric operations, and suggests increasing the role of dry port terminals in hinterlands. The research analyzes labour strike statistics in detail and concludes that, in developed economies, logistics operations are labour strike sensitive, especially in Europe and America. Another China-centric study is that of Li et al. (2018), which concentrates on grain imports from OBOR countries to China. This activity has increased substantially in recent years. The role of railways cannot be underestimated in this activity, but also important are other transportation modes like roads and waterways. Based on this study, it is proposed that for China, six transportation nodes for national distribution should be established. These are the following: Xi'an, Chongqing, Guangzhou, Shanghai, Lianyungang and Tianjin. Many of these nodes are important in railway network.

A similar sea-port-centric study is by Kim et al. (2018), one of the few research studies from Africa, together with the caveats and strengths of foreign direct investments (Koomson-Abekah & Nwaba, 2018). Kim et al. (2018) evaluate the potential of sub-Saharan sea ports in the growing trade environment, but also potentially serving European supply chains (originating from Asia). The analysis illustrates that containerization is still developing in this region. Some of the sea ports will take a hub sea port role in the future. The authors see South Africa as a lucrative place for this. Other sea ports are then, concentrating on other cargo types, like bulk and liquid bulk. The study keeps as a starting place in Asia, the transshipment hub of Singapore. It also recommends which sizes of vessel should be used in these maritime supply chains (mega-vessels do have a role, but other sizes are in demand too).

In conclusion, it is worth stressing that in the initial phases of OBOR research, it was predictable to see standard terms, such as "countries", "development", "economic" or "trade" shown in the tag cloud analysis (Figure 5). These more critical topics of the future are in the first-mentioned group of words/themes. Meanwhile, less common themes, which were somewhat surprising to notice, also deserve a final note. They include emissions (emissions, emission, pollutant or CO2) that were mentioned as often as energy, oil, gas, water as well as logistics and transport. Specifically, some exciting features of the analyzed OBOR studies were the estimations of trade balances of China concerning CO2 and water. Ding et al. (2018) argue, based on their foreign trade analysis, that Chinese export activity causes vast CO2 emissions. Most of the emissions are due to trade-related activities. These are primarily within trade with the US, Hong Kong, Japan, Germany and the Netherlands. Hong Kong and the Netherlands are just critical points in global trade flows, not places of final consumption.

Regarding water, agricultural trade analysis in terms of OBOR illustrated that Russia is the key country in both the import and export of "virtual water" (Zhang et al., 2018). These are all important themes, and also problem areas that need to be solved as Eurasia will grow further economically in the following decades. However, at least for now OBOR investments have not helped to reduce CO_2 emissions. Even if total factor productivity may have been improving, in some cases, the productivity effects are questionable (Feng et al., 2019).

3.3. Economic appraisal of construction projects

The investment programme "One Belt One Road" is deployed from the Eurasian continent to the Middle East, to assure the availability of raw materials and increase trade further (Sheu and Kundu, 2018). However, these countries, which also include African countries, are risky investment environments. Some are in the middle of military conflicts. Meanwhile, large-scale progress has recently been made concerning Pakistan, Eurasian

Economic Union countries and Eastern Europe (Cheng, 2016; Huang, 2016). Also, there was pain from oil and raw material prices that have constrained the interest of other countries to participate in these projects (Cheng, 2016). So-called economic and political risks should be taken into account during the appraisal of such capital-intensive investments (Panova, 2016). The infrastructure investments across Asia, Africa and the Middle East within the framework of all Belt and Road projects are worth of $1.8 trillion, including such projects as oil drilling in Siberia, new ports in Southeast Asia, railways in Eastern Europe and power plants in the Middle East (51voa.com, 2018; Seo et al., 2017).

The success of the planned projects is determined by an important economic factor of profitability, the return on investment; in other words, the ratio of the profit to the initial investments. Therefore, the successful implementation of the idea is associated with several prerequisites. The smaller the amount of money invested in the project, the better. At the same time, the volume of profit received during the functioning of the designed object should be higher.

However, in order for the project to be implemented without problems and unnecessary costs, it is essential to draw up a business plan correctly, allowing for the impact of risks. Naturally, this task is not simple, and often projects face a problem such as over expenditure of funds. Because of this, plans can completely lose their liquidity (the rapid return on investment), discourage investors, and, in the end, be suspended or not implemented at all.

There is a large number of different indicators of the economic efficiency of investments, which can be divided into two subgroups: including discounted values and not including discounting (Nepomnyashchiy, 2003). The first group includes such indicators as NPV (net present value), IRR (internal rate of return), DPP (discounted payback period), and PI (profitability index). Almost all of the same indicators can be attributed to the second group, but without a discounting factor, so they would be named as a payback period, present value, etc. Keown et al. (2013) suggest considering four commonly used criteria for determining the acceptability of the investment proposals: DPP, NPV, IRR, and PI.

The *Profitability index* is based on the ratio: present values of cash flows/initial investment. A ratio lower than one (or 100%) indicates the rejection of the project, as a project cannot guarantee the required rate of return and, therefore, should be rejected. A PI above 1 is ranked according to the magnitude of the PI. The profitability index of discounted investments shows the profitability of the funds invested in the project, taking into account a discounted ratio. Then, the calculation of the index of discounted PI (DPI) is made by the following formula:

$$\mathrm{DPI} = \mathrm{NP} \times \alpha_t / \mathrm{I} \times \alpha_t,$$

where NP is the total net profit; I is the total initial investment; and α_t is the discount factor.

The discount factor, in turn, can be found by the following formula:

$$\alpha_t = \frac{1}{(1 + \mathrm{E})^t},$$

where E is the discount rate; and t is the period number.

The indicator of the *internal rate of return* shows a specific rate of profit of the project, in which the net present value (or the difference between discounted investments and net profit), is equal to zero. The IRR indicator can be determined by the following formula:

$$\mathrm{IRR} = \mathrm{E} \Big| \textstyle\sum_{m=0}^{T} \mathrm{NPV} = 0,$$

If the IRR is less than the discount rate (E), the project is considered unacceptable; otherwise, the project can be implemented.

Net present value shows the real profitability of the project, which can be achieved during the implementation period. In particular, the accumulated NPV is used to determine the total value of the discounted profit at the end of the settlement period. The following formula can be used to calculate the NPV:

$$NPV = \sum_{t}^{T} (PV_t - I_t) \times \alpha_t,$$

where PV_t is the net profit of the period; and I_t is the capital investments of the period.

The *payback period* shows the amount of time in which the initial investment will be returned, and the gaining of a real profit will begin. There are many ways to calculate the payback period for the project; one of them is the graphical method. For the calculation, a graph is created based on

NPVs that change from negative to positive during the implementation period of the project. Once the value of NPV crosses the zero value and begins to grow in positive numbers, from this time on, the investment is paid off. In turn, the period until this point in time (when NPV=0) is considered as the DPP. To calculate the DPP accurately (for example, with the precision of months), various formulas or software solutions, such as spreadsheets, can be used. The description of such calculations is provided in detail by Kockelman et al. (2013) and in the following sub-chapter.

On the whole, the indicators mentioned above not only allow an assessment of the effectiveness of the investment in the project, but also allow risks to be taken into account. Such calculations enable an evaluation of the impact of the losses caused by threats to the project. Several leading indicators of the project activity are useful for the assessment of risk impacts, but some of them have limitations. For example, the IRR is used in capital budgeting to measure and compare the profitability of investments, not liquidity. The problem with the IRR is that for projects whose cash flows change direction more than once, this criterion cannot be used.

As an investment decision tool, the calculated IRR should not be used to rate mutually exclusive projects, but only to decide whether a single project is worth investing in. Consider the following example. One project has a higher initial investment than the second mutually exclusive project. At the same time, the first project may have a lower IRR (expected return), but a higher NPV (increase in shareholders' wealth). Therefore, the first one can be accepted over the second project (assuming no capital constraints). The IRR should not be used to compare projects of different duration. For instance, the net present value added by a project with a more extended period, but a lower IRR, could be higher than that of a project of similar size, in terms of total net cash flows, but with a shorter duration and a higher IRR. The internal rate of return also suffers from the possibility of multiple solution rates in some circumstances. Thus, if it suggests a different decision to that obtained from the net present value, the decision should be taken by the NPV. The reason is that the net present value is a superior decision tool (Dymowa, 2011; Keown et al., 2013; Pyles, 2014; Vitollo and Cipparone, 2014).

Meanwhile, decision-making on the acceptance of the project by the positive NPV alone also omits the exposure of the project's useful life to risks. The causes of the uncertainties can stem from the changes in political, technological, and economic factors. The variety of risk factors requires a focus on capital investment appraisals, which ensure project profitability and liquidity. This is why the project should be additionally assessed by the second criterion, the discounted payback period (DPP), which satisfies both characteristics (profitability and liquidity; Bhandari, 2009).

Methods that allow the calculation of the above-mentioned project performance criteria include qualitative and quantitative approaches. Examples are expert estimates, analogy-based estimation, the practice of adjusting the discount rate, sensitivity analysis, and the scenario method. Qualitative analysis is usually carried out when the investment has not yet been made for the project. The study determines possible design risks and their factors. However, even for such an analysis, it is required to have information about the leading indicators of the future project, such as the cost plan, procurement plan, material plan, etc. Among the methods of qualitative analysis, one can single out the method of expert evaluations (among them, the Delphi method, the method of scoring risk, and the method of ranking), the method of analyzing the appropriateness of costs and the method of analogies (Popova, 2011). These approaches allow not only a qualitative assessment of the possible risks of the project, but also provide a basis for further calculations using quantitative methods.

Quantitative methods of project assessment, as a rule, solve the problem by computing the probability of the occurrence of risks in value terms. These methods are considered to be the most effective and are often used in practice. In the quantitative approach, there is a method of adjusting for the risk of the discount rate, sensitivity analysis, the scenario method, the statistical method and simulation modelling (Koshechkin et al., 2014; Limitovsky, 2011; Panova and Hilmola, 2015). A description of the quantitative techniques will be provided below.

The method of adjusting the discount rate implies bringing future financial flows to a certain point in the present tense. It is often used in practice because of its simplicity, which is its main advantage (Hill and Hult, 2018). However, on the other hand, the method does not allow for a sufficiently in-depth assessment of the degree of risk and therefore, does not give the expected effectiveness. Moreover, critics of this method also argue that it penalizes early cash flows too heavily and does not penalize distant cash flows enough (Hill and Hult, 2018). The result directly depends on the established "risk premium", which is considered in the calculations and does not take into account the possibility of reducing the risk over the project implementation time.

Sensitivity analysis involves an analysis of the factors that affect the occurrence of the risk, their evaluation in percentage values and the change in factor value relative to the original value. The spreadsheet programme is often used in order to perform such an analysis. However, in this method, the negative side is that the influence of various factors of risk cannot be studied simultaneously. The risk impacts can only be analyzed one at a time.

The scenario method can be called a more advanced version of the sensitivity analysis method. In it, the factors that influence the occurrence of risk are combined into a single correlated system of project implementation conditions. The technique implies an assessment of all possible scenarios for the development of the project, with identification of the suitable and less preferable scenarios. Even though the method mitigates the shortcomings of the previous one, it is still not compelling enough. It is impossible to determine absolutely all scenarios, and consequently, the most suitable options for actions can be ignored.

The statistical method is based on indicators of mathematical statistics, such as the coefficient of variation, variance, etc. For the analysis, indicators are calculated based on data for any period. This method is complicated to apply to the projects at the time of planning due to the lack of real information about the activity. As a matter of fact, the reliability of this analysis is quite low.

Finally, the most advanced method, *simulation modelling*, is based on the creation of detailed concrete models of scenarios with the help of specialized programmes. In this method, both the sensitivity analysis method and the scenario method are used simultaneously. At the same time, the probability of error is reduced owing to the use of computer technologies. When combining the results of the simulation with the results of the statistical analysis, the final result is sufficiently reliable and optimal. This method is currently considered one of the most effective among all the others.

In practice, the *Monte Carlo simulation* is mainly used, very often to calculate risks. The Monte Carlo method is a method of simulation, which implies the modelling of random variables for the assessment of risk factors (Oparin, 2015). The method describes uncertainty and risk factors by compiling a sequence of random numbers and further obtaining performance indicators based on the selected distributions.

The method was described for the first time in 1949 by mathematicians from America, J. Neumann and S. Ulam. It was named after the city of Monte Carlo which is known for a large number of casinos, where roulette is used as the simplest example of a random number generator. Based on this approach, the method itself works. The technique is applied through a spreadsheet program or specific computer programs, possessing the possibility of statistical and probabilistic calculations and capable of calculating random values for various positions.

The Monte Carlo method works according to a certain scheme, consisting of several stages:

1. First, a list of factors is formed that can have any effect on the financial component of the project;
2. Then, for each of the selected parameters, the probability distribution is computed. The choice of the type of distribution is on the problem-solver, but it is most often assumed that a normal distribution can suit well;
3. After that, a numerical value is assigned to each factor (this is done randomly using a computer program) based on the probability distribution.
4. As a result, the impact factors are evaluated by the program. This procedure is carried out many times (usually about 500), after which a model is constructed based on the results of the probability distribution of the NPV.

The main project performance criterion accessed by the Monte Carlo method is the net present value (NPV). Less frequently, the Monte Carlo method is used for the calculation of the discounted payback period and the internal rate of return (Esipova, 2011; Grimsey and Lewis, 2007; Jeffery, 2004; Lorenzo et al., 2012; Merkova et al., 2013). As the Monte Carlo method is based on the use of mathematical statistics and probability theory, the practically oriented terms of these spheres will be outlined below. In particular, to obtain the probabilistic result in the form of the NPV or any other project performance criterion, the distribution function for each variable should be determined. Most often, in practice, the normal distribution is taken as the basis of the method.

In the Monte Carlo method, it is necessary to search for the values of the mathematical expectation and the variance of random variables, e.g., the NPV or another criterion of project appraisal. In turn, the mathematical expectation is calculated as the weighted average of all selected parameters of a random variable. The spread of the random variable, which can be the NPV, DPP, etc., relative to the mathematical expectation, or mean value of the NPV, DPP, etc., is determined by the numerical measures of variability. Examples would be variance, standard deviation, range, and others. The variance shows how much variance of parameter values is relative to the mathematical expectation. The standard deviation is defined as the positive square root of the sample variance.

In the sphere of business and economics, standard deviation receives wider applications than variance (McClave et al., 2014). Specifically, standard deviation is used to define the impact of risks (Panova, 2016). Unlike the variance, the standard deviation is expressed in the original units of measurement. For example, if the original measurements are in the expected dollars lost due to the impact of risks, the variance is expressed in the peculiar unit “dollar squared”, but the standard deviation is expressed in dollars.

Moreover, the Monte Carlo method helps to *avoid point estimates*. For most practical problems, the point estimate, or the so-called single number of the variable or its mean value, is inadequate (Newbold et al., 2013). For instance, if a large shipment leads to an estimate that 10% of all parts are defective, a manager would hopefully ask questions so as to seek information beyond that contained in the point estimate (10%). The additional question could be of the form: “Can I be sure that the true percentage of the defectives is between 5% and 15%?” This type of question is asking the reliability of the point estimate. More directly, the manager’s quest is for the *interval estimate*, a range of values in which the quantity to be estimated appears to lie (Newbold et al., 2013). Thus, increased precision of information is reflected in the interval estimates (McClave et al., 2014; Newbold et al., 2013). In the output of the Monte Carlo analysis, any indicator of the project assessment criteria (NPV, DPP, and IRR) is reflected not as the point estimate value, but as a probability distribution of the random variables (criteria), which are sensitive to the factors of risk under consideration.

In conclusion, it is worth noting that despite the advantages of the Monte Carlo method over other methods of calculating risks, the technique has its drawbacks (Sazonov and Sazonova, 2016):

1. There is the problem of the connection between various factors that cannot be taken into account in the model. That is, if one of the factors changes, in reality, there can be changes in other elements.

However, the system cannot take this change into account, and the result may not be realistic enough;

2. The choice of distribution remains on the problem-solver, which cannot always lead to a positive outcome. Usually, calculations are not carried out by professionals. The normal distribution is initially taken. However, it can often be that for the most rational results it is necessary to use a different type of distribution;
3. The problem of unprofessionalism itself is quite significant since the application of the method by a non-specialist can lead to errors in the calculations, which, in turn, may result in incorrect conclusions. Therefore, it is advisable to resort to the help of professionals for the purpose of the most rational investment project analysis. Meanwhile, despite the listed problems, the Monte Carlo method is still the most effective method for assessing risks in investment projects. It allows the identifying of possible changes in the project results depending on the maximum possible number of variables (Lättilä, 2012; Panova, 2016).

For a better representation of the outcome and an advantageous allowance for the different variables, it is advised to compute Monte Carlo in specific computer programs rather than a spreadsheet program. Among the most popular Monte Carlo simulation environments are Vensim, AnyLogic, @RISK plugin for MS Excel, Arena, Stella, etc. Further on, the calculations of risks will be carried out with the help of MS Excel and the Vensim program for the business case of the logistics centre.

3.4. Risk management practices

According to Bender and Ayyub (2001), risk assessment is "a technical and scientific process, by which the risks of a given situation for a system are modelled and quantified". The risk implies the likelihood of an event occurring in the life cycle of a project or organization that entails damage. Most often, it is expressed in a negative impact on the financial performance of the project (total profit, project costs, NPV, etc.). This causes the disruption of plans for the cash flows of the project (Black et al., 2012). The problem of the deviation of real cash flows from those planned is the one main issue in the sphere of creating large infrastructure projects (Bruzelius et al., 2002; Flyvbjerg et al., 2003). It often happens that the difference between the planned costs and the actual costs of implementation reaches 50%, and sometimes up to 100% (Flyvbjerg et al., 2003). Modern studies show that in almost every significant transport project cost overrun is an integral part of its implementation. Approximately 9 out of 10 infrastructure projects are undervalued, which leads to massive overruns.

Underestimation of risk factors for projects, especially capital-intensive, or so-called “mega-projects”, at the stage of their feasibility study leads to financial overspending. This happens not only in the process of their implementation but also in some cases, even before construction begins (Flyvbjerg et al., 2003; Baumann and Matheson, 2013). Examples of cost overruns in large transport projects are given in Table 3-4 (Flyvbjerg et al., 2003).

Table 3-4. Cost overruns on transport infrastructure projects. Sources (combined, modified): Flyvbjerg et al. (2003); Aleksandrova (2014)

Project	Cost overrun (%)
Big Boston Tunnel/Tunnel Project	196
Humber Bridge, United Kingdom	175
The Boston–Washington–New York Railroad, USA	130
The railway tunnel of Big Bely, Denmark	110
Motorway A6 Chapel-en-le-Frith/Whaley Bridge bypass, Great Britain	100
The Shinkansen railway line to Joetsu, Japan	100
Washington Metro, USA	85
Tunnel under the English Channel, United Kingdom, France	80
Narrow-gauge railway Karlsruhe-Bretten, Germany	80
Access roads of the Bridge-Tunnel of Öresund, Denmark	70
Metro Line in Mexico City	60
Trans-Sib and Baikal-Amur Mainline (BAM), Russia	47

Deviations of future cash flows from the expected flow in the amount of 50-100% of the initial financial cost are typical for large infrastructure projects in Russia and other countries. For example, the sum required for the reconstruction of the leading Russian rail lines of the Trans-Siberian Railway and Baikal-Amur Mainline (BAM) ballooned to 1 trillion RUB from 562 billion RUB (Aleksandrova, 2014). The cost of the tunnel project under the English Channel (Channel Tunnel, Great Britain–France) increased by more than 100%; the Great Belt Bridge (Denmark) – by 55% three years before the expected completion date; and the Øresund Bridge (Sweden) – by 10% at the beginning of its construction.

Basically, the present value of projects is higher than stated in the business plan, on average, by 28-30%. During the development of large logistics infrastructure facilities, the number of unforeseen costs can be a substantial sum of money. This is difficult to tackle in the middle of the implementation of a particular project. Therefore, it is necessary to know about the risk of overspending in advance. In the designing phase, the possible causes of over expenditures should be taken into account.

The book of Flyvbjerg et al. (2003) gives an example of the successful implementation of the most significant projects. This is the space programme "Apollo" with a cost overrun estimated at only 5%. Meanwhile, the total cost of the project amounted to 21 million US dollars. A relatively small difference between the planned expenses and the real ones is explained by the fact that at the planning stage, possible risks were identified. Then, they were mathematically estimated in monetary terms and pre-planned as contingency costs. In this way, the cost overruns that could have appeared in the form of colossal amounts of money were prevented, thus, allowing the implementation of the project on time and quite successfully.

It is essential to adopt this experience and to note that the most critical element in this regard is a prior assessment of possible risks. The reason for this type of investment appraisal is that even in an almost risk-free investment, the so-called risk-free asset is only a hypothetical commercial construction. Business activities always involve risks. Broadly speaking, at the planning phase, projects are related to the future period, therefore, it is problematic to forecast the material and associated flows for the project accurately. Consequently, it is necessary to consider all possible outcomes, including the influence of risk factors.

It should be noted that, in the economic literature, the terms "risks" and "uncertainties" are not identical. Uncertainty is the incompleteness and inaccuracy of information about the conditions of the project under implementation (Maksimova, 2005; Oparin, 2015). It leads to the perceived inability to make accurate predictions or probability statements. "Knightian" uncertainty is a risk that is immeasurable, not possible to calculate. The uncertainty is named after the University of Chicago economist Frank Knight (1885–1972), who distinguished risk and uncertainty in his work Risk, Uncertainty, and Profit in 1921.

The term risk, on the contrary, refers to the possibility of determining the probability of the occurrence of an unpleasant event (Maksimova, 2005; Oparin, 2015). To a more considerable extent, risks are the possibility of occurrence during the project implementation of such conditions that will lead to negative consequences for all or individual project participants (Black et al., 2012).

There are different classifications of risks in the literature. Euromoney magazine publishes an annual "country risk rating", which incorporates the assessment of various risks, and is widely used by businesses (Hill and Hult, 2018). The classification of risks differs from country to country, as well as among different topics of research (Bing et al., 2005; Ke et al., 2011; Power et al., 2015; Moslemi; 2016; Grimsey and Lewis, 2007). For example, in Russia, two main groups of risks should be taken into account. In the sphere of warehousing and container terminal infrastructure development (Panova, 2016), these are economic and market risks. According to Popova (2011), investment risks can be divided into six groups (Popova, 2011):

1. Technical and technological risks are associated with the reliability of equipment. At the same time, these are the unpredictability of production processes and technologies, their complexity, the level of automation. The pace of modernization of equipment and techniques also belong to this type of risks.
2. Economic risks are affecting the investment activity in the state and, therefore, the expected economic effect of the project.
3. Political risks caused by changes in the political situation, administrative restrictions on investment activity, and international political pressure on the state.
4. Social risks related to social tension; strikes, and implementation of social programs.
5. Environmental hazards, which are associated with environmental pollution, radiation conditions, ecological disasters as well as environmental programs and movements.
6. Legislative and legal risks caused by changes in existing legislation, statutory guarantees, incompetence or lobbying of interests of separate groups of persons at the acceptance of acts, and not the perfection of the existing tax system in the state.

Each group of risks can be further classified into different sub-groups of risk. For instance, economic hazards include such factors as a stagnation of the economy, a decline in freight traffic, and long-term structural barriers to industrial development. In turn, a decrease in freight traffic, timeliness of the loading and shipment of goods at transportation stages, and insufficient or excessive capacity of warehouses can be attributed to the specific group of transport risks (Table 3-5).

Table 3-5. Classification of investment risks. Source (original; modified with the specification of risks in relation to investors and owners): Kazaku and Panova (2015)

Construction risks	*Transport risks*	*Market risks*
Delay in the transfer of assets, supplies of materials and other resources	Reduction of freight turnover in general and for separate tariff groups of goods	Reduction of the cost of services for the transportation
Delay in commissioning at each stage of the investment project	**Timeliness of the loading and shipment of goods at the transportation stages**	Increasing the cost of storage services
Involving unscrupulous contractors	**Increase in costs of inventory**	Decrease in the cost of the processed goods

Current analysis (Table 3-5) provides a specification of risks concerning investors and owners. In Table 3-5, threats to contractors are highlighted by the bold text. Meanwhile, the rest of the risks were attributed to the owner. The reason for the analyses of risks from both sides is that parties responsible for risks can help to mitigate their causes more constructively, resulting in a so-called "win-win" situation. According to the research of Ramanathan et al. (2012), responsible groups for successful project realization can be ranked; that is, the Owner (Rank 1), Contractor (Rank 2), etc. Meanwhile, Al-Tami (2015) highlights that the responsibility for delays in timing is most often attributed to contractors.

The initial stage in the process of risk management is risk identification and attribution to the different responsible parties. Typically, the risk management process includes three main stages: risk identification, risk evaluation, and risk mitigation (according to ALARM, AIRMIC, IRM (2002), COSO (2004), FERMA (2003), ISO (2009) standards; Kirilmaz and Erol, 2015). The second step is based on the application of methods for risk management (Figure 3-6).

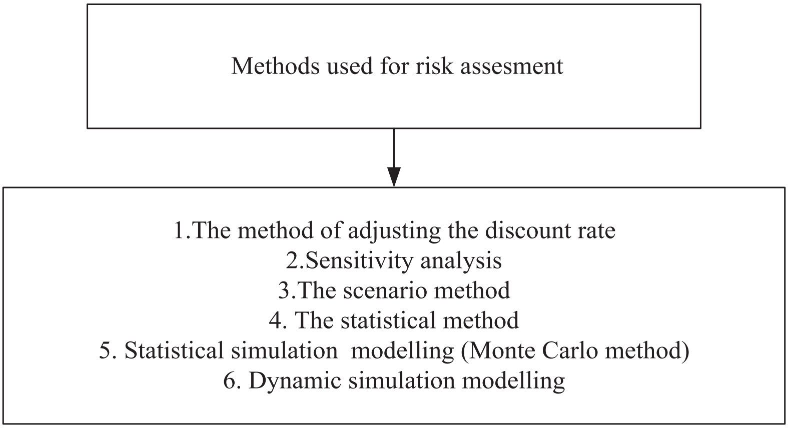

Figure 3-6. Quantitative methods for risk analysis.

The classification of quantitative methods that were described in the previous sub-chapter can be added by the *dynamic simulation modelling method* that allows for the factor of time (Panova and Hilmola, 2016; Panova and Hilletofth, 2018; Panova, 2016). In the Monte Carlo statistical simulation method, there is no explicit time representation. This aims to solve the "not probabilistic" problem in a probabilistic way. Therefore, the dynamic modelling method will be more suitable for the description of a dynamic system. An example is a system dynamics model, which includes the development of an infrastructure project over some time.

Moreover, the dynamic modelling method can be used in combination with the Monte Carlo method, using a specific simulation environment. Thus, the statistical simulation method will be underpinned by the dynamic simulation modelling method. In the literature it is also called more generally "computer simulation modelling" or directly "simulation modelling". Such an approach refers to the simulation of the functioning process of the system under investigation. Additionally, it allows the studying of the state of the system and its individual elements at certain moments of model time (Akopov, 2015). On the whole, there are four main approaches/paradigms in computer simulation modelling (Anylogic.ru, 2018):

1. Agent modelling is the direction in simulation modelling, which is used to study decentralised systems. The dynamics in such systems are determined not by global rules and laws (as in other modelling paradigms). On the contrary, these global rules and laws are the result of the individual activity of group members.
2. Discrete-event modelling is an approach to modelling that offers to abstract from the continuous nature of events and to consider only the main events of the simulated system, such as: "waiting", "order processing", "movement with cargo", "unloading" and others. Discrete-event modelling is the most developed approach and has a huge scope of applications (from logistics and queuing systems to transport and production systems).
3. System dynamics is a modelling paradigm, where graphical diagrams of causal relationships are constructed to study the system. At the same time, global influences of some parameters on the others in time are analysed. With the help of system dynamics, models of business processes, city development, production, population dynamics, ecology and epidemic evolution, to name a few, have been built so far.
4. The dynamic systems approach is used to model specific objects at the lower level of abstraction, with the precise dimensions of speed, distances, times. The models, which are built on the grounds of this approach, include state variables, state charts, and algebra-differential equations.

In some simulation environments, the listed approaches can be combined into one model to obtain the benefits from individual paradigms simultaneously. To assess the risks of investment projects, the system dynamics approach, which is represented in the Vensim professional version of the program, will be used. This program also has an embedded Monte Carlo method. To analyze and assess the risks associated with the project, as an example, the project of creating a container terminal is considered.

For the initial appraisal of the investment project, it is necessary to calculate such indicators as revenue, costs, profits, taxes, etc., in a risk-free environment for the entire period of project realization (from 2018 to 2023). These calculations can be conducted in the Microsoft Excel program. Afterwards, the risks will be assessed with the help of two quantitative methods. One is analytical (a method of adjusting the discount rate). The second is simulation modelling (the Monte Carlo method). The dynamic modelling method can be applied to the considered case by simple modification of the model (i.e., inclusion of the risk factors, such as supply chain delays in the delivery of materials to the construction site and associated costs due to such delays; Panova and Hilletofth, 2018; Panova 2016).

The first step in the risk assessment process is related to the preparation of a commercial project plan, which reflects the central positions of costs and revenues. These are calculated for the entire period of the project. In further calculations, the following financial indicators of the plan (in EUR) will be used (Panova and Hilletofth, 2018):

- ✓ Capital investment: 10 000 000
- ✓ Taxes: 125 530
- ✓ Income: 9 480 900
- ✓ Direct expenses: 5 266 000
- ✓ Indirect expenses: 1 185 000
- ✓ Gross profit: 3 029 900
- ✓ Net profit: 2 904 369

The income and expenses were associated with the provision of logistics services. Indirect costs have been calculated with allowance for the wages' payment fund and administrative expenses. The taxes for this project were calculated, taking into account income tax, property tax and value-added tax. For each period, the value of the tax amount was found using the formula:

$$N_t^{total} = R_t^{total} \times 18/118 + 0.2 \times (R_t^{total} \times 100/118 - C_t^{total}) + \frac{2.2 \times I_t}{100},$$

where R_t^{total} is total inflows; C_t^{total} is total operating expenses; I_t is total investment; *18/118* is the coefficient for calculating the value-added tax of 18%; *100/118* is the coefficient for calculating the revenues without VAT; *0.2* is profits tax in the absolute measure (or 20%); and *2.2* is property tax.

Based on the obtained data about the financial indicators of the project, it is possible to calculate the key performance indicators (such as NPV and DPP) of the container terminal for the billing period. In the first scenario, the environment is considered as hypothetically free of risks. In this regard, for the calculation of the NPV and DPP, the interest rate will be taken at 7.25%, allowing for the critical refinancing rate of 7.25% provided by the Central

Bank of Russia (since March 26, 2018; Cbr.ru, 2017). Additionally, the growth of income, as well as expenses over the settlement period of six years, was taken into account. To do so, the chain price index (also known as the consumer price index for the UK and the US; Black et al., 2012) was used. The index is calculated by the following formula:

$$1/(1 + In)^n,$$

where *In* is the inflation rate corresponding to a particular period n; and *n* is the period of calculation.

It should be noted that the whole financial plan was calculated from the investor point of view. The computations of the project investment indicators were performed by the formulas described in the previous sub-chapter and with the help of MS Excel (Table 3-6). The output of MS Excel calculations (Table 3-6) has been presented in the graphical form (Figure 3-7). As can be seen, the NPV equals 9 795 573 EUR, while the PI is 198% (19 795 573/10 000 000 = 1.98, Table 3-6). The project will pay off in 3.2 years (Figure 3-7).

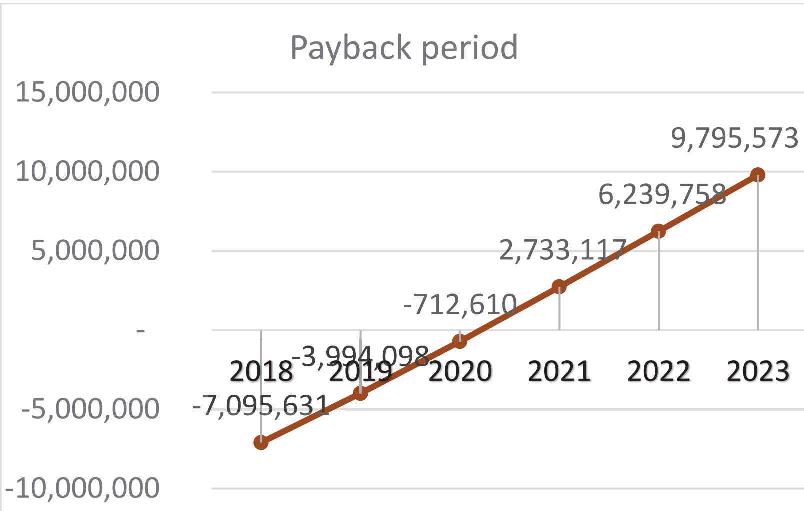

Figure 3-7. Graphical representation of the project payback period.

Table 3-6. The calculation of the project appraisal indicators in the risk-free environment.

Year	Calculation step	The rate of inflation	Chain price index	Capital	Income	Direct costs	Indirect	Taxes	Sales profit	Net profit	The	Discount	Capital	Net profit	Not	NPV
				EUR	EUR/Yea	EUR/Yea	EUR/Yea	EUR/Yea	EUR/Yea	EUR/Yea	In	In	EUR	EUR/Yea	EUR/Yea	EUR/Yea
2018	-	0,052	1,00	10 000 000	9 480 900	5 266 000	1 185 000	125 531	3 029 900	2 904 369	0,0725	1,00	10 000 000	2 904 369	-7 095 631	-7 095 631
2019	1,00	0,045	0,96		9 907 541	5 039 234	1 133 971	407 941	3 734 335	3 326 394		0,93		3 101 532	3 101 532	-3 994 098
2020	2,00	0,046	0,91		10 373 204	4 813 018	1 083 066	702 568	4 477 120	3 774 553		0,87		3 281 488	3 281 488	-712 610
2021	3,00	0,047	0,87		10 881 521	4 588 184	1 032 472	1 010 046	5 260 865	4 250 820		0,81		3 445 726	3 445 726	2 733 117
2022	4,00	0,045	0,84		11 306 150	4 415 864	993 695	1 256 990	5 896 590	4 639 600		0,76		3 506 641	3 506 641	6 239 758

2023	5,00	0,044	0,81		11 758 504	4 245 984	955 467	1 511 303	6 557 052	5 045 749		0,70		3 555 815	3 555 815	9 795 573
Total													10 000	19 795		

As can be seen from Figure 3-7 and Table 3-6 (last column), the NPV changes its sign from minus to plus after the year 2020, which means that the project will pay off in 3 years from its initiation in 2018. To calculate precisely the DPP, which equals 3.2, it is required to divide -712 610 by 3 445 726 = 0.2 (Table 6). So, the project payback period equals 3 years and 2 months.

As mentioned before, these calculations have been done in a risk-free environment, when the discount rate equalled 0.0725 (Table 6). This discount rate allowed the finding of the economic indicators of the investment project without risks. This rate can be determined by investors independently. As a rule, it is set following the minimum permissible future yield of the funds that can be established with the help of deposit rates of banks. In the given case, the discount rate was accepted at a rate of 7.25% as corresponding to the average refinancing rate of the Central Bank of the Russian Federation. In the case of a risk assessment, the discount rate should be adjusted.

According to this method (adjusting the discount rate), all risks are treated as a single problem. In countries where political risks are perceived as high, the discount rate applicable to the projects is increased. For example, according to Hill and Hult (2018), a firm might apply a 6 per cent discount rate to potential investments in Great Britain, the United States, and Germany which reflects these countries' economic and political stability. However, a 12 per cent discount rate might be applied for potential investments in Russia, reflecting the higher perceived political and economic risks in the country. In theory, the choice of the discount rate adjusted for the risks requires some more detailed calculations. In particular, the value of the risk adjustment should account for possible losses to investors (Panova and Hilmola, 2015; Panova, 2016; Minfin.ru, 1999):

- Low level of risk, e.g., investments in the development of product on the basis of advanced technology and technology (3-5%);
- Average: Increase in sales volumes of the products (8-10%);
- High: Production and promotion of a new product (13-15%);
- Very high: Investments in research and innovation (18-20%).

To take into account the influence of the risks to this project, further on the method of adjusting the discounting rate and the Monte Carlo method will be used. The magnitude of possible risks can be estimated as an average. The project, which is targeted in this work, is the creation of a new facility. It is rare for the city, where it is implemented. Therefore, the value of the risk adjustment will vary from 8 to 10 per cent. For further calculation, the amount of correction of the discount rate will be accepted as 9%.

The method of adjusting the discount rate is based on the change in the discount rate of the project. Thus, in the following calculations, the discount rate will be adjusted according to the formula:

$$E^{*} = (0.0725 + 0.09)/(1 - 0.09) = 0.179,$$

where E^{*} is a new discount rate adjusted for risk; 0.0725 is the initial discount rate; and 0.09 is the value of the risk adjustment.

Accordingly, the obtained discount rate, which allows the impact of risks to be taken into account, is 0.179. Most often, a change in the discount rate within the specified limits is necessary for taking into account the effect of political and other risks on the project. It allows possible changes to be foreseen in the refinancing rates of banks, depending on the foreign policy situation. The higher the discount rate, the higher the projected net cash flows must be for an investment to have a positive NPV (Hill and Hult, 2018).

According to the method of adjusting the discount rate, the calculations should be done similarly as in the case of the risk-free scenario. The only difference is in substituting the previous (risk-free) discount rate with an adjusted discount rate. Thus, the same spreadsheets and formulas of the prior sub-chapter will be used. The appraisal of project performance criteria required only quick re-calculations based on the new discount rate (Table 3-7).

Table 3-7. The calculation of the project appraisal indicators with allowance for the influence of risks.

Year		2018	2019	2020	2021	2022	2023
Calculation step		-	1,00	2,00	3,00	4,00	5,00
The rate of inflation		0,052	0,045	0,046	0,047	0,045	0,044
Chain price index		1,00	0,96	0,91	0,87	0,84	0,81
Capital	EUR	10 000 000					
Income	EUR/	9 480 900	9 907 541	10 373 204	10 881 521	11 306 150	11 758 504
Direct costs	EUR/	5 266 000	5 039 234	4 813 018	4 588 184	4 415 864	4 245 984
Indirect	EUR/	1 185 000	1 133 971	1 083 066	1 032 472	993 695	955 467
Taxes	EUR/	125 531	407 941	702 568	1 010 046	1 256 990	1 511 303
Sales profit	EUR/	3 029 900	3 734 335	4 477 120	5 260 865	5 896 590	6 557 052
Net profit	EUR/	2 904 369	3 326 394	3 774 553	4 250 820	4 639 600	5 045 749
The	In	0,179					
Discount	In	1,00	0,85	0,72	0,61	0,52	0,44
Capital	EUR	10 000 000					
Net profit	EUR/	2 904 369	2 822 394	2 717 400	2 596 599	2 404 677	2 218 942
Not	EUR/	-7 095 631	2 822 395	2 717 401	2 596 599	2 404 678	2 218 943
NPV	EUR/	-7 095 631	-4 273 236	-1 555 835	1 040 764	3 445 442	5 664 385

Total													10 000	15 664		

As can be seen from the obtained results (Table 3-7, Figure 3-8), the risks have a significant impact on the project payback and other efficiency indicators. The accumulated net present value at the end of the accounting period is 5 664 385 EUR, which is 42% less than in the risk-free scenario. This result shows the importance of risk accounting, since profit is significantly reduced compared to the first calculations, and if risks are ignored, the project may not bring the value claimed at the initial phases of the planning process.

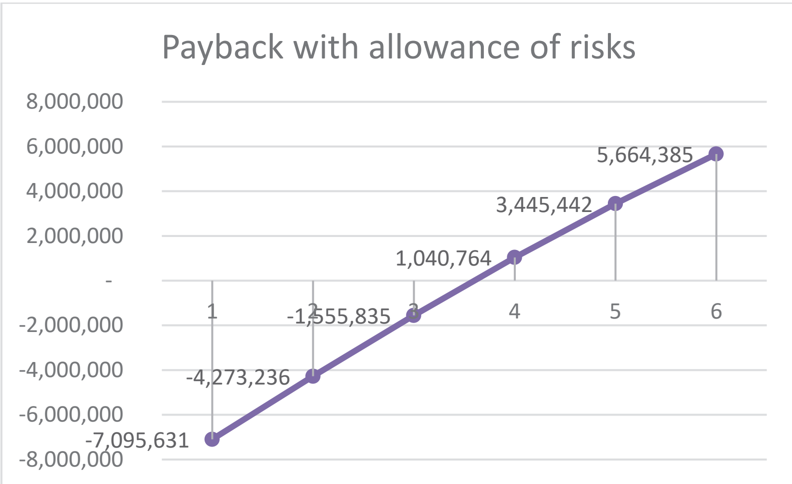

Figure 3-8. Graphical representation of the project payback period with the allowance for risks.

Also, it is worth paying attention to the indicator of the PI, which decreased to 157%. The payback period was impacted likewise and became 3.6 years, which means that the project will pay off by the second half of the 4th year, starting from its implementation (DPP = 3 years 7 months). If comparing it with the payback period in an environment without risks, the magnitude of risks in a time equivalent can be estimated at 5 months. In conclusion, it is worth mentioning that the project can still be implemented in practice despite changes in the indicators. These are the significant decrease in the received cumulative profit (NPV), the lower level of PI, and the lengthening of the payback period. Still, the values of these indicators do not contradict the commonly accepted notions of their range.

To obtain more accurate results in the form of interval estimates, the use of the Monte Carlo method in the Vensim program will be demonstrated below. For the method application, the parameters of the financial project plan (income, capital investments, taxes, etc.) should be added to the simple model. These can be found in the function examples of the Vensim help option (Figure 3-9).

As can be seen from Figure 3-9, apart from the financial indicators of the project, additionally the parameter for the interest rate should be created. At the same time, the equation for Excel data extraction should be used. For the first experiment with the model, the interest rate was set at 7.25%, meaning a risk-free environment. With the allowance for the interest rate, the discount factor is calculated automatically by the program, which is why the outcome may slightly differ from the calculation of project appraisal criteria in MS Excel.

The NPV and DPP have also been automatically calculated and represented in the form of the graph (Figure 3-10). As can be seen from the figure, the values of net cash flows (net profit without discounting) and the NPV of the project from 2018 to 2023 are changing over time. By the end of the calculation period, the NPV is growing and changes its value after 2020. It is similar to the experiment in Excel for the risk-free environment, see Table 6. At the same time, the net cash flows highlighted by the red line show a sharp change at the level of 2019, and then a smooth increase in the following years. This is due to the one-time investment made in the year 2018, which pays off afterwards (in 3 years 2 months) throughout the billing period.

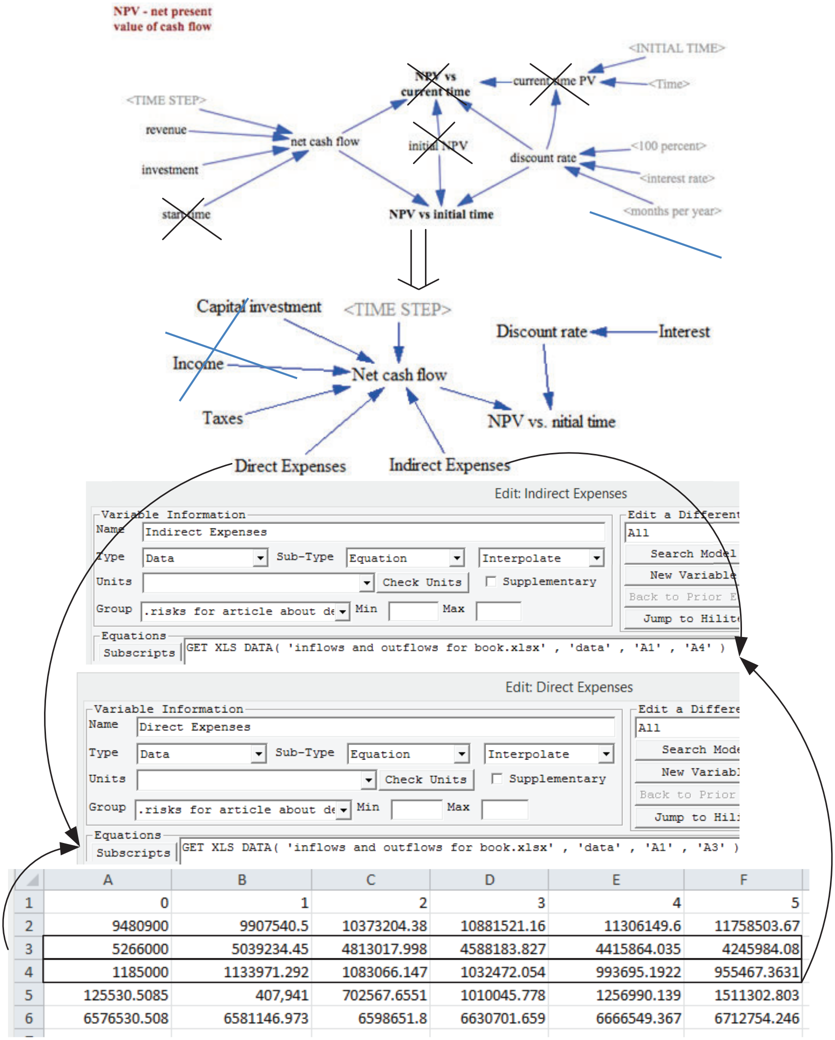

Figure 3-9. A simple model for the application of the Monte Carlo method via the Vensim program. Sources (original; modified with an initial model from Vensim Help and Excel Function): Panova and Hillethofth (2018); Vensim.com (2019)

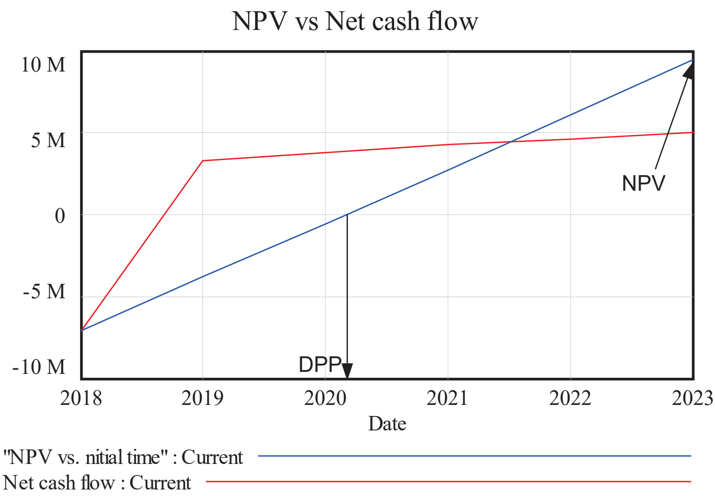

Figure 3-10. Net cash flows and the NPV of the project.

It should be noted that Figure 3-10 is not the outcome of the Monte Carlo method, as it involves a large number of runs, in which the value of the discount rate parameter varies. To do so, further on, the simulation experiment was set up (Figure 3-11).

According to Figure 3-11, the discount rate during a simulation experiment will vary from 0.0725 to 0.16 using uniform distribution. The choice in favour of uniform distribution is based on the following fact. The value of the discount rate from the given interval [0.0725; 0.16] is represented by the finite number of outcomes, which are equally likely to happen. Apart from an interest rate, other parameters which are subject to variation can be added to the setup window (Figure 3-11). For instance, in the case of the dynamic modelling method application, the change can be done concerning specific factors of transport risks.

The probability of delay days in delivering materials to the construction site can be additionally modelled to access the impact of a transport risk factor on the project performance indicators (Panova, 2016; Panova and Hilletofth, 2018). At the same time, the decrease of traffic flows at the specific time of the project realization can be programmed, thus allowing for the modelling of the second transport risk factor that causes a decrease in profits on the project. The parameters of variation (delays, cargo flows and the specific time of their decline) can be set with different probability distributions, such as standard, triangular, etc.

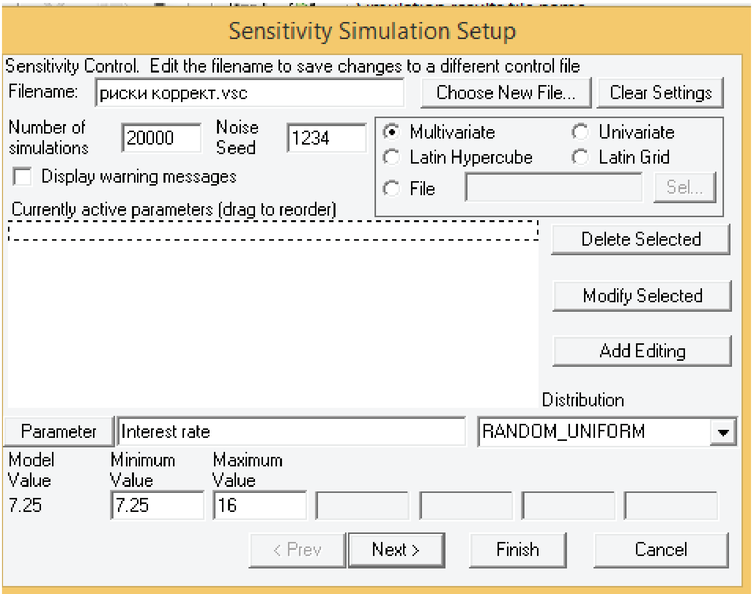

Figure 3-11. Monte Carlo simulation setup.

In the current study, only the interest rate will be varied to access the overall impact of risks on the project (without their specification). After running a simple Monte Carlo experiment, it is possible to obtain the distributed values of the NPV. As can be seen from Figure 3-12, the coloured area shows the spread of probabilities (confidence bounds).

According to the sensitivity graph, the investments will pay off on average in 2 years and 10 months (DPP). However, the DPP can deviate from the average figure by ±1.2 months with the probability of 75% or by ±1.8 months (with the probability of 95%). The risk also affected the NPV (Figure 3-13).

The Vensim program allows the user "to enter up to 8 confidence bound regions (in any order) and the colour that should be used to display them. For example, for confidence bound at 50, 1/4 of the runs will have a value bigger than the top of the confidence bound, and 1/4 will have a value lower than the bottom" (Vensim.com, 2019). In the legend of the graph, the colour on the graph indicates the receipt of the NPV in a certain amount. These indicators are yellow for a probability of 50%, green for 75%, blue for 95% and grey for 100%.

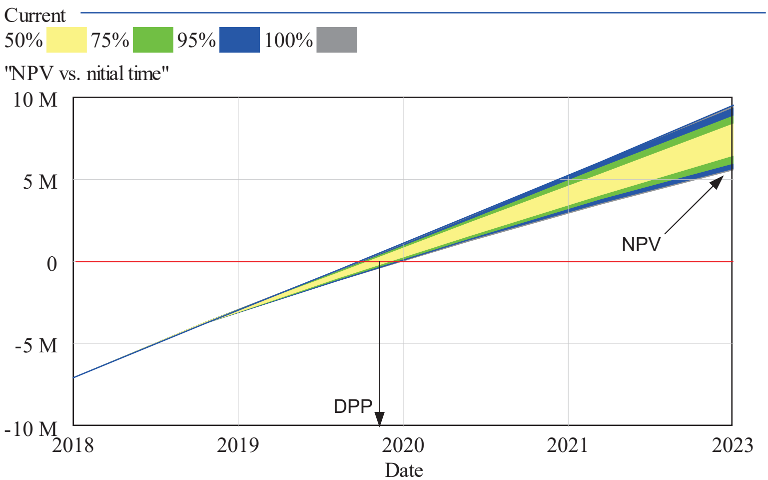

Figure 3-12. Outcome of the sensitivity analysis.

Statistics

Variable	Count	Min	Max	Mean	Median	StDev	(Norm)
NPV vs. nitial time sensitivity results at time 5 Runs:	Current						
"NPV vs. nitial time"	200	5.585 M	9.388 M	7.46 M	7.455 M	1.128 M	.1512

Statistics

Variable	Count	Min	Max	Mean	Median	StDev	(Norm)
NPV vs. nitial time sensitivity results at time 5 Runs:	Current						
"NPV vs. nitial time"	200000	5.554 M	9.448 M	7.376 M	7.318 M	1.121 M	.1519

Figure 3-13. Statistics outcome based on the sensitivity analysis.

Figure 3-13 shows that the outcome of the Vensim system can be represented in the form of statistical indicators. The figure depicts the statistics from two different sets, depending on the number of iterations (200 and 200 000). As can be noticed, the statistical outcome differs depending on the number of the runs. This is because an increase in the number of iterations reduces the probability of error. This indicator is very critical for projects with the most accurate data (for example, projects of companies already operating). The possibility of setting numerous iterations is regarded as one of the main advantages of the Monte Carlo method. This option, in turn, helps to reduce the likelihood of an error in the calculation of the risk impact on the project cash flows.

On the whole, from the obtained results, it can be concluded that the investments in the project will be paid back during the billing period. The minimum, maximum, and mean values of the NPV equalled respectively, 5.554, 9.448 and 7.376 m EUR (Figure 3-13). Additionally, in Figure 3-13, the value of the standard deviation (StDev value) and the coefficient of variation (Norm) can be seen. The standard deviation allows the estimation of the measure of the dispersion of the data. This shows the degree of accuracy of the data. Particularly, when more experiments are conducted, the StDev value decreases, which means that the accuracy of the calculations increases. Also, the standard deviation is used as a characteristic of risks, when the statistical mean represents the expected net present value and discounted payback period (Panova, 2016). The coefficient of variation is the ratio of the StDev to the arithmetic mean. It allows the estimation of the homogeneity of the set of analyzed features, and the smaller the coefficient, the more homogeneous is the set. In the calculation, the ratio of variation does not exceed 33% (values of 0.1519 and 0.1512%, respectively), which indicates the uniformity of the calculations.

Finally, based on all of the data obtained after the calculations, it is possible to make the following conclusion. The Monte Carlo method provides the computation of a much more accurate assessment of the risks. Meanwhile, it is more time-consuming and requires knowledge of specialized software. The method of adjusting the discount rate, which was applied in MS Excel, only allowed the calculation of a point estimate of the NPV and DPP. This means that there is a very high probability of error if this method is used. The Monte Carlo method, on the contrary, generated an interval estimate of the NPV and DPP owing to the discount rate variation following the probabilistic nature of risk occurrence. Thereby, the method provides a reasonably accurate forecast of possible changes of the NPV and DPP under the impact of risks.

Moreover, the application of the Monte Carlo method in the Vensim program allows a broader number of parameters to be collected from the printout. An example of an additional indicator would be a coefficient of variation used as a unitized risk value (Panova, 2016) which helps to assess the influence of risks from a different perspective.

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CHAPTER FOUR

METHODOLOGY OF SYSTEMS ANALYSIS

YULIA PANOVA & OLLI-PEKKA HILMOLA

4.1. Systems approach, its aspects and principles

The systems approach has been applied in systems engineering due to the need to study large real systems. The occurrence of a systematic approach was influenced by the increasing number of input data during the development phase, the necessity of taking into account complex stochastic relationships in the system, and the effects of the environment. All of these factors have forced researchers to explore a complex object not in isolation, but in interaction with the external environment as well as in conjunction with other systems, which belong to some metasystem (Sovetov and Yakovlev, 2012).

Currently, a systematic approach is used during the analysis and synthesis of complex (large) systems. This differs from the *classical (or inductive)* approach. The classical approach considers the system through a transition from the particular to the general, and synthesizes (constructs) the system by merging its components that are developed separately. In contrast, a systematic approach involves a gradual transition from the general to the particular (Panova, 2016), when the goal is the basis of initial considerations, and the object under study is distinguished from the environment.

In the systems approach to systems modelling, it is first of all necessary to clearly define the purpose of modelling. Since it is impossible to completely simulate a real functioning system (the original system), a model is created for problem consideration. The goal can be formulated qualitatively, then it will have more content and can display the objective possibilities of this modelling system for a long time. In the quantitative formulation of the goal, there is a target function that accurately reflects the most significant factors affecting the achievement of the goal.

Broadly speaking, the *systems approach* means that each system is an integrated whole entity even when it consists of separate, disjointed subsystems (Volkova and Denisov, 2014; Sovetov and Yakovlev, 2012). Thus, the systems approach is based on the consideration of the system as an integrated whole, and at the same time as a subsystem of a bigger metasystem. This is an *integrative aspect* of the systems approach.

The systems approach also allows gaining *access to the so-called "black box"* and seeing what is in there, e.g., that the object is in fact a set of related elements (structure), which also affect each other (Pandia.ru, 2019). An example of such an approach can be demonstrated based on the following explanation. Any artificial object can be viewed from two points of view: (1) the eyes of the user, and (2) the eyes of the developer. In particular, when buying a mobile phone, a client is primarily interested in its specifications and design. Thus, the consumer looks at the object as if from the outside or the eyes of the user. In this case, the mobile phone is literally a "black box" and its contents are of no interest.

An absolutely different approach would be taken from the developer's point of view. To design the same mobile, a designer needs to decide on its manufactured parts and how to put them together to make everything work. Thus, the developer is interested in the internal structure of the object. The considered example demonstrates two alternative approaches to modelling – the isolated approach and the systems approach. In the first case, the object is treated as a "black box". Its operation (behaviour) is described by some function and is accompanied by a certain set of parameters. These parameters are called *system parameters* – the values characterizing the quality, properties or modes of operation of the object. They include output and external parameters in the case of the "black box". However, if a "black box" is a dynamic object, then another coordinate, t, is added to the global function (F). Due to the fact that usually there are many parameters of each type, these are represented by respective vectors:

$$\bar{Y} = F(\bar{I}, \bar{E}, t)$$

Output parameters are indicators of the quality of the system: $Y = (y_1, y_2, y_{3,\ldots,} y_n)$. They can be used to judge the correct functioning of the system and its quality. They allow a comparison of the same type of system working in different scenarios and the choice of the appropriate one. *External parameters* are parameters of the external environment that have an impact (usually negative) on the functioning of the system: $E = (e_1, e_2, e_{3,\ldots,} e_n)$. The parameters of the input signals are sometimes separated into another group of *input parameters:* $I = (i_1, i_2, i_{3,\dots}, i_n)$.

If the dynamic object is regarded from the system point of view, then the group of additional parameters is added to the global function:

$$\bar{Y} = F(\bar{I}, \bar{E}, \bar{X}, t)$$

Internal parameters are parameters of structural (internal) elements of the system: $X = (x_1, x_2, x_{3,\dots}, x_n)$. There is some dependence between different types of parameters (Figure 4-1).

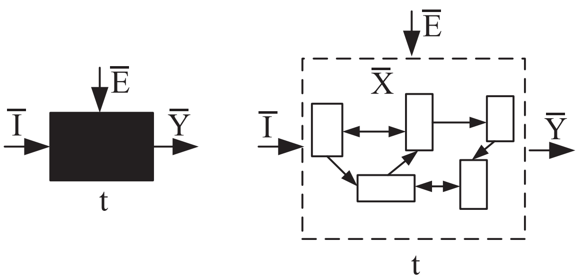

Figure 4-1. Graphical representation of the dynamic object in the form of the “black box” and the system.

The output parameters of the object (and, hence, its quality) depend on the input effects, environmental parameters and, of course, the quality of the elements that make up the object (Figure 4-1). In the first case of a “black box”, nothing is known about the elements that make up the object; that is, the X-parameters are not given. Therefore, the global function of the object is written in a simplified form, such as its reaction to external influences, input parameters, and time coordinates. Such an isolated view greatly simplifies the study of objects, but leads to the need to make a lot of (sometimes unreasonable) assumptions. However, the main advantage of this approach is the simplicity of the object study that often comes into conflict with the accuracy and reliability of the results.

In terms of the systems approach, an object is regarded as a complex organized system consisting of many interacting elements rather than a simple “black box”. Each element of the system can, in turn, be broken down into smaller parts, to which a systematic approach can be re-applied. It is thus possible to talk about the structural decomposition of the object and its hierarchical organization. The process of the functioning of the system is not so much due to the properties of its individual elements, but also to the properties of the structure itself. This is a so-called *structuring aspect* of the systems approach that allows an analysis of the elements of the system and their relationship within a specific organizational structure.

The two operations of opposite action are defined for the hierarchical description of the system (Pandia.ru, 2019):

- Push – a lower level of the abstraction, i.e., a detailed description;
- Pop – a higher level of abstraction, or hiding the structure in the "black box".

The *aspect of the hierarchy* is also applied to the structure of the system; that is, the presence of a set of at least two elements located on the basis of the subordination of lower-level elements to upper-level elements. On the whole, the systems approach allows the presenting of a complex task as a set of simpler ones that can be solved faster and easier. And most importantly, they can be solved in parallel.

Another notable feature of the systems approach is its *versatility:* with the same success, it is applicable for both complex and simple objects, and in the multi-level description of complex systems, it works at any hierarchical level that is applicable not only to the system, but also to any part of it. It is achievable partly due to the *aspect of multiplicity,* which allows the use of a set of cybernetic, economic and mathematical models in the description of separate elements of the system.

If the systems approach with its numerous aspects is applied, regardless of the system and corresponding type of model, one should be guided by some of its following principles (Sovetov and Yankovlev, 2012):

- Proportional and consistent progress in the stages and directions of the model creation;
- Coordination of information, resource, and reliability characteristics;
- The correct ratio of individual levels of hierarchy in the modelling system;
- The integrity of separate stages of model construction.

The above principles should be used at different levels of modelling (Sovetov and Yankovlev, 2012):

1) The conceptual level at which the boundaries of the system are defined, i.e., its basic inputs and outputs.
2) The topological level at which the connections of input, output and internal variables of the system are determined (the models of this level are graphs or networks).
3) The structural level at which the structure of operators describing the relationship of input, output and internal variables is determined. The relationship can be defined by functional static relations, dynamic description operators, matrix transformations, etc.
4) The parametric level at which parameters of operators of communications are set, providing full certainty of the model of this level, thanks to how experiments and calculations are carried out.

These principles have been used to develop the following models of systems dynamics, which is part of a larger school of thought; systems thinking that studies dynamic complexity through the systems approach discussed above. Many of the readers are aware of the compound interest rate effect on invested capital. Based on Einstein, it is the *"eighth wonder of the world"*, and in his opinion, it divides people into two categories: those who understand it, and typically earn through it, while at the other opposite end, people not fully aware of the "interest on interest" effect lose and pay heavy sums due to it. Think about investing initial capital of 1000 USD in a bond providing an annual yield of 10%. After the first year, its value is 1100 USD, and after two years, it is 1210 USD. After seven years, the initial investment value is nearly doubled to 1948.7 USD. This is all due to the "interest paid on interest" effect. There is also a practical rule of thumb available: 72 divided by the interest rate will yield an approximate number of years needed for the investment to double in value. Here, the bond yield was 10%, so 72 divided by 10 results in 7.2 years (the correct and exact duration for doubling is 7.272 years, so this is a rather close estimate).

The compound interest rate for initial capital is also one *"system"*, where you have the initial amount of money to be invested, a known (or estimated) annual interest rate and the development of the total capital amount based on these, and the most valuable asset, that of time. This could be described as shown in Figure 4-2 – the interest rate is flow variable (like water from the shower, but taking place every year), which is based on the amount of capital stock (or inventory as said in system dynamics models) multiplied by the variable of the current interest rate. In the model in Figure 4-2, capital inventory only accumulates further based on interest earned.

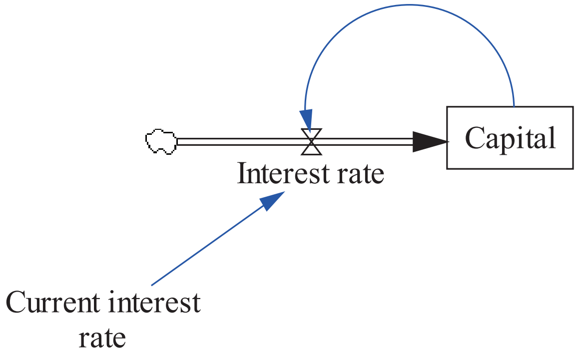

Figure 4-2. Simple system dynamics model, where a compounded interest rate takes place for the initially invested capital each year.

Nowadays, simulation models are built with graphical and guided interfaces, where equations and simulation model data are fed into the system. However, in terms of a computer simulation program, simulation is just a bunch of differential equations, which are solved with the massive computing power of a processor. A small model of Figure 4-2 would appear as follows in equation terms:

Capital = INTEG (Interest rate, 10000)
Current interest rate = 0.1
Interest rate = Capital*Current interest rate
FINAL TIME = 100
INITIAL TIME = 0
SAVEPER = TIME STEP
TIME STEP = 1

This small model is also fruitful to understand the limits of the system being replicated or built e.g., as a computer simulation model. The presented ideal model of Figure 4-2 is not taking any steps to show how the initial capital amount was earned (or is going to be earned and what is the duration of this activity) – is it the amount saved from small salaries or inherited? In addition, the capital usage period is not dealt with in Figure 4-2 – will it be left in the bank account or taken away after doubling the capital inventory to pay, e.g., the down payment of a mortgage for a new house? It is also assumed that the interest amount is kept invested on 10% yielding assets – of course, the availability of these is questionable, over time. The counter-party risks are not dealt with either in the model – there could be some chain of events, where the depository bank could go bankrupt and/or a debtor (government or private sector company) would partially be constrained to pay the interest and/or principally invested amount at the end of the period. Many heartbreaking stories are available due to an inability to pay loans taken out. For example, after 1917, when the Bolsheviks took power in Russia, a small delay meant that many bondholders in Europe lost their principal investments and future expected interest rates during the 1920s. Tsarist Russia often used very long-term bonds to fund their ambitions to expand and renew the railway network. These bonds were an extremely popular investment type in the UK and France among ordinary citizens – they were considered to be safe, providing a high yield (Ukhov, 2003). In many cases, the payment times of Imperial Russia's bonds (debt maturities) were numerous decades, even close to a century.

You may gather similar sad investment stories from the *"safe bonds"* of the USA-based housing market credit crunch of 2008-2009 (also, in other countries at that time, which experienced severe difficulties in honouring debts, like Iceland and Ireland) and from the Southern Europe debt crisis which followed in the period 2010-2015. Many companies and governmental parties have also failed their payments due to debt haircuts and restructurings, as well as completely losing bankruptcies. Sturzenegger & Zettelmeyer (2005) estimated that based on country-level haircuts of the period 1998-2005, which took place in Russia, Ukraine, Pakistan, Ecuador, Argentina and Uruguay, at a minimum these were 13% (Uruguay) and at a maximum 74% (Argentina), where an average level was 25-55%. So, in these situations, it is difficult to recover the effect of "interest on interest" (as typically promised interest rates are considerably cut), but what is even worse, the principal investment, in quite significant amounts, is also lost. In addition, countries under debt restructurings typically experience other undesired effects for the foreign investor, like a continuous devaluation of the currency.

So, the presented and used simulation model has its limitations, but this is assumed in the build-up phase – so the model has a certain area from which it starts and where it ends. As numerous factors are just assumed, it is easy to show exponential growth in capital amounts during the time period of the century (Figure 4-3). The initial investment of 10,000 USD will grow to 8.7 m USD in 100 years with a 7% annual interest rate (or yield); however, if the yield is only 5%, it means that 1.3 m USD is the capital amount at the end of the simulation period. This well illustrates a high sensitivity of interest rates – over a longer period of time one or two percentage points' difference in annual interest are actually very significant. Economic growth and prosperity are very sensitive issues.

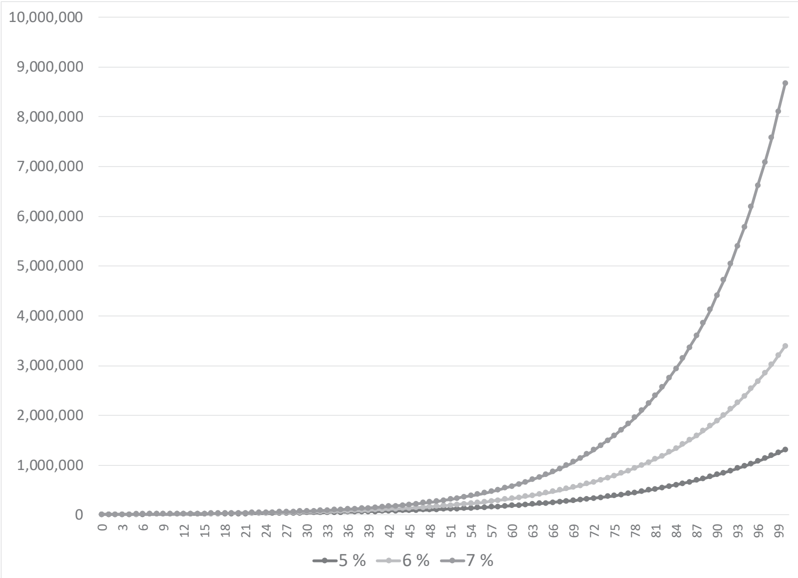

Figure 4-3. Amount of 10,000 USD invested at the very beginning and its accumulation through the compounded interest rate in 100 years in three different interest rate scenarios (5%, 6% and 7%)

Exponential growth (like interest on the interest effect) is one of the archetypes of system dynamics models (Senge et al., 1994). However, in Figure 4-3 it was only shown as "positive" (growing) acceleration of capital. As a counter effect, there is deceleration too. To illustrate this further, Figure 4-4 presents a simulation model, which is expanded to consist of a withdrawal phase of saved capital (and earned interest during the years). The model now resembles an active working life period, where a person does not need to touch the saved capital, and it is left to grow with interest rates being earned. However, the model will start a monthly withdrawal process after the capital inventory has grown to 150,000 USD (grown from 10,000 USD as the initial amount). The model assumes that an annual interest rate is 5%. The withdrawal amount is fixed, 850 USD per month, until all capital inventory is depleted. Do note that during the withdrawal process "interest on interest" is continuing, which makes the usage period of funds much longer.

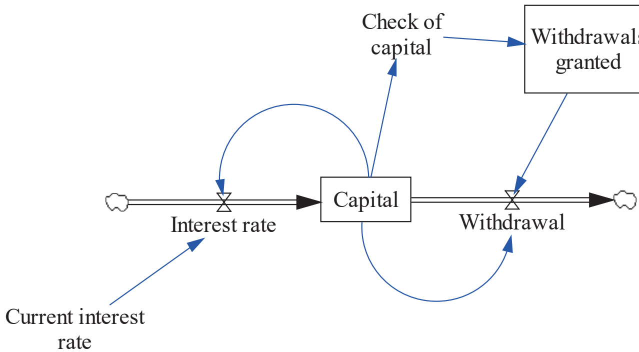

Figure 4-4. A more advanced system dynamics model, where the compounded interest rate takes place for the initially invested capital, which after a certain point starts to be withdrawn (e.g., pension or leaving work).

Modelling outcomes can be accessed from Figure 4-5 – there is a clear acceleration and growth period (exponential) until capital inventory in the model reaches 150,000 USD. This will take 667 months or 55.6 years. Thereafter, the withdrawal amount is somewhat larger (850 USD per month) than the interest earned on 150,000 USD (611.1 USD per month). This causes a deceleration effect on the capital inventory (in the first place this is slow, but thereafter very visible), which, at the end of the simulation period, leads to a complete depletion of the savings. In Figure 4-5, this means that withdrawals of 850 USD will start in the 668th month, and last until the 984th month. There is some small amount left in the 985th month (approximately 206 USD), but thereafter all of the capital inventory is used. So, the usage period is 317 months or 26.4 years.

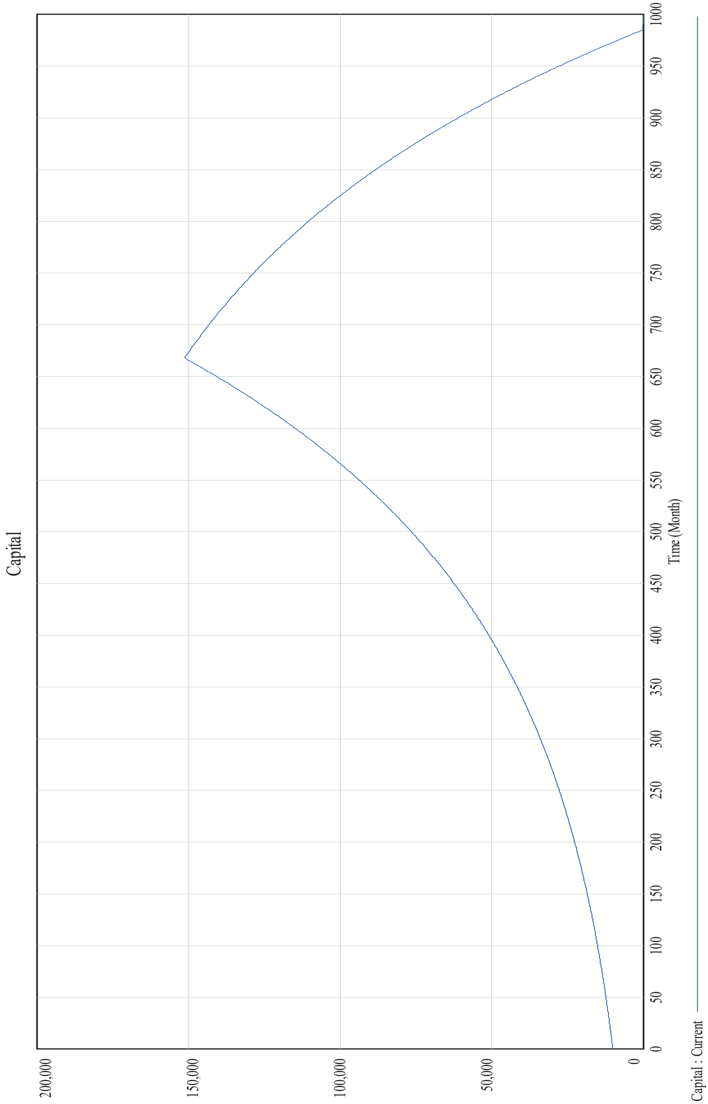

Figure 4-5. Amount of 10,000 USD invested at the beginning of the simulation, which is left to grow, until 150,000 USD is reached (5% p.a., in the model, interest is paid monthly), from which 850 USD is withdrawn monthly.

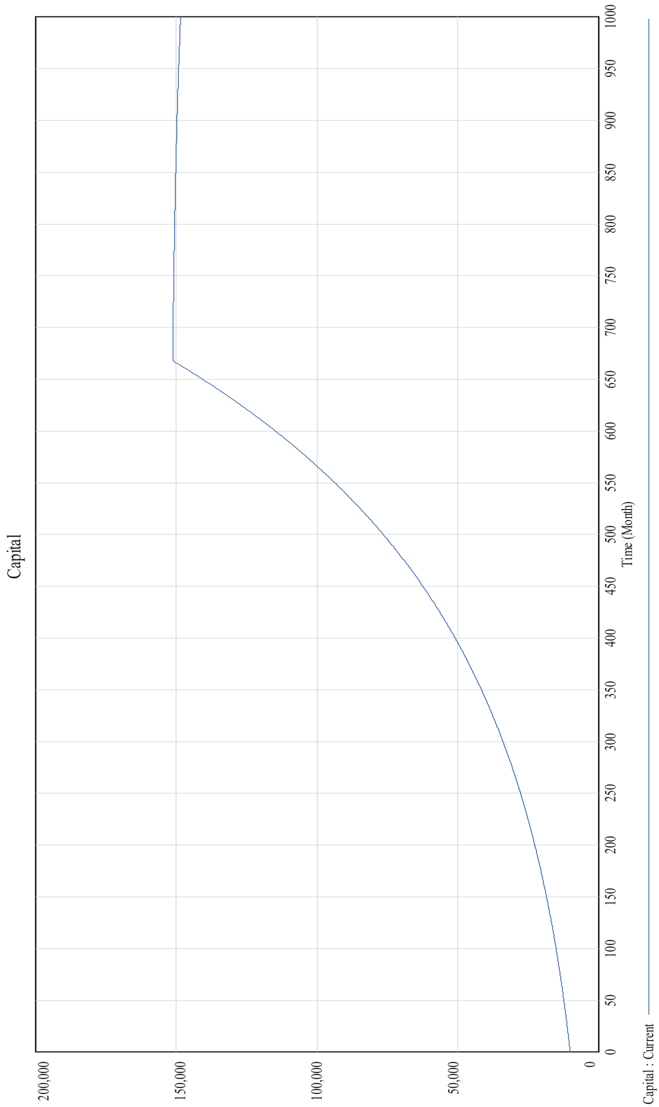

Figure 4-6. Amount of 10,000 USD invested at the beginning of the simulation, which is left to grow, until 150,000 USD is reached (5% p.a., in the model, interest is paid monthly), from which 620 USD is withdrawn monthly.

As an additional archetype of system dynamics simulation models, Figure 4-5 illustrates a typical "shoot and collapse" model, although this one takes a long time to form: 985 months (or 82 years). It is similar to the product sales' life cycle (the maturity phase is not present or that long, but otherwise it is basically the same). The model could yet produce another archetype outcome of the system dynamics simulation, that of "constrained growth", if withdrawal amounts were set lower, and close interest earned on 150,000 USD – Figure 4-6 shows the situation where the withdrawal amount is 620 USD per month. At the end of the simulation period (month 100), a person still has 148,380 USD in the bank account. This further modelling also explains in rather good fashion, why pensions have been, and are going to be small around the world (on average). It also illustrates, how the interest rate level earned on invested capital is critical for pension systems to sustain their performance and ability to pay (OECD, 2015: 111-148). It is also challenging to earn 5% p.a., for a longer period of time. In the year 2017 there were two OECD countries which earned a negative rate of return on their pension assets, and 13 countries had a return rate below 3% (these were mostly European Union countries; OECD, 2018).

Many readers could argue against the shown pension model, that it is too simplistic, in real life pension payments follow your working month, and therefore pension accumulation will be much higher. Models have also been built for this (if interested you may check one additional model via the web browser or the Vensim simulation program, please visit: Forio, 2018a), and it is interesting, how the initial savings model (like in here previously analyzed) with compound interest still gives a good proxy about the state of pensions. In real life, it will take at least 20 years (240 months) from when that person on average enters the workforce, to be able to save for their pension (or the government does it by taking pension payments from their monthly salary). In the early years of their career people typically have low salaries, so payments are not that significant. These will of course increase as time goes on, and work experience and personal competencies increase. However, during a working career nearly every person is for some period unable to partially or completely earn their pension (e.g., due to long-term sicknesses, unemployment, taking care of a young family, etc.). All of this means that earned pension payments during a working life are accumulating compounded interest for a shorter period of time (vs. the initial saving model), and with people's longer life span (and this basically increases life on pension), this will correspond with the difficulty of increasing monthly pensions. So, all in all, modelling will only tell one story, and that is, that retirement is difficult in financial terms for pension funds. However, the story could be different if interest rates were high, but in the low-interest rate environment, a pension system is under stress. In the situation where the annual rate of return is below 3%, this is an increasingly critical issue (based on own modelling experience). Do also note that once pension withdrawal starts in reality, the monthly sum hardly stays the same forever. In many countries, the monthly pension follows consumer price index development (e.g., changed annually). It is again one reason, why a starting pension needs to be low in value (due to the force of the compounded CPI effect during the pension years).

From the system dynamics perspective, it could be suggested that for the current pension system to be sustained in the following decades, it should be changed even further. Each person ought to have initial savings made at the beginning of the person's life, and these should be invested in profit making and safe assets. Of course, this is very difficult for young families to complete (or quite often impossible), but the government could always find ways to transfer capital through taxation (one way would be a transfer from inherited taxes directly to newborns, or to provide inheritance without taxes, if they are transferred to newborns, etc.). These sorts of arrangements would ease the pension payments of the workforce in the future, and create economies that are more competitive. Also, economies could get an opportunity to grow, and not be completely frozen or halted. There exists a danger that the current system of smaller and smaller new generations in the old west with an increasing amount of people on pension (and not only in the west, but increasingly so in Japan, Russia and China) will result in massive increases in the pension payments and taxes of future working-life generations. As the system dynamics model showed – time is the most prestigious asset, and strategies should be tied to it. A systems solution is always different from ordinary thinking of the two-variable-based cause and effect.

4.2. Main elements and stages of systems analysis

Systems analysis is considered as a methodological ground of modelling systems (Volkova and Denisov, 2014). In turn, systems analysis belongs to the broader concept of the systems approach, from which it borrows the basic definitions and main elements. The key element is a *system* – a collection of related elements combined into a single whole to achieve a specific goal (Sovetov and Yakovlev, 2012). In other words, any object of any complexity can be considered as a system. To understand the system, to study, and to investigate it (the task of analysis), it is necessary to describe the system, to fix its properties, behaviour, structure and parameters.

The structure of the system is a fixed set of elements that make up the system, and the links between them. Most often, the structure of the system is depicted in the form of a diagram. It can be a block diagram, a structural, functional or schematic diagram. In system dynamics, the structure of the system is represented as a set of positive and negative feedbacks and delays in interacting with each other (Forrester, 1961). One feature that is common to all systems is that a system's structure determines the system's behaviour. For example, system dynamics can be used to analyze how the structure of a physical, biological system can lead to the behaviour that the system exhibits.

Another mathematical form of structure mapping is a graph. In this case, the elements of the structure are represented by the vertices of the graph, and the links are represented by its arcs or edges (Panova, 2012). The movement over the graph simulates the dynamics of the system, changes of its states in time. The *state of the system* is one of the possible sets of stable values of system variables, while the *process* is a dynamic change of the system in time. In turn, *a function* is a process that takes place in the system and has a certain result. The representation of the functions of the system in time, i.e., the functioning of the system, means the transition of the system from one state to another, i.e., movement in the state of space.

The function of the system is always a formalized or meaningful (verbal) description of the principle of operation (functioning) of the system. It is desirable to present the function of the system in analytical form, using a particular mathematical apparatus, such as functional analysis, queuing theory, Markov models, operations research, mathematical logic, etc. For complex systems, a formal description cannot be obtained. In this case, the behaviour of the system is represented by an algorithm written in one form or another (block or graph schemes of algorithms, operator schemes).

The next element is the *external environment* – a set of elements of any nature existing outside the system, which influences the system or is under its influence. The *structural element of the system*, in turn, is an elementary unit (part) of the system that is indivisible at this level of detail. The indivisibility of an element is a convenient assumption, but not a physical property. In terms of the element, a researcher reserves the right to move to a lower hierarchical level and talk about what the element consists of. This indicates the physical decomposability of the latter. An element of the system is often called a structural primitive. In fact, it is a "black box" and indicates the inputs, outputs, and function to be performed.

In contrast to the element, the whole object under study is considered from the systems approach, which allows the problem of constructing a complex system to be solved, taking into account all of the factors and possibilities proportional to their importance at all stages of the study of the system and construction of the model (Sovetov and Yakovlev, 2012). On the basis of the systems approach, a certain sequence of systems analysis is proposed that includes *macro-designing and micro-designing*. At the stage *of macro-design* on the basis of data on the real system and in the external environment, a model of the environment is built. At the same time, resources and constraints for building a model of the system are identified. Then, a model of the system is selected and criteria are chosen to assess the adequacy of the model of the real system. The stage *of micro-design* largely depends on the specific type of model chosen. In the case of a simulation model, it is necessary to ensure the creation of an informational, mathematical, technical and software modelling system. At this stage, the main characteristics of the created model are set. Also, at this stage, the time to work with the model is estimated and the cost of resources to obtain a given quality of compliance with the model of the process of functioning of the system is considered.

It should be noted that the development of a model based on the classical approach involves the summation of individual components into a single model, with each component, solving its own tasks, isolated from other parts of the model. Moreover, the goals that are set on the data about the system representing different or fragmented parts of the process are required. Therefore, the classical approach can be used to implement relatively simple models, in which it is possible to separate and consider mutually independent and individual sides of the real object.

The process of synthesis of the model on the basis of the systems approach is as follows. The initial requirements for the model of the system are set on the basis of the initial data, which are known from the analysis of the external system as well as on the grounds of the restrictions that are imposed on the system and based on the functional purpose. Then, on the basis of these requirements, i.e., some subsystems, elements are subsequently formed, from which the components of the system are chosen.

Finally, it should be noted that regardless of the approach to modelling a system, it is necessary to ensure the maximum efficiency of the system's model. Thus, the final stage of designing a complex system, carried out by any approach, is the analysis of performance indicators of the designed system. Efficiency is usually defined as the difference between a measure of the value of the results obtained from the operation of the model and the costs that have been invested in its development and creation.

Further on, particular models of the systems dynamics approach will be discussed. In an earlier sub-chapter were introduced some basic elements of systems dynamics models – inventories ("Capital" in Figure 4-4), flows ("interest rate" and "withdrawal" in Figure 4-4) and feedback loops (formation of "interest on interest" in Figure 4-4). Also, models always have variables (like the "current interest rate" in Figure 4-4) and relationships between the elements. In the model in Figure 4-4, there also existed feed forward, which was the linkage from capital inventory to withdrawal – this was needed due to the functionality of the model that as cash in the bank account was running out, withdrawals were limited to the amount of money in the account (and not to the fixed sum, previously taken on a monthly basis). The systems dynamics model can quite often also be built into spreadsheet programs, but larger models will become very complex and unreliable, as it is difficult to verify that everything is correctly stated in functions and linkages. In addition, systems dynamics simulation has the advantage of making changes in the model in a rather rapid fashion, and running different scenarios by changing numerous variables is rather easy and safe to conduct.

However, until this point, the last element of systems dynamics simulation modelling has not been introduced, and this element is a vital part of numerous advanced models (and system behaviour). This element is called "delay". In the simulation program used (Vensim), it is modelled with a flow variable, and just by typing delay function. In other simulation programs, there even exists its own separate graphical element. Delays are rather common in everyday decision-making – there is a delay in deliveries, there is a delay in production, there is a delay in transports, not to mention the multi-year delay of construction of a house or ship. Also, all of the preparations, design and planning of, e.g., larger investment is part of the overall delay. The effects of this vital element and the long delays are typically very devastating for different models, decision-makers, and real-life systems. Results are often asymmetrical and therefore hard to predict without simulation. Understanding delay consequences in different contexts is a life-long process.

To understand "delay caused dynamics", in the following, a two-stage manufacturing supply chain (OEM and supplier) is analyzed, both producing to an end-item inventory with the aim of serving customers in the best possible way (short lead time deliveries and in the correct quantities).

Of course, both parties (OEM and supplier) have delayed internal process times, which are being varied in the following. In the hypothetical example, Original Equipment Manufacturer (OEM) and its supplier (a two staged supply chain) manage their production via a finished item inventory. The product itself does not contain any multipliers between these two parties – each time one end product is supplied from OEM, it consists of one supplier component or module within it (like a car with one gearbox or a smartphone with one high-resolution display). OEM is trying its best to keep its end-item inventory to the amount of 2,000 units – all production decisions are based on this objective. There is a similar arrangement for the supplier's operations – it has a goal of 6,000 units in its end-item inventory. The latter is mostly due to a sudden variation in OEM's orders due to delays, as illustrated in the following analysis.

As illustrated in Figure 4-7, before week five, demand for the manufacturer's only end-item was 1000 units per week, but it will increase without any warning to 1200 units during week six (+200 units, +20%). Demand continues to be 1200 units, but in week 12 it declines to 800 units (-400 units, -33%). Demand stays at this lower level until the end of the simulation period. So, bigger demand changes take place in the first part of the simulation period.

OEM and its supplier are both facing a delay in their internal processes, which varies from two to seven weeks (different simulation scenarios). The amount of production is 1,000 units per week in the beginning, and depending on the internal lead time duration, it is held at this level for two to seven weeks. So, production is always frozen for the lead time amount. As an example, a two-week lead time means that a decision on the production schedule in week one could have its changes in week three. A seven-week internal lead time situation means that during the first week, decision-makers are making decisions regarding week eight of production. Therefore, the demand change in week six in Figure 4-7 will have its response in the production structure weeks later. This is mostly due to labour inflexibility at a plant (e.g., extra working hours, new shifts and/or even hiring), the inflexibility of suppliers and short-term capacity constraints of machines. This sort of arrangement is well-known in the industry as a "frozen period".

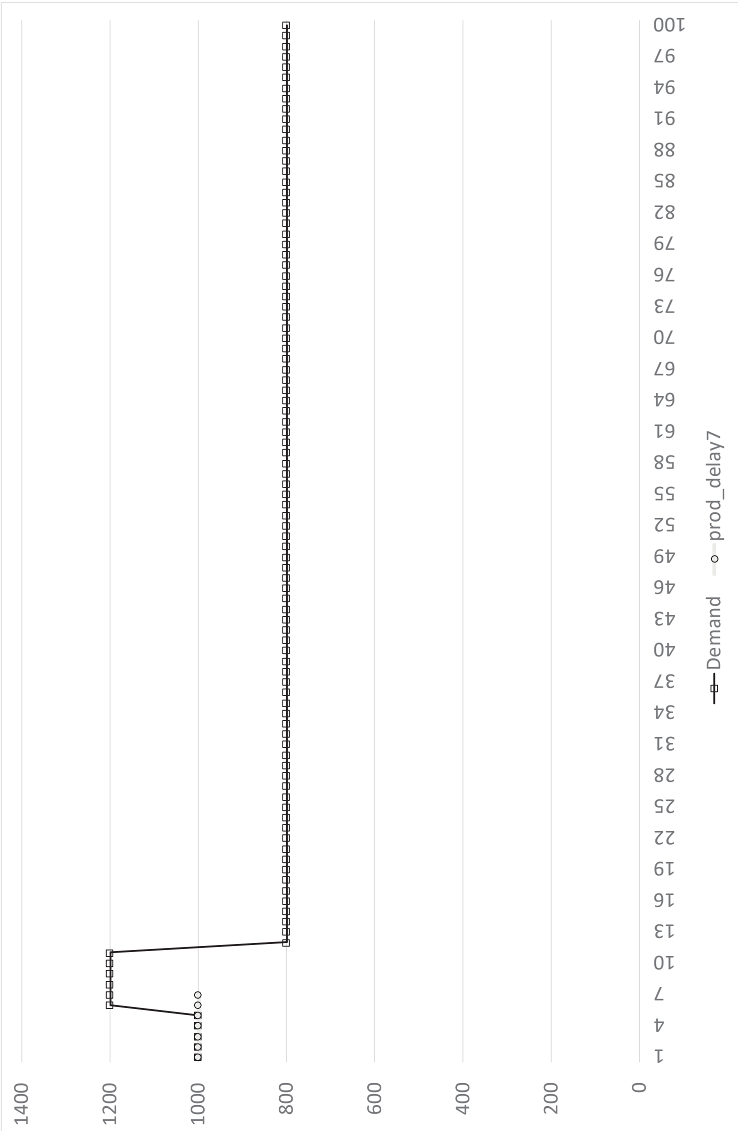

Figure 4-7. Demand of the factory (y-axis; units) during 100 weeks (x-axis) and the production program already agreed with a frozen period/delay of seven weeks

In general, both OEM and its supplier have rather similar simulation models, as shown in Figure 4-8 concerning OEM. The only difference between these models is that the end-item demand of OEM is independent (as described earlier in Figure 4-7), while the demand of the supplier is dependent on the production process decisions of OEM ("production delay" plus "already agreed production" from Figure 4-8). A delay (internal lead time) at OEM and its supplier in each case is the same. Order decisions (orders from production) are completed with the following algorithms in OEM and supplier operations:

- OEM: IF THEN ELSE ((Demand+(2000-"End-item inventory")/Delay)<0, 0, (Demand+(2000-"End-item inventory")/Delay))
- Supplier: IF THEN ELSE ((Demand supplier+(6000-"End-item inventory supplier")/Delay supplier)<0, 0, (Demand supplier+(6000-"End-item inventory supplier")/Delay supplier))

As algorithms illustrate, they will order either zero or some positive number of products from production. The first situation takes place when the end-item inventory has grown too large. Think about 4,000 units in OEM's end-item inventory, where customer demand is 800 units, and the internal delay is two weeks. This would mean that no orders will be placed as the following equation is below zero: (800 + (2000-4000) / 2). However, if the internal delay were three weeks, then the order would be 133 units (based on the following equation: (800 + (2000-4000) / 3)). In the situation of seven weeks of internal delay, this particular order size would be 514 units. The decision about the production order quantity in the supplier's manufacturing process is rather similar, but in this situation, the demand for the desired inventory is much higher at 6,000 units. So, in many situations, orders are rather large.

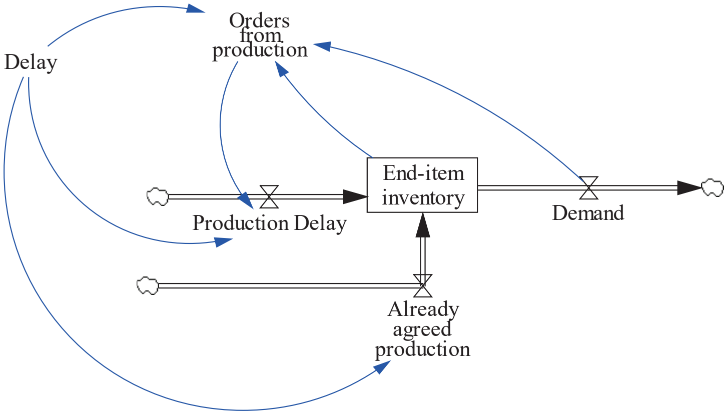

Figure 4-8. Systems dynamics model for a "make-to-stock" factory with varying frozen periods/ delays.

The ordering behaviour, and the end-demand changes, are difficult to comprehend for first-time readers (if experience exists from the beer game or the Forrester effect, then this is easy to understand). In Figure 9, after a frozen period of different scenarios (two to seven weeks) the production orders first shoot up to cover for inventory loss and due to increased customer demand (the manufacturer cannot know that demand will drop in the near future). However, as customer demand suddenly declines, production orders will rush to correct over-inventory investments and weaker demand. Amplification of these decisions lasts in some cases until the end of the simulation period (100th week). Typically, low lead-time scenarios will change their production quantities in a rather rapid fashion, and flexibility is indeed needed in production. However, these short lead-time scenarios will adapt and trace the changed demand in a much better fashion as compared to longer lead times. In the latter, production orders rise and fall in motion, which is like a large ship being steered at sea. It is understandable that the inventory in these longer lead-time scenarios is larger on average, however, the most important downside is big changes experienced in inventory amounts. On average, inventory amounts are not significantly larger than, e.g., the two-week scenario, but the highest amounts of inventory are really big, and require a lot of working capital for operations. Senge et al. (1994) call system behaviour as described here as a "balancing loop" – seek a new level and a balance takes that much longer in the long lead-time scenarios.

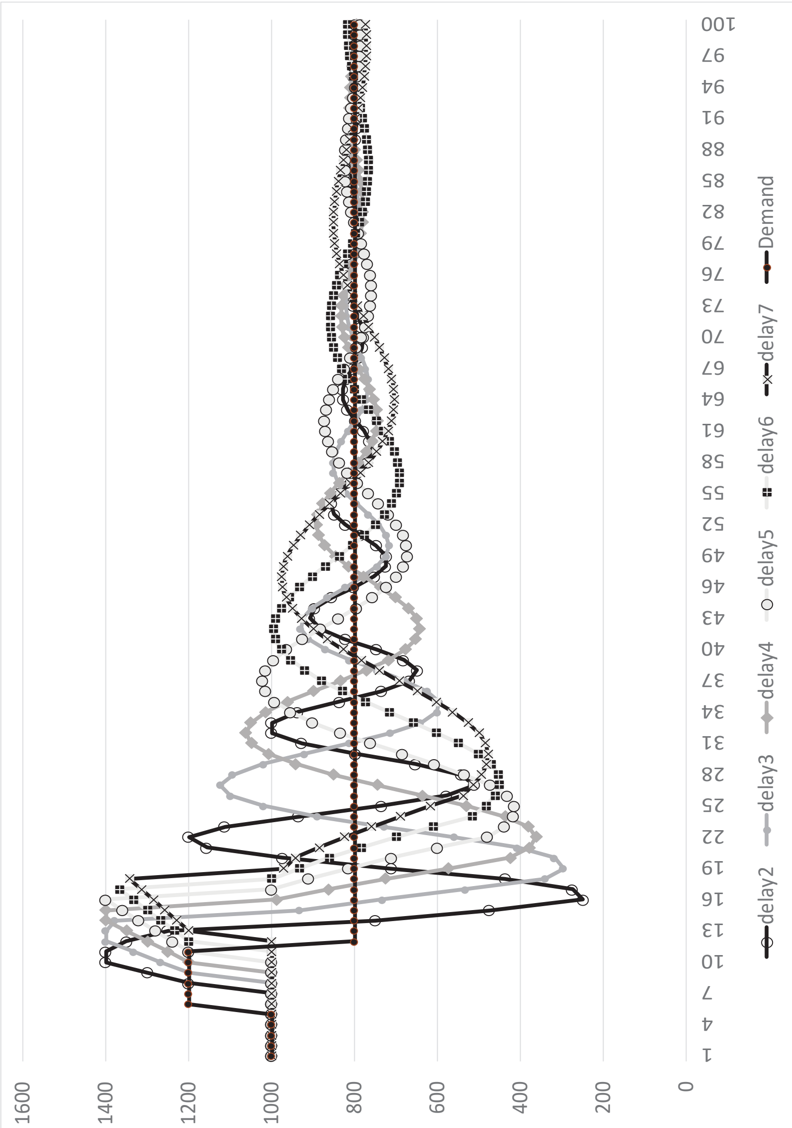

Figure 4-9. Orders from production (units) during 100 weeks in different frozen period/delayed production order decisions.

Oscillation will further amplify in the two-staged supply chain upstream (supplier) as different lead-time scenarios are analyzed in Figure 4-10. After the frozen period of each scenario, production order surges and strong declines become rather large, everything from zero to two thousand units. Until the end of the observation period, much longer lead-time scenarios are still on the way to stabilizing themselves for the customer demand changes taking place in the OEM side in the early part of the simulation. This only illustrates, why manufacturing in some longer chains, with considerable delays, is often totally messed up and uncontrollable as some sudden changes take place in demand. These changes do not need to be great on the final customer side for suppliers, e.g., in emerging economies, to experience the threat of bankruptcy (lack of orders) or having significant difficulties to have the needed capacity and resources to fulfil the demand (demand upswing).

As said earlier, the oscillation of inventory in the two-staged supply chain gets higher as lead times grow. Figure 4-11 illustrates the total inventory amounts in these two stages. The longer the internal lead time, the higher the upswing will be (a very high inventory), and in turn, the downswing will lead to lower amounts as well. This is not the only worry for working capital requirements, but it is also difficult to manage from the risk management perspective. Think about completely losing markets and demand as inventories in the supply chain are at a very high level. This would be a very difficult situation for supply chain members to swallow, and would result in deep losses, and in worse situations in sudden business failures.

Actually, in longer lead time models two connected inventories (supplier and OEM) start to repeat chaotic behaviour, where inventory amounts start to go round a “strange attractor” in the middle (Helo, 2000). Do also note that in chaotic systems a small system change (like the inventory of OEM) will result in huge swings at the other end (like the inventory of the supplier); to detect and illustrate this in the appropriate manner, both axes in Figure 4-12 have the same scale (from 0 to 12,000 units). Here, the simulation run is 100 weeks – if the simulation run were 1,000 weeks, Figure 4-12 would be repeating a similar pattern as before in 900 additional weeks, with the only exception being that the variation would be lower and lower and the simulation would be trying to find a strange attractor point of 6,000 units on the y-axis and 2,000 units on the x-axis. In supply chains, chaos is stronger, if order decisions are based on inventory rather than on actual demand. Also, the longer the chain and the longer the lead time delay, the higher is the strength of chaos (Hwarng & Xie, 2008). Chaotic systems are present everywhere, like on the shores of an island or at the border of a country

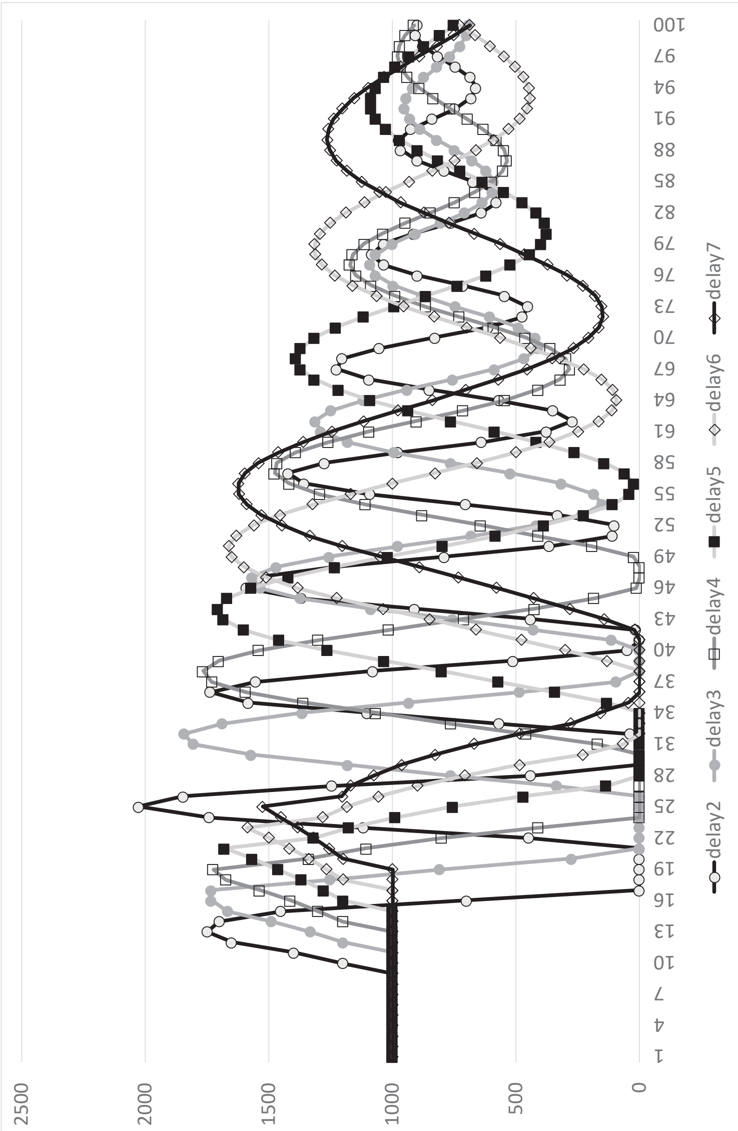

Figure 4-10. Orders from supplier's production (units) during 100 weeks in different frozen period/delayed production order decisions.

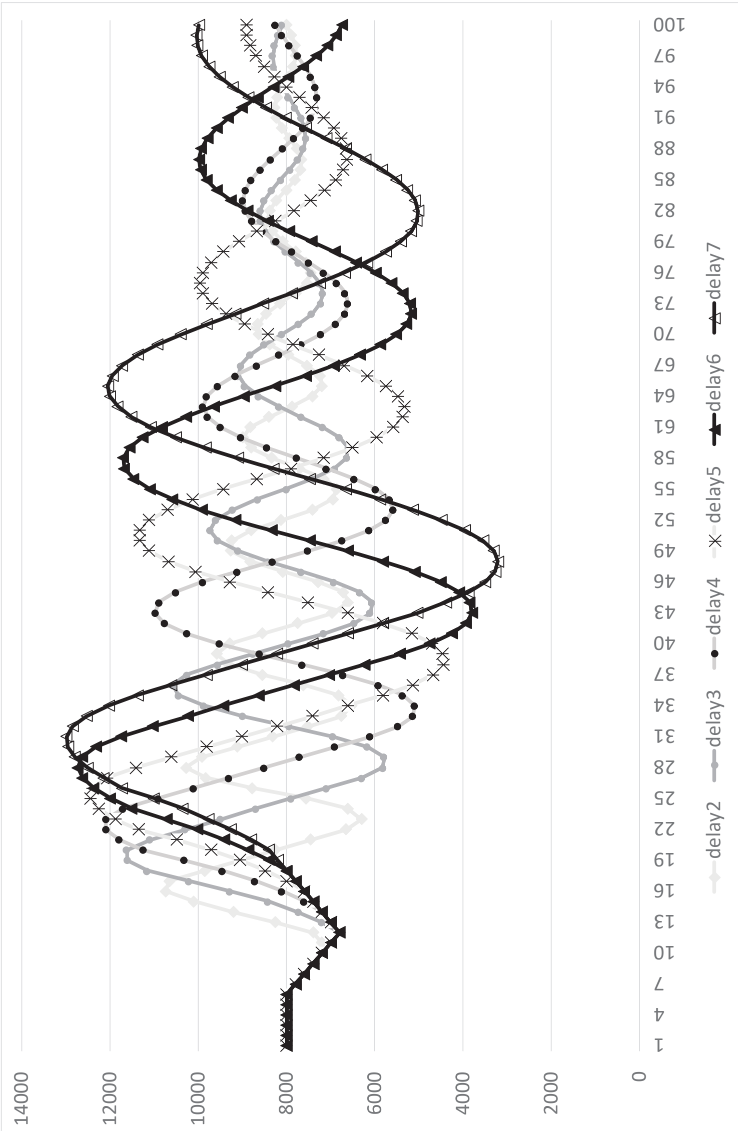

Figure 4-11. End-item inventory of a two-stage supply chain (factory and supplier in total, in units) during 100 weeks in different frozen period/delayed production order decisions.

(edges repeat the same patterns again and again, it just depends on the observation magnification). Chaos is actually a good thing in systems as it gives forecasting power to a decision-maker, as to where a totally uncontrollable system is heading. There is order in chaos. Interested parties should visit search engines with the keywords, "Lorenz butterfly effect" and/or "strange attractors".

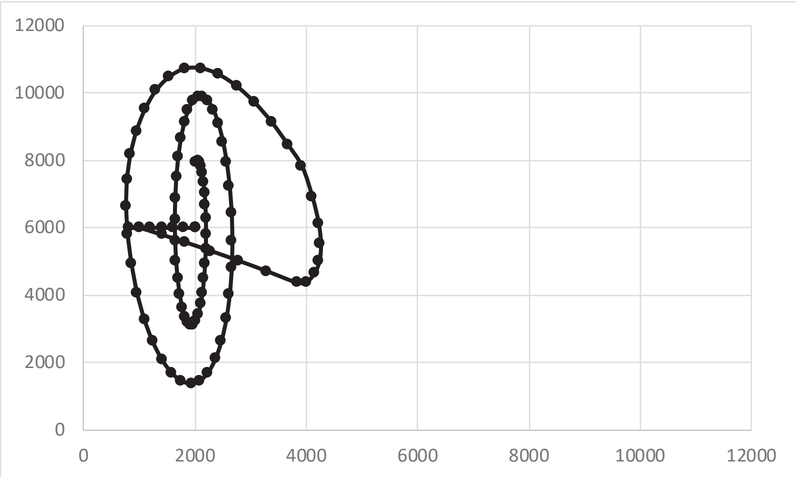

Figure 4-12. Chaotic behaviour in a seven-week delay scenario between inventory values of the end-item inventory of OEM (x-axis) and the end-item inventory of the supplier (y-axis).

4.3. Decision-making process

The dynamic world view leads to complexity in decision-making. In a static world, everything is a given, and a decision-maker can just seek and select an optimal strategy (and ensure that an organization remains within it, like a military force). In a dynamic world, things change over time, and a decision that is rational today might be entirely wrong at the end of the year. System linkages and interactions are difficult to foresee, and behavior is difficult to predict. In the earlier two-staged supply chain, a harmless-sounding internal lead-time delay caused devastating effects on performance. This situation very much needs to be solved – shorter lead times, information sharing (and collaboration in general, such as through inventories; e.g., Holweg et al., 2005), limits on order size changes, the leading role of a downstream actor, and patience in decision-making (Costas et al., 2015; Kembro & Selviaridis, 2015; Dev et al., 2014; Stefansson, 2002; Yu et al., 2001). If it is possible to change the supply chain to be more order-driven (vs. producing to inventories), this ought to improve inventory performance and dampen the amplification/bullwhip effect (Jammernegg & Reiner, 2007).

However, solutions for higher performance are not necessarily that complex, what previous supply chain example would argue them to be. At the company level, solutions are often easier to find as some policies are just taken for use. This could be highlighted with another hypothetical example of a manufacturing company, which is producing every week an average of 100 units of end-products (in a simulation model this production is set to be normally distributed, with a mean of 100 units, where the minimum and maximum are 50 and 150 units), which all require one raw material each. The acquired raw material pricing is based on the daily spot-rates of world markets (it could be chemical, oil, copper, etc.), which change rather suddenly over time. It is not uncommon that prices could fluctuate even 30% within a few weeks (think about oil price moves in August-September 2015). The key issue for the manufacturer's purchasing success is to ensure that these declining markets are used effectively as they appear (and again disappear as prices recover). In the model, raw material price development is built in such a manner that it is 100 USD all the time, apart from a price plunge of 50 USD downwards in week 10, which shortly recovers back to 100 USD. The following company is using such a purchasing policy; that is, if prices decrease sufficiently (more than a 30% weekly change), the purchasing department may acquire 5,000 units towards the inventory. Otherwise, purchasing is dependent on the inventory situation, and only the average daily amount on a daily basis is called to the inventory. An inventory of the system starts with 200 units.

The model of a new policy evaluation is shown in Figure 4-13. It is basically an extension of a simple manufacturing-purchasing, inventory model, where market prices are followed continuously on a weekly basis. In the model, there is also a purchasing unit price follow-up based on the deliveries made. A new policy of lower purchase prices will, of course, lead to risks – as shown in Figure 4-14, inventories will increase significantly to 5,000 units as raw material markets provide very low prices. Thereafter, for a year, production consumes these raw materials at a predictable as well as a constant rate, and after a while, a normal situation in inventories starts again. This is the risk to be taken, if lower purchasing prices are desired (and in turn, an objective is higher profits). It is of course a case-dependent decision based on the margins of manufacturing, the role of raw material in overall costs and the possibility of selling the raw materials in second-hand markets, if production volumes shrink suddenly. However, it should be emphasized here that for supply chains, these sorts of sudden demand spikes of large raw material orders are not by any means beneficial (think about the demand amplification/bullwhip effect earlier, one root cause is price discount), which will result in inventory increases in chains and unutilized capacity. These sorts of decisions are still rather common as price discounts become available and management is under pressure to deliver financial results (Tan et al., 2015; Zotteri, 2013).

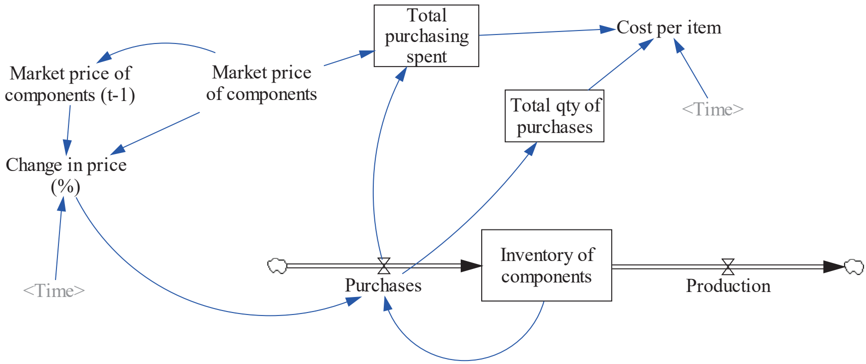

Figure 4-13. Cost effective raw material purchasing for manufacturing.

A new purchasing policy results in a substantial decline within raw material prices as shown in Figure 4-15. It should be highlighted that raw material prices are 100 USD all of the time in the simulation model, apart from week 10, when they plunge to 50 USD. The utilization of a sudden price change will yield profits for a long period of time, and is worthwhile to conduct, if risks with inventory can be managed somehow.

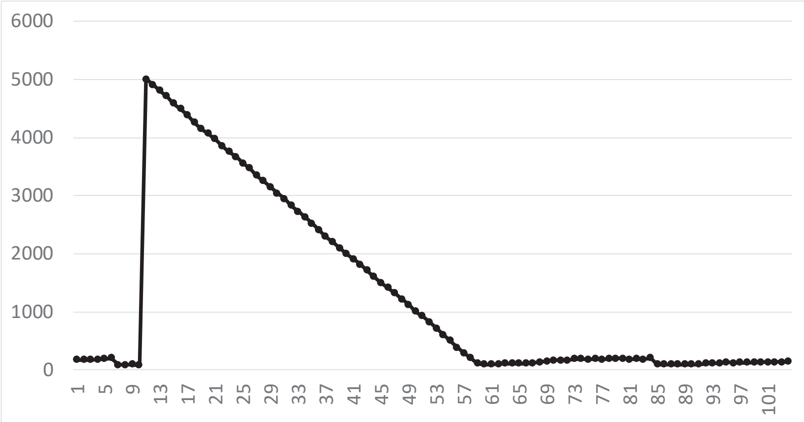

Figure 4-14. Raw material inventory development in the model during a simulation run of 104 weeks.

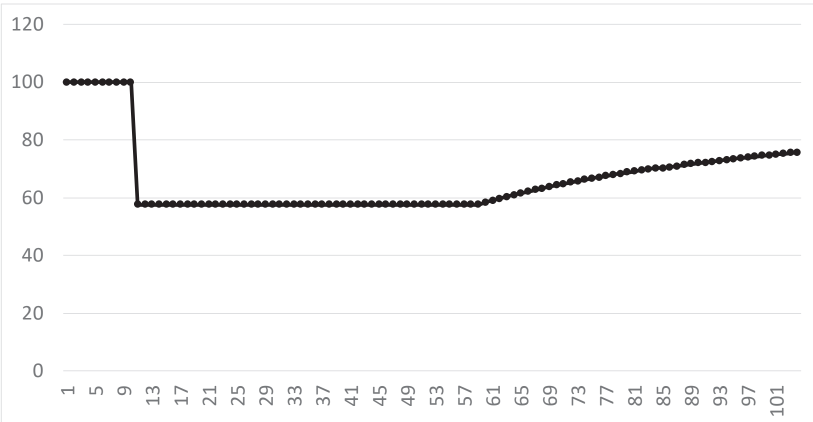

Figure 4-15. Average purchase costs for material used in production.

Another example from a decision based on dynamic systems could be related to global markets, technological development and pricing (concerning further interest and making additional analyses, please visit Forio, 2018b). In the long-term, many industries have faced the challenge of declining prices in every year, but on the other hand, increasing global volumes. Of course, niche markets always exist, where higher prices could be sustained, but these have very limited volumes. Examples from such dynamic and price pressure industries could be taken as solar panels, electronics, different machines, aircrafts and textiles (e.g. Sterman, 2014; Milberg & Winkler, 2013: 122; Grimm, 1998). Even if pricing is a challenge, it should be remembered that higher global volumes offer opportunities for manufacturing and overall organization to learn higher efficiency. In the scale economics theory, every time volumes double, costs will drop typically by 10-30%. This provides opportunities for profits, but requires companies to *"get big and fast"* – dominant players in the industry in this scale economy period will gather most of the revenue and nearly all of the profits.

In the following hypothetical simulation model, a manufacturing company is facing growing markets, but this would require sales prices to be substantially lower than they are today (simulation model, see Figure 4-16). Currently, the sales price per unit sold is 100 USD, and the overall market of the product is 10 units per week. A manufacturer has a market share of 10%. So, basically, currently the manufacturer has a one-unit order per week with a price of 100 USD. There is another alternative, which would require a price discount of 30% to current prices, and then the market would be five times larger (50 units per week vs. the current 10 units per week). It is estimated that with a 30% drop in sales prices, the market share of the manufacturer could increase to 50%. So, this would correspond to a 25-unit weekly demand with a price of 70 USD per delivered unit.

The challenge in this example comes from the starting cost level per unit (manufacturing cost). They are at 100 USD per unit at the very beginning. However, total production before the simulation was 100 units, and the experience/learning curve effect is estimated to be a 25% decline in production costs per unit every time volumes double. So, at the beginning of the simulation period, it would simply be unprofitable to sell items at 70 USD per unit. The organization also has other weekly expenses (fixed costs in Figure 4-16) of 300 USD. So, even with the 100 USD sales price it is difficult to make profits, since the weekly volume is so low (one unit), and margins are even at the manufacturing unit cost level low (although the experience/learning curve will benefit manufacturer as volumes accumulate).

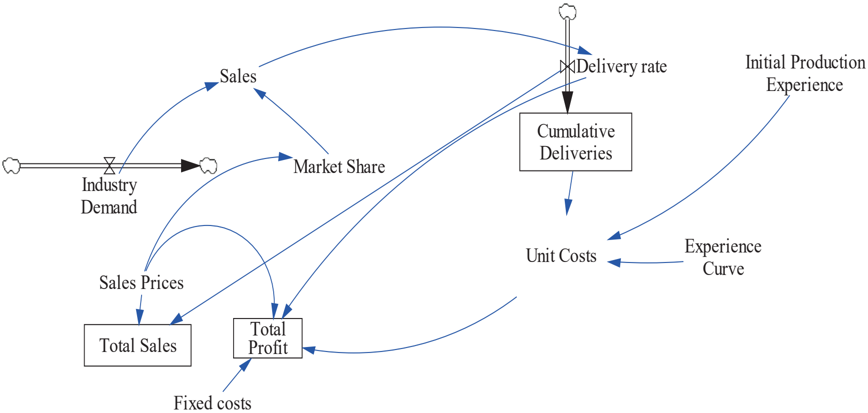

Figure 4-16. The simulation model from the rate of learning in growing markets.

It is necessary to trust manufacturing cost declines as well as examine the manufacturer's alternatives regarding revenues (Figure 4-17) and profits/losses (Figure 4-18). In period 20 (week), the manufacturer in an alternative scenario enters discounted sales prices, and in the long-term the profit impacts are significant. Of course, in the first year the manufacturer is similarly in loss even without any discounts given. However, thereafter profits start to swell, and increase all the time (and make a remarkable difference to an alternative laissez-faire situation). Actually, the manufacturer breaks even in week 60.

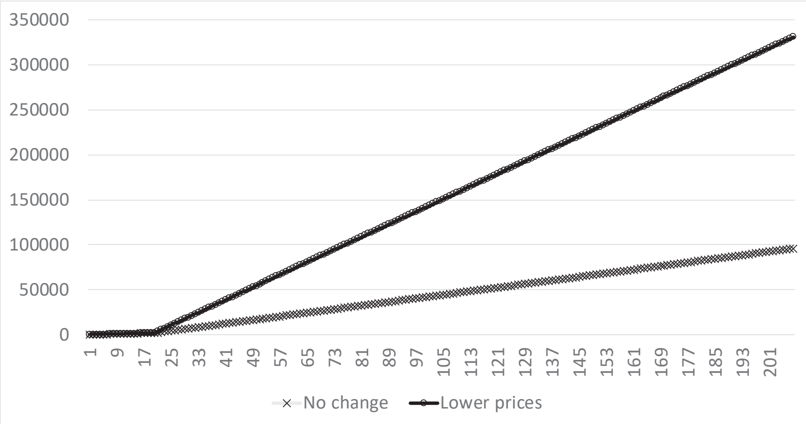

Figure 4-17. Revenue development in two scenarios, where prices are held at the same level as earlier, and alternative prices are discounted to gain higher volume.

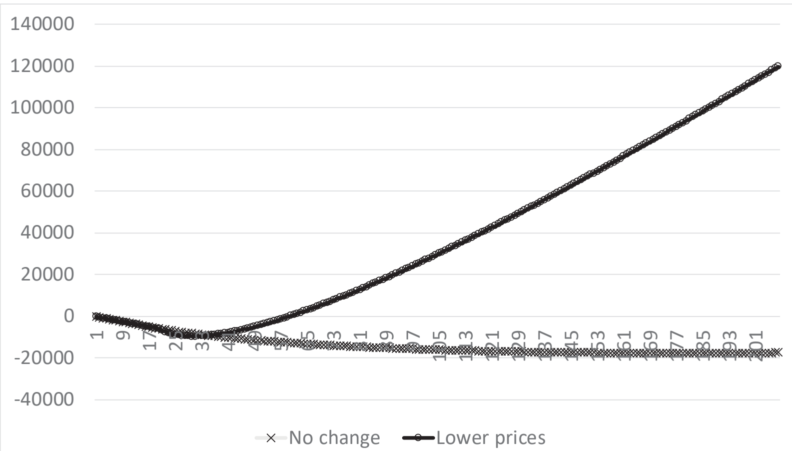

Figure 4-18. Profit/loss development in two pricing scenarios.

The reason for the profits could be accessed from manufacturing unit cost development (Figure 4-19). As a price discount offers volumes, manufacturing is able to achieve substantial cost decreases in a short amount of time (volumes double in the first five weeks, and at the end of the year they are sevenfold as compared to the situation in week 20). This volume growth continues throughout the simulation period. So, volumes double numerous times, and cost advances are substantial particularly in the first two years. Therefore, the price of 70 USD per unit is actually a good and appropriate decision, if examined retrospectively from the viewpoint of the end of the second year. In the third and fourth years, its benefits are even clearer.

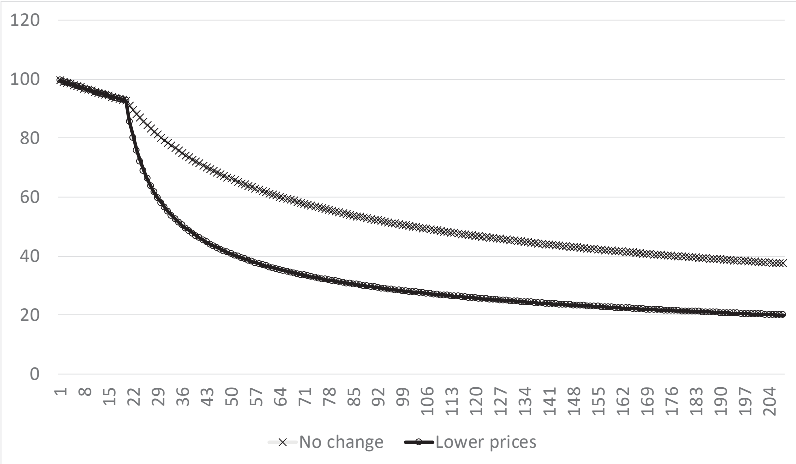

Figure 4-19. Unit cost development in two pricing scenarios.

It should be emphasized that relying on experience/learning curve effects is case dependent, and works in situations, where new high-technology products are brought to the markets. Production processes are then at the inaugural state, being inefficient (often departmental) and production takes place in a high-cost country. Typically, the role of leading-edge product development and patents gives a competitive advantage for a particular manufacturer over others. In addition, the raw material content from the final cost structure of the product should not be too high (to have "space" for efficiency improvements, of course, raw material content could always be lowered with engineering) – to avoid losing efficiency gains, e.g., if raw material appreciates in value globally. The decision is better informed, if it is analyzed properly before making price discounts. Internally, it starts from an understanding of the current manufacturing process, and the possible efficiency opportunities gained, if volumes increase substantially. In addition, there should be analysis of the kinds of investments these sorts of volume growths in production require. Understanding customer preferences and price sensitivity of order decisions is the key factor in making a final decision. If customers are price sensitive, and manufacturing clearly provides efficiency gains with much higher volumes, it is typically so that an aggressive price discount strategy yields good long-term results. Many global industries exist because of price competitive end-products (and with annually declining prices, see Milberg & Winkler, 2013: 122) – think about solar panels, wind turbines, smartphones, tablets, cars, clothes, cameras, furniture, etc. Similar price erosion has been present in illegal global products too (Clements & Zhao, 2014: 79-84). In addition, pharmaceuticals also have price pressure (Camejo et al., 2012).

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CHAPTER FIVE

SIMULATION MODELLING OF DYNAMIC SYSTEMS

YULIA PANOVA & OLLI-PEKKA HILMOLA

5.1. Dynamic systems and their characteristics

In order to give a strict mathematical definition of the notion "dynamic system", it is endowed with the property of having "inputs" and "outputs", i.e., it is defined as some structured object, where at certain times it is possible to introduce substance, energy and information, and at other times, to output them (Lerner, 1967; Peregudov and Tarasenko, 1989). Dynamic systems can also be represented as systems where processes run continuously, and as systems in which all processes occur only at discrete points in time. In both cases, it is assumed that the behaviour of the system can be analyzed at a certain time interval, and this directly determines the adjective "dynamic" in the term "dynamic system".

On the basis of taking into account the dependence of the modelling object on time, the dynamic characteristics of the systems can be reflected in the respective models. In particular, the dynamic characteristic shows the response of the system to the disturbance (dependence of the output variables on the input and time). On the contrary, in the static systems, the characteristic shows the dependence between the input and output values in the steady state.

The behaviour of a dynamic system can be represented: as a table of values of output variables for discrete points in time, in the form of a set of graphs showing the process of changing the output variables with time, and in the form of a graph (phase trajectory) in the state space (phase space). Therefore, on the whole, the definition of the term "dynamic system" can be reduced to the assignment of the eight values (Peregudov and Tarasenko, 1989; Glushkov et al., 1974):

$$S = \{T, X, U, \Phi, Y, O, \eta, \varphi\},$$

where T is the set of moments of time;

X is the set of permissible input effects;
U is the set of states or internal characteristics of the system;
Φ is the set of instantaneous values of input effects;
Y is the set of instantaneous values of the output signals;
O is the set of output values;
η is the output display; and
φ is the transient state function.

Any dynamic system can be in one of three modes: *equilibrium, transitional, or periodic.* The *equilibrium* of the system corresponds to the situation, when its state does not change in time. In this mode, the state does not change any of its "coordinates". In the state space of a system, its equilibrium states will be represented by fixed points. The *transitional mode* is the mode of motion of a system from some initial state to some steady state — equilibrium or periodic. The *periodic mode* is characterized by the fact that in the system, there are fluctuations in external information and the entropy of activity. Moreover, these oscillations occur with a phase shift, similar to oscillations of velocity and coordinates in a spring pendulum (Bortnovsky et al., 2010).

The main properties of dynamic systems are *observability, controllability, identifiability, and stability* (Voronov, 1979; Lyapunov, 1950). *Observability* is the ability to determine its state x(t) by the values of the system output y(t). The complete observability of the object can be identified by R. Kalman's criterion (1957). *Controllability* is the ability to bring the system into any given state X_g from the initial X_o by using the appropriate effect on the system inputs U(t). In other words, if an object is completely controllable, then there is always such an admissible control, in which a finite time will ensure the transfer of this object from an initial state to any given final state. The assessment of controllability is also carried out on the basis of R. Kalman's criterion (1957).

The assessment of the *controllability* of an object must precede the formulation of any problem of dynamic optimization, as such a task may be unsolvable for a not fully controlled object. The assessment of the *observability* of an object must precede the formulation of the problem of its identification, because a not fully observable object cannot be identified. *Identifiability* is a property of a dynamic system, characterizing the potential possibility of finding its structure and parameters by known inputs. In other words, this characteristic of the system is related to the possibility of assessing its output parameters and the structure, which should effectively respond to any influences from the environment. An identifiable system is always *controllable and observable.*

An important characteristic of dynamic systems is *stability,* which is understood as a property of the system to return to the equilibrium state or cyclic mode after the removal of the perturbation that caused the violations of the latter. Stability is a category relating primarily to the proper motions of the system, generated by the initial conditions (disturbances) and the internal properties of the system, but not by external influences. The equilibrium state to which the system is able to return is called the steady state of equilibrium. The state of stability (steady state) is such an equilibrium state of the system, to which it returns after the removal of disturbing influences.

Also, management theory experts identify such important characteristics as *connective stability* (Siljak, 1969), which is applied to complex systems where some (or all) of the connections between subsystems can be switched off, switched on or unpredictably changed during the operation of the system. Such systems include, for example, power systems in which individual subsystems can be switched on and off from a single network, aeroplanes that are influenced by the parameters of the atmosphere through which their subsystems are connected, and others. The task of ensuring connective stability is formulated as follows: to build a controlled system in such a way that the assumed changes in the links do not violate the stability of the target operation and a number of dynamic indicators of both the system and the connected subsystems.

For the purposes of economic cybernetics, the concept of a dynamic system is especially important, as economic objects belong to the class of dynamic ones. Until now, a prerequisite for describing a complex system has been the idea that the system interacts with the external environment using inputs and outputs. Systems of this kind are relatively separate. In reality, completely isolated (closed) systems do not exist, although such an abstraction is sometimes used for research purposes.

It is easy to discover dynamic systems and dynamic changes, but this is often the case in a retrospective view. Changes that we expect to happen, often take a much longer period of time to realize, and when they eventually happen, their destructive force is so significant that only a handful of businesses will survive. Also, products and companies in a new disruptive wave are coming from relatively unknown actors, and do not have the potential in the first place to challenge the old modus operandi and actors. Take Apple as an example – they brought the first iPhone to the markets in 2007. This was not thought to be a big deal among bigger rivals like Nokia (the definite global market leader in 2007). However, in 2011, Nokia was forced to sell its mobile phone business (as it was under huge pressure from a decline in handset sales and subsequent deficits) to Microsoft. Nokia entered into a strategic alliance with Microsoft, under which it agreed to license and use the Microsoft Windows mobile operating system in Nokia phones. Microsoft's motivation for the alliance was in part to establish the Windows mobile operating system as opposed to rival operating systems, such as Apple's iPhone and Google's Android (Hill and Hult, 2018). It only took four more years for Microsoft to admit that its own mobile phone production with the Windows operating system did not have market opportunities. A similar storyline could be developed relating to tablets and other digital reading devices, which have become increasingly common for use as a reading device for newspapers, books, news portals and for watching movies as well as short videos. Mobiles and tablets have also brought us to massively use pictures – taking them, sharing them and of course viewing them. For example, the iPad was introduced in 2010. It could be said that this started a process, where we use a decreasing number of physical paper-based newspapers and magazines. Also, the physical rental of movies is already a dead market – in some countries, it is only used to attract younger visitors to museums – not to mention physical cameras and the film business. Many companies went bankrupt or experienced severe damage (where the business is the only a fraction of what it used to be) because of rapid technological change. Take the big US-based video-rental company Blockbuster, the iconic camera and filmmaker Kodak, and the large-scale paper producer Norske Skog as examples. There were also severe difficulties for newspapers and magazines in carrying on their operations, while seeing advertising revenues decline annually. There were, of course, many companies which benefitted from this change, and young readers can name them in a short amount of time (starting with where you spend your daily free time).

Earlier, physical paper production was centred in North American (Hujala & Hilmola, 2009; Hetemäki et al., 2013) and European markets, and companies believed in their dominance and the sustainability of demand. A strong USD as currency supported the profits of foreign manufacturers as well. However, in the 1990s the first indications were received of the softness and even decline of paper markets in the USA. These fluctuations diminished away as economic growth was so strong at the end of the decade that it gave support for newsprint, writing paper and book paper demand. It should be highlighted that demand did not just "collapse", but first it declined, and nicely recovered, only to decline very strongly in the following decades (first little by little and then with strong downward force – similar to E. Hemingway's statement about bankruptcy). Some leading companies in this branch had such high beliefs in paper demand in the early 2000s that, e.g., the Finnish-Swedish manufacturer Stora-Enso paid nearly 5 billion EUR to Consolidated Papers (a US-based manufacturer), only to book huge deficits in the following years (in the range of 2-2.7 bill. EUR; Koulumies, 2010). The story is similar to Norske Skog, which was a leading paper producer based in Norway (its operations were and still are global – at the end of 2017 the bankrupted company was sold to an investor group). Norske Skog was a really high performing paper producer, but declines in demand, low sales prices of the end product, increasing costs and the increasing cost of pulp made the business equation unsustainable (also debts increased during these years, which meant even higher costs in profit and loss statements). Paper demand not only declined in the USA, but after a delay this trend also moved to Europe. Figure 5-1 will give details of the demand development of "newsprint" paper in the USA, the UK and Germany as well as the world in total. As could be noted, its decline began in the USA after the IT bubble burst (in 2002), and the UK, as well as Germany, followed this development after the 2008-2009 global financial crisis. Consumption in the USA has declined by more than 80% since the best year of 1989. In the UK decline has been from highs of 63.3%, and in Germany of 39.4%. Globally, the decline reached 40.2%. Reasons for the USA's lead in substantial declines could be explained by the fact that digitalization and the Internet originated in this country (Hetemäki, 2005; Hujala & Hilmola, 2009; Hujala, 2011; Hetemäki et al., 2013), and leading companies in this branch were established there.

It should be highlighted that digitalization and the use of less paper in terms of newspapers, magazines, advertisements and books are not a trend everywhere (typically emerging markets have it differently, as analyzed in Li et al., 2006; Hujala et al., 2013; Hilmola et al., 2014). For example, India is still on a growth track in all of these sub-categories. Similarly, China is growing in all sub-categories apart from newsprint. China's hunger for raw materials, and that of pulp is massive, and it seems that India is following this path (still a marginal importer of pulp mass as compared to China). Therefore, for Eurasia, paper industry products still play an important role, and their supply chains are a vital part of prosperity and well-being.

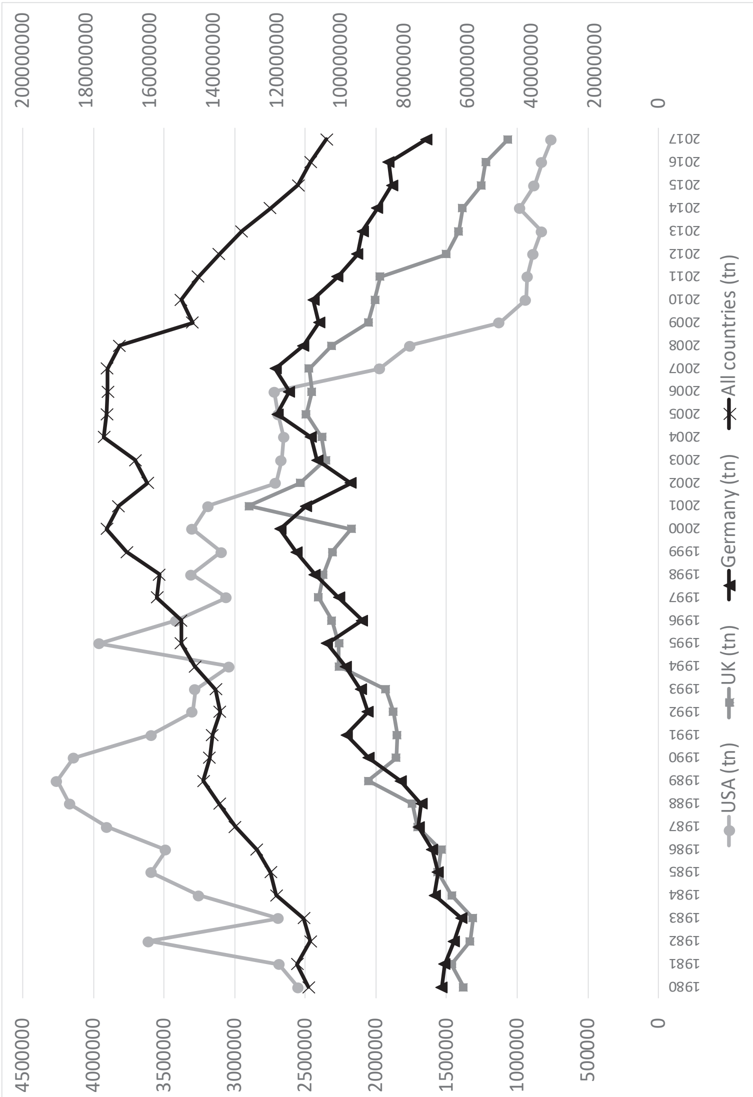


Figure 5-1. Estimated annual consumption of newsprint in the USA, UK, Germany (y-axis on the left) and all countries (y-axis on the right) in total (estimated from FAO statistics with the following equation: domestic production plus import minus export). Source (data): FAO (2018)

It should be noted that there are segments in the paper industry, which are growing globally. One of these is packaging products due to the increased need to deliver small e-commerce shipments. Also, tissues and other hygienic products are in constant demand. In the developed world, this industry holds importance, even if there are clear weak points in the product offering. However, as stressed above, weaknesses are not that apparent in developing/emerging markets, and these products hold importance in supply chains due to their volume. It should also be remembered that, e.g., recycled raw materials of the paper industry can no longer be imported to China – the only approved imports are those from fresh and new sources (a change that became effective in 2018; Economist, 2018). This will further increase this transportation activity from northern parts of the world (and also from Latin America) to Eurasia. However, on the downside, sea-based container traffic from North America and Europe will decline (as waste export is simply lost). The Economist (2018) estimates that half of the Trans-Pacific container transports back to China is waste.

5.2. Definitions and classifications of dynamic forecasting modelling

The concept of state (the concept of the full spectrum of phase coordinates) takes a central place in the modern theory of dynamic systems. A dynamic system is an adequate model for describing the flow of cause-effect relationships from the past to the future (Arbib et al., 1971). In dynamic modelling, time is an independent parameter and it becomes possible to take into account and determine cause-effect relationships as well as to study the development of a process in time or to control this development.

A *system dynamics model* is called an imitation (in some cases, an analytic imitation) model of a dynamic system, built on the basis of identifying the relationship between aggregated variables, reflecting various aspects of a big system in concentrated form. The term "system dynamics" was proposed by J. Forrester, who investigated a number of similar classes of models: industrial dynamics (dynamics of an industrial enterprise), world dynamics (dynamics of ecological-economic processes of world development), urban dynamics (city development), etc. (Jay Forrester's Industrial Dynamics, 1961).

For example, five aggregate variables are introduced in the model of world dynamics: the level of resources, population, the standard of living, the level of investment (or production), and the level of environmental pollution. For various types of hypothetical dependencies between these variables, the curves of changes in levels (components of the state vector) in the five-dimensional phase space are constructed, on the basis of which the development forecast is made.

The main types of models of system dynamics are those constructed using the apparatus of differential and difference (finite difference) equations. The use of other types of models of system dynamics is also promising: logical-dynamic, gaming, stochastic, etc. These models can be used in solving problems related to the study of all types of management functions from forecasting to operational management.

Apart from system dynamics models, the *program models (planning models) of a complex of works (operations)* can be attributed to the general dynamic modelling of complex systems. Program models are usually described by a system of differential equations or a system of equations in finite differences and belong to the class of such analytical models, on the basis of which optimization problems can be stated if necessary (Krasavin, 1998). These models allow the determination of the minimum time for solving a production task with restrictions on the cost of the work performed and the resources used to minimize the cost of a work package, while limiting the time for their implementation and available resources as well as resource consumption with cost and time limits. Such models are most effective in the operational management of production.

The next type of models in general dynamic modelling are *models of dynamic systems with a non-stationary (tunable) structure.* These models are used to describe systems in which the time-varying relationships of the subsystems play an important role. Examples include large production complexes, moving objects with a variable number of components, manipulator robots, and dynamic models using the theory of meta-populations. These and many other similar systems have common properties (Kirillov, 2009); in the course of their operation, their structure changes in such a way that the subsystems of which they consist can be in a passive or active mode at various time intervals.

A more special class of model of the type of discrete dynamic systems is represented by *Petri Nets.* The special type of graph, which later received the name "Petri nets", was first introduced by Carl Petri in the 1960s. In the next decade, a "boom" of developments began in this direction. The popularity of Petri nets is due to the successful presentation of various types of objects present in many simulated systems and the "event-based" approach to modelling. They are used for a formal description of the structure and interaction of parallel systems and processes as well as the analysis of cause-effect relationships in complex systems (Peterson, 1984).

Further on, the dynamic model will be analyzed. It was built during 2008, before the global financial crisis, and it concentrated on Russian newsprint and magazine paper consumption scenarios up to the year 2020 (Hujala & Hilmola, 2009). The model's data ended for the year 2007, and it gave a rather different picture from the most likely future development, which in reality took place in the following decade. Actually, one of the main variables in the model, Russian GDP, was growing very strongly in the years 2007 and 2008, and the country's raw material asset base was argued to be providing sustainable growth in the future as well. During the time of building the simulation model, it seemed that the Internet would not spread greatly in this country, however, the use of mobile phones already had a stronghold. The country's population was in a longer period of decline that took place in the 1990s and 2000s, and with the first interpretation, this trend was supposed to continue.

The used simulation model relied on extensive analysis of emerging markets and their macro-economic and technological development variables vs. paper demand (of, e.g., newsprint and magazine paper). In these longitudinal data regression models, it became apparent that GDP per capita is one key driver of paper consumption growth. Technological issues such as the number of mobile phone subscriptions (basically, SIM cards) and the Internet adaption had their role too. The data suggested with statistical confidence levels that the use of mobile phones increased paper usage (newsprint and magazine paper); however, Internet usage was already shrinking paper use. Therefore, technology was having a twofold role in the forecast ending in the year 2020.

It is worthwhile noticing that this forecast was made before iPhone and Android phones were in any mainstream position in mobile phones – actually, both started to take off in 2008 as a marginal phenomenon (and this was in developed economies, not emerging ones). Therefore, mobile phone use with Internet browsing, video watching and online applications was very rare. Regression analysis is based on the following data of the years 1990-2007, and it could be assumed that in emerging economies the adaptation was even slower in this period. However, the change since the year 2010 has been dramatic – this could be examined, e.g., in the bigger cities of emerging economies – people are constantly on their mobiles, they use electronic cash and physical deliveries of products are made every morning to nearby post offices. Therefore, nowadays mobiles are clearly a partial driver of Internet use, and this will again decrease paper demand. However, in the following, it is assumed that mobiles are causing more paper use as suggested by data and statistical analysis of the period 1990-2007.

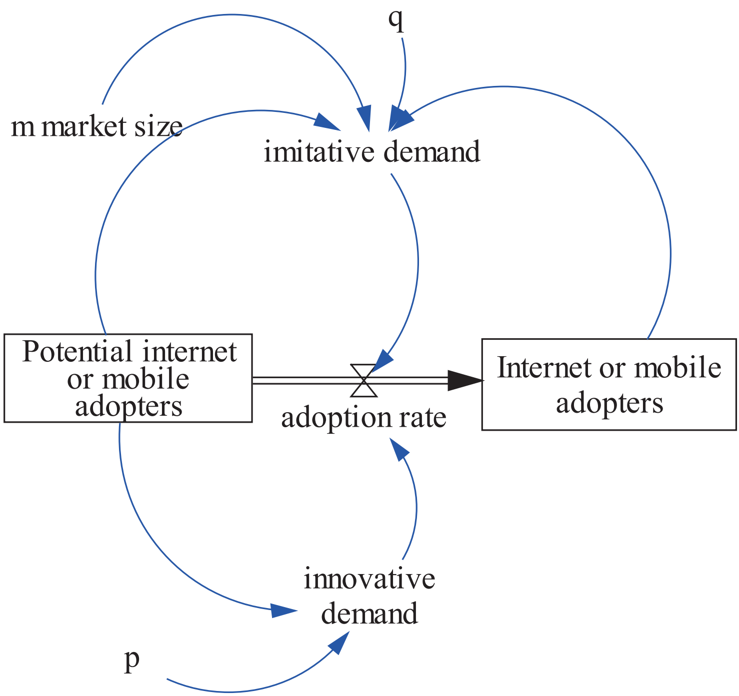


Figure 5-2. Using the Bass diffusion model to forecast the development of Internet users in Russia. Source (initial bigger model, modified): Hujala & Hilmola (2008)

From the modelling perspective, the most interesting aspect of the forecasting model of paper demand is the modelling of technological development. For this, Bass diffusion models were used in the model – these assume the diffusion to progress in the S-shaped form. Typically, in management books, these models are explained with examples from marketing new products to larger crowds (system dynamics model, see

Sterman, 2000). In the beginning, a new product does not have that much demand and people are not aware of it. Therefore, marketing is needed to attract early users for the product. These "innovative" early adopters are in turn driving imitative users (typically called "followers"), who hear about products by word of mouth, and they adapt to using it by the same rate. For Bass diffusion models, it is vital to estimate market size before the model can run. This is the hardest part as in 2007 Internet usage rates in many emerging countries (like Russia) were somewhat above 20%. Who could have estimated that this would increase to 70% and even higher (see Figure 5-3)?

Figure 5-2 shows a diffusion model used in the paper demand forecasting model concerning Internet use (the model is the same as for mobile phones). There are three parameters in Figure 5-2, which need to be introduced. Overall market or Internet use is given in a parameter, m (here with current knowledge, it is approaching 80% by 2020 in Russia; originally it was 45%). Another parameter, q, is the imitation effect amount (or the strength of word of mouth). The third parameter is p, and it is often called an innovation effect (or advertising). Here, q has a value of 0.392, and p has a value of 3.380E-04. Typically, q has values around 0.3 to 0.5, and p is a small value, often below 0.01. In general, higher values of q and p will result in much faster technology adaptation. Equations of imitative and innovative demand are as follows:

Imitative demand: (q/m) *Internet adopters*Potential internet adopters

Innovative demand: p*Potential internet adopters

In the model shown in Figure 5-2, the equation of the adaptation rate is simply a sum of imitative and innovative demand. The inventory element of "Potential Internet adopters" is based on the outflow of the adaptation rate, and its value will start from the overall market size, m (which is corrected with the amount of "Internet adopters" in the beginning). The inventory of "Internet adopters" accumulates based on the inflow of the adaptation rate, and in the beginning, it has a value of 0.21053 (the share of Internet users in Russia in 2007).

Parameter values for mobile phone penetration development in the simulation model were different – as growth was more aggressive and of short-term duration (this could also be concluded from Figure 5-3 with realized data). This was also present as a Bass diffusion model fitted with data ending in 2007. A parameter value of q (imitation effect) was very high and aggressive, 0.977. The innovation effect value of p was 2.86E-07. In the following market size (or in this case mobile phone penetration), m is 160% (originally it was estimated to be 128.7%).

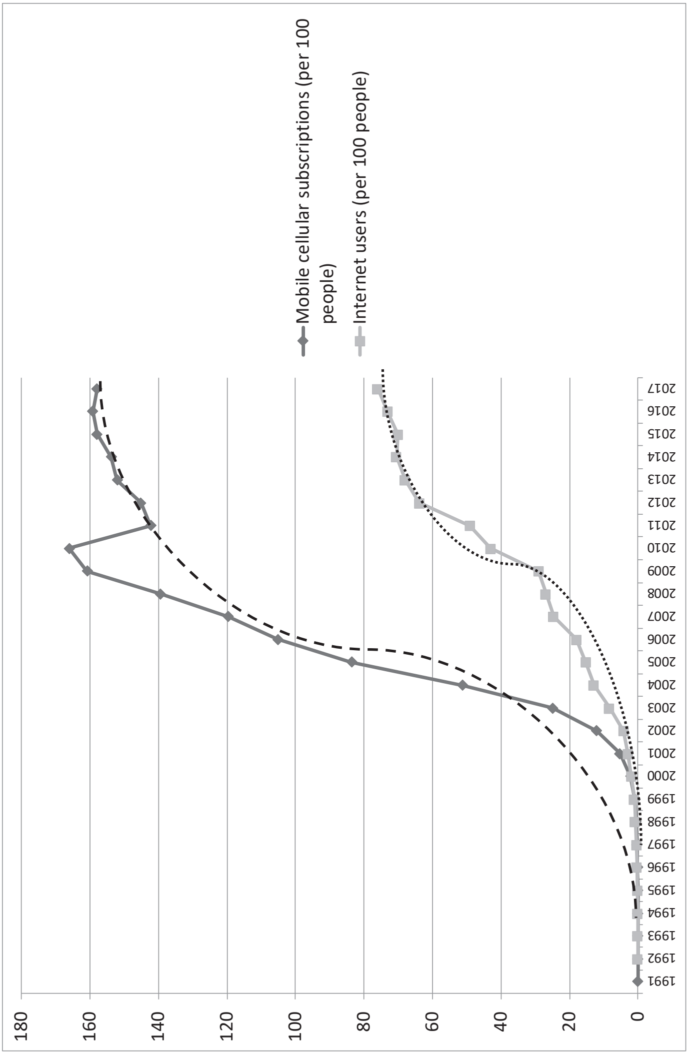


Figure 5-3. The Internet (grey curve) and mobile phone (dark curve) penetration rate (per 100 people) and in Russia. Source: World Bank (2018)

Technological progress is presented with data from the early 1990s until 2017 in Figure 5-3 concerning mobile phone subscriptions (SIM cards) and Internet users. In the initial forecast, it was assumed that Internet users would grow to 23.6% or 45% (just examine the details of Figure 5-3 – in 2007 user amounts were slowing down, only to start new growth due to the mobile Internet in the period 2010-2012). So, the initial forecast and simulation model underestimated Internet growth – also underestimating paper demand decline due to this. Similar under-forecasting was present in mobile phones; however, here the initial assumption was 125%, but it actually grew to around 160%. Russia is a country of numerous SIM cards per user – people in this country really like prepaid and anonymous cards. However, there are some countries and regions, which have even higher amounts. Hong Kong is leading the World Bank (2018) data, wherein there was a 249% mobile phone subscription penetration rate 2017 (followed by the United Arab Emirates at 210%). In Internet use, Russia is not exceptional as a country, as in the year 2016 (complete global data set), based on World Bank data, Internet use was 98% or higher in Bermuda, Liechtenstein, Luxemburg and Iceland.

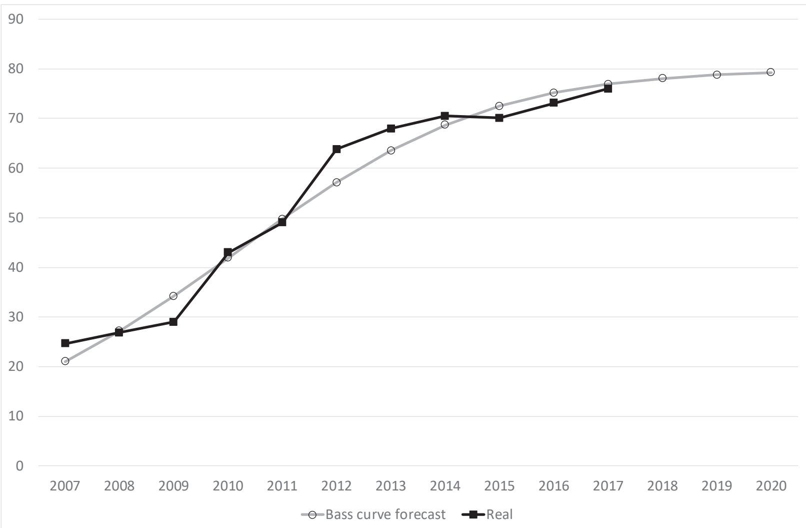


Figure 5-4. Internet penetration rate in Russia (real series until 2017), and a Bass diffusion model function simulation-based forecast until 2020.

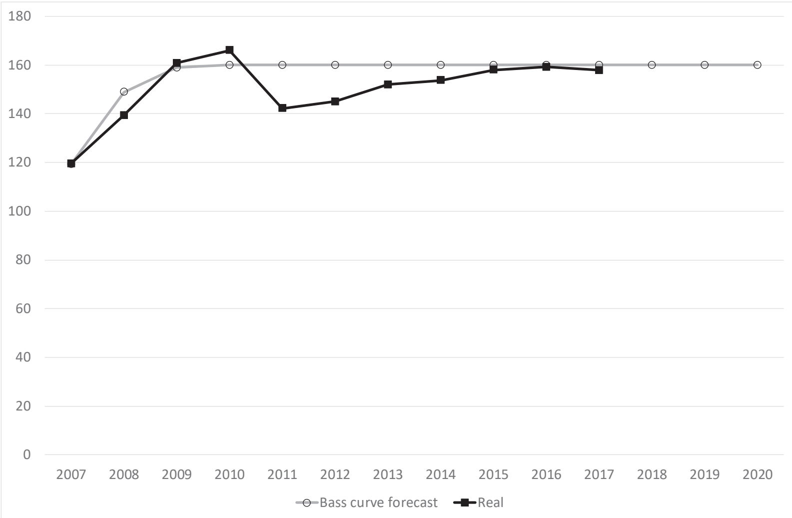


Figure 5-5. Mobile phone penetration rate in Russia (the real series until 2017), and a Bass diffusion model function simulation-based forecast until 2020.

It is illustrated in Figures 5-4 and 5-5, how Bass diffusion models have performed with the given parameter values against real data. Originally, a parameter value of q was conservative in the Internet use Bass diffusion model, and as noted from Figure 5-3 in the year 2020 Internet use should be close to 80% in Russia (79.3% in the model). The forecasting model fits real data rather well as the model is now using an 80% market size (as compared to 45%, which was originally used with these p and q values). Real data, of course, contain a fluctuation around the forecasting model, but the overall direction and level are the same in both series (do note that year 2007 data have been slightly changed in the World Bank, meaning that Internet use was higher in 2007 than earlier reported in 2008). Mobile phone penetration development in Russia was much more rapid based on the Bass diffusion model built with data ending in the year 2007. As the market size (or mobile phone use) in the model was corrected to 160%, it became apparent that the forecasting model again works rather well against real data (Figure 5-5).

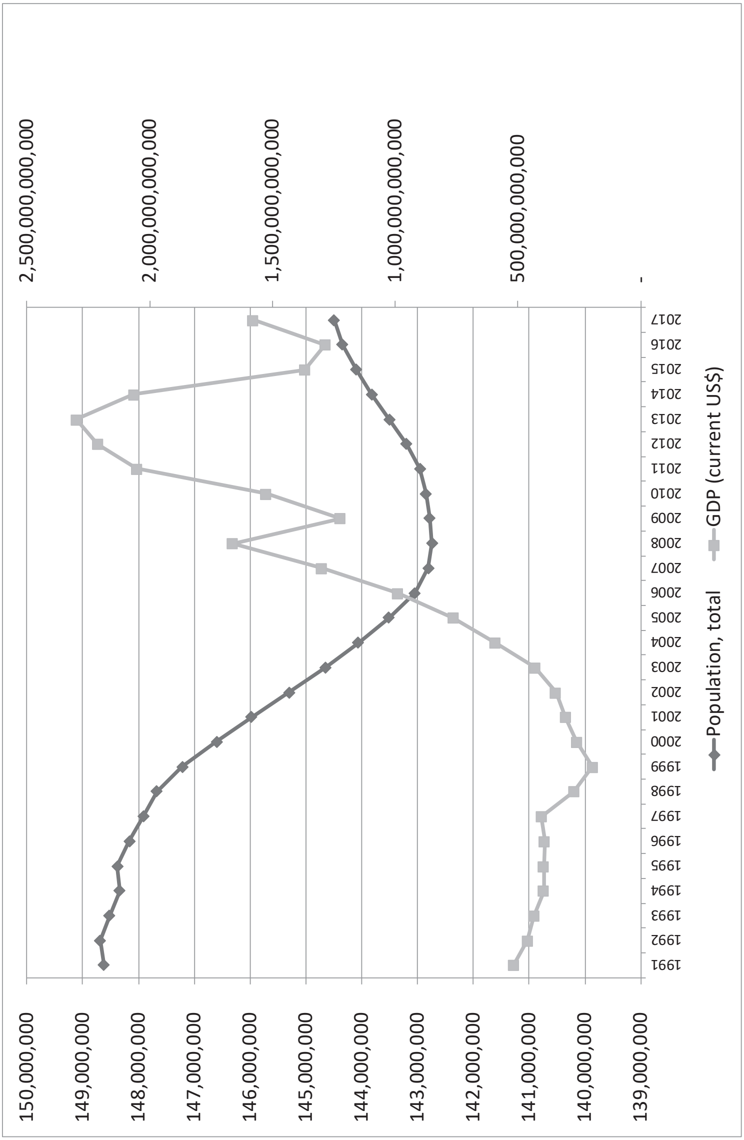


Figure 5-6. Population of Russia (dark curve, right y-axis) and GDP development (grey curve, left y-axis) during the period 1991-2017. Source: World Bank (2018)

The simulation model also used GDP and population (GDP per capita) to forecast paper demand. With data ending with the year 2007, it seemed like an obvious alternative that GDP would grow somewhat (the growth trajectory from 1999 to 2007 was so brisk). The annual growth rate was in double digits in the period 2000-2007, but this was in USD terms (as Russian currency was strengthening all the time). However, for the original forecast different scenarios of GDP growth starting from 2% annual growth up to 8% were used (motivated at that time by Ayres, 2006; Hilmola, 2007; Dent, 1999). In USD terms a growth of 2% was realized in GDP per capita terms (with data ending in 2017; Figure 5-6). Economic growth has been troublesome in USD terms in Russia since 2008 as the currency has continually depreciated against the USD, and at the same time the export of key commodities has been hurt in price terms in global markets (also the ageing population is increasing this issue within the country). As for the population, original research assumed that it would continue to decline or level off. Within real data, it is apparent that the population first levelled off in the period 2008-2011, but thereafter started some sort of increase (Figure 5-6). This was mostly caused by the fact that Russians are living longer, that there is more immigration and also the birth rate has increased.

5.3. Approaches to simulation modelling

Under simulation modelling (SM) a computer program is assumed to be able to reproduce the behaviour of a real system over time, once its structure is described and certain parameters are set (Garina, 2013). Depending on the entered data, the simulation model allows statistics to be obtained at various stages of the system's operation. Thus, in other words, a simulation model is an economic-mathematical dynamic model, which is investigated using an experimental method (Vlasov and Shimko, 2005) which combines its experimental approach with special conditions for the use of computer technology. It is a machine-based method and, accordingly, was generated before the advent and development of computers.

According to experts, the main advantage of SM over the analytical approach, is the ability to solve more complex problems. Thanks to the use of simulation models, it is quite easy to take into account the presence of discrete and continuous elements, non-linear characteristics of system elements, numerous random effects, and others that often create difficulties in analytical studies (Nikiforov, 2008; Osetrova, and Pavelko, 2013; Sovetov and Yakovlev, 2012). From the authors' point of view, an important advantage of SM is the fact that in the process of studying the system, it is possible to use all of the collected information, regardless of the form of its presentation or degree of formalization. Also, when building the model there are no hard restrictions on the data (Toluev, 2008).

In addition to the above advantages, there is the possibility of using SM in the absence of a complete mathematical formulation of a specific task (for example, the model of multi-channel queuing systems). There is also access to specific parameters of the system under study, for monitoring the process over a period of time. Finally, the option to change the time scale (acceleration or deceleration of time) is available. It allows specific results to be obtained with the appropriate system parameters.

The developers of the simulation modelling software (Anylogic.ru, 2019) highlight additional advantages of simulation modelling on their website:

- ✓ Cost: the price of modelling includes only the purchase of the necessary software and the payment of consulting services, while mistakes in making decisions, in reality, can lead to significantly greater losses.
- ✓ Time: to evaluate the effectiveness of a new project, months or years are necessary, while by modelling the result can be obtained in a few minutes.
- ✓ Repeatability: If there is a need to quickly and correctly respond to all changes, using the model it is possible to conduct an unlimited number of experiments, changing certain parameters in order to select the best option.
- ✓ Accuracy: compared to mathematical calculations that require the use of strict formulas, but do not take into account reality, the model can describe the system and its processes in a natural way.
- ✓ Visibility: the model can be visualized, presented graphically, which is much clearer for presentation to customers or colleagues.
- ✓ Versatility: simulation modelling can be used in various areas of life today, it reproduces the real system that can be changed using the program without affecting existing objects.

Despite all the advantages, SM has a number of disadvantages (Nikiforov, 2008; Osetrova and Pavelko, 2013; Sovetov and Yakovlev, 2012):

1. The process of SM is quite expensive, because it requires a considerable amount of time and the hiring of highly qualified specialists;

2. It is rather difficult to achieve an accurate result; however, the accuracy can be estimated by analyzing the sensitivity of the model to changes in certain parameters;
3. In reality, SM does not reflect the full state of affairs, which should be taken into account when studying an object. That is, the system is considered at the abstract level, where only the most important elements remain, and the extra elements are removed. In real life, the system itself is much more complicated.

Considering the possibilities of simulation modelling, it is worth underlining the most popular areas where it traditionally finds its applications. According to Anylogic.ru (2019), the industry and field of application of simulation modelling are wide and varied, and can also be traced through the published articles on the website (Figure 5-7).

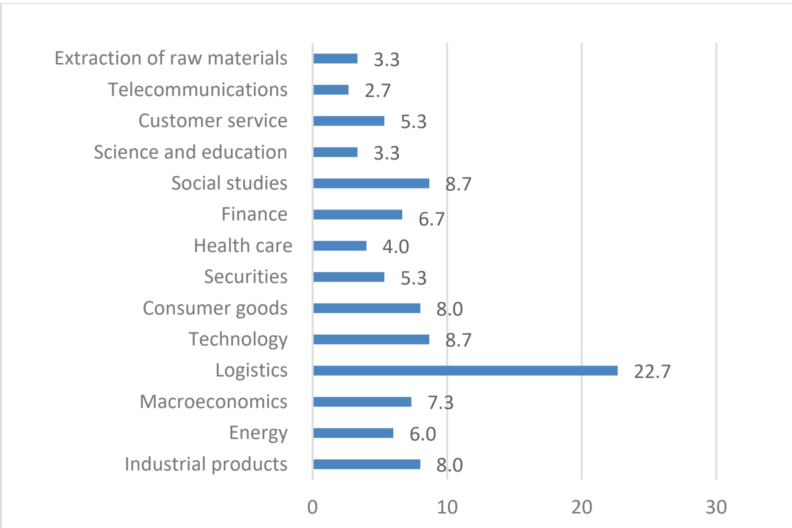


Figure 5-7. Relative (%) distribution of applications in different spheres.

First of all, simulation modelling is popular in logistics (almost 23% of all articles are devoted to this particular sphere). Other applications include modelling of technological and various business processes. Also, SM is used in social and economic research, the modelling of various systems: transport, informational and other global processes.

The analysis of the articles from the website shows the frequency of use of various approaches in simulation modelling: agent, discrete-event, system dynamics, and multi-approach modelling (Anylogic.ru, 2019). Figure 5-8 presents the percentage ratio of the number of articles by the type of modelling for the last 17 years.

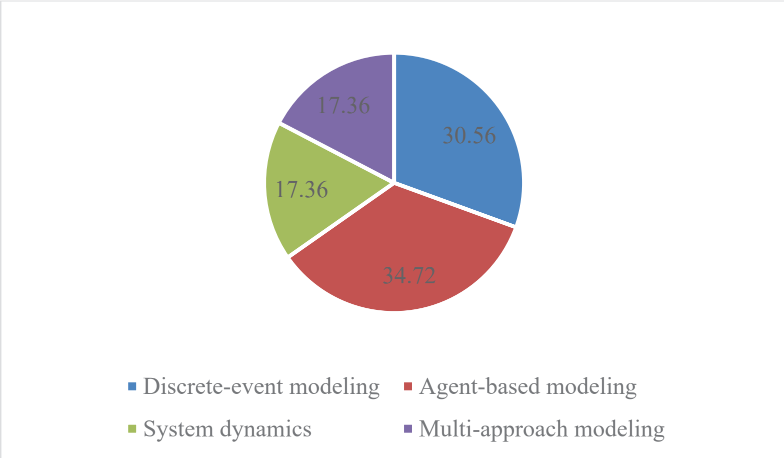


Figure 5-8. Distribution of simulation modelling approaches.

It is noticeable that agent-based and discrete-event modelling are described in articles much more often. For agent-based modelling, articles have been published during the period 2004-2017, while for discrete-event modelling, system dynamics and multi-approach modelling, the start of publication is earlier, since 2000. The reason is objective, as agent-based modelling is considered a new approach in simulation modelling. The emergence and beginning of the practical application of agent-based modelling are the only breakthrough in the 21st century in the field of SM, if not taking into account a combination of methods in simulation for a more natural description of the problem. On the contrary, system dynamics for the last 50 years has, practically, not experienced any changes. Nothing has definitely happened in discrete-event modelling, since the 1960s, only more convenient process description blocks have been created (Kindinova and Kuznetsova, 2009).

In recent years, simulation modelling has had a trend of integration with GIS-services, which is also essential. However, no less interesting are the changes concerning the implementation of the simulation in the cloud, the storage of models, launch scenarios and the results from these, and the use of a browser to manage experiments and results. This includes the possibility of launching the model, to compare results, and to view 2D and 3D animation from any location.

With the natural development of simulation modelling approaches, the market of simulation software is also transformed. It is mainly occupied by small companies, the dynamics of which can be easily traced (Borschev, 2015). The author notes that Quest, MicroSaint, SimProcess, and GPSS have ceased to exist forever. Some non-graphic products, CSIM, Silk/SML, SLX. ExtendSim, ProModel, and Witness likewise show a slow decline. The Arena's market share is gradually decreasing, and according to forecasts, the market will soon be divided between products such as AnyLogic, FlexSim, Simio, and Simul8 (Borschev, 2015).

Regardless of simulation software and different approaches, in the process of simulation modelling, a researcher encounters four main components: 1) a real system, which she/he studies and on the basis of the software develops; and 2) a logical-mathematical model. Further, on the grounds of the latter, a simulation model is compiled (3), which in order to be realizable, is coded in 4) computer programming language (Lychkina, 2014). Nowadays, simulation modelling thus includes conceptual (initial stage of model formation) and logical-mathematical (involves artificial intelligence) modelling in order to provide a detailed description of individual parts of the systems (subsystems) and related processes, to analyze the results of computer experiments, and, in general, to support decision-making (Lychkina, 2014).

The following illustrates the difficulty in accurately forecasting the branch demand, when there is a great technological and economic transformation in progress, which concerns these branch products. Based on one scenario of the forecast of earlier research and data ending in 2007, it was seen that newsprint demand in Russia will progress upwards in a steady fashion, and reach 8 kg per capita (see Figure 5-9). However, this was based on partially false assumptions on technological development (GDP per capita was assumed in this "old forecast" to be 2% p.a., and in this period, it has achieved just that, however, with great variation over the years). So, Internet use was seen to be lower in a decade than it actually was, and mobile phone use was also a bit lower. In statistical analyses with an older data set, it seemed that Internet use lowers the newsprint demand, and mobile phone use, in turn, increases it. In Figure 5-9 is the reported "New forecast" model, where new levels of adaptation regarding the Internet and mobile phones are used. The model also uses realized GDP per capita until 2017, and for the last three years, it assumes that GDP per capita increases annually by 2%. This will result in a newsprint demand overall in the period and a somewhat lower demand in the year 2020; however, the forecasting model shows great volatility during the years. It just illustrates, what a significant role GDP per capita has in the forecasting model – at the end, in the original regression model technological factors had a much lower role. This could be explained by the economics of newsprint (and magazines), where advertising revenues are typically a significant source of funds gathered as "subscription fees" from the general public. It could be argued that as general interest in newsprint reduces, it will also mean lower advertising interest in this medium. As the general interest further lowers little by little (due to, e.g., more use of the Internet to receive news information), advertising will increasingly be placed over in the new medium. This is a vicious cycle, which firstly enforces a lower page count of newspapers, and then considers the size of the newspaper again (to match the size requirements of online reading). These changes are combined for an increased use of the Internet will result in lower and lower newsprint paper consumption per capita. So, rightfully GDP per capita is having such a significant role. Declining advertising revenues are devastating for printed media. Think about revenues gathered on the other side of the token – ad revenues of Google and Facebook are the base of their financial model.

Another forecast, named "New forecast*", was completed to justify a further role of GDP per capita in newsprint demand. This is successful in explaining the significant lowering of newsprint consumption in Russia during the period 2008-2017. In the model, it is assumed that the effect of Internet use will double the harmful effect as compared to the original forecast. This doubling effect will take place after 2011. GDP per capita, in turn, will have a 5% lower role prior to 2011, and thereafter a 10% lower role. This is mostly due to a drop in advertising interests. The forecast follows rather closely the realized newsprint consumption.

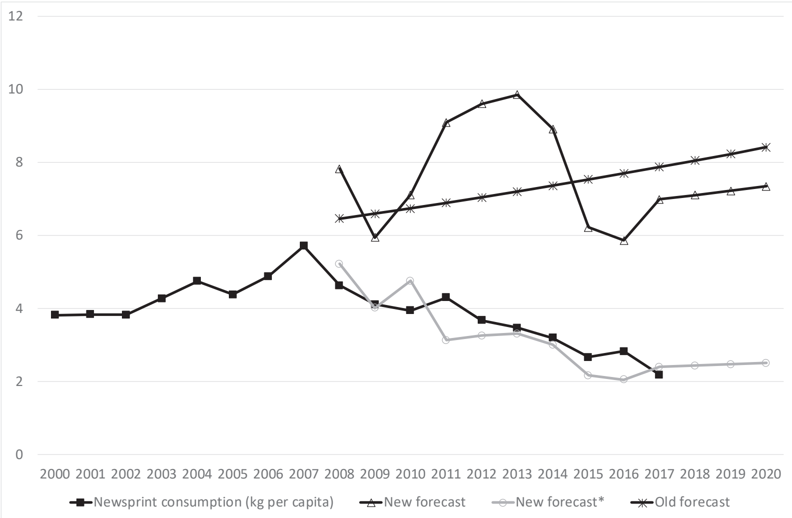


Figure 5-9. Newsprint consumption per capita (kg) in Russia, two new forecasts and an old forecast.

In the original simulation model, the Risi annual statistics of newsprint and magazine paper consumption were used. This database was not available for use in the update of this book. Therefore, public data of the FAO (2018) were only source to be used. These data contain the country's own production, and imports as well as exports of, e.g., newsprint. From these data, the country's consumption was estimated as follows: production minus export plus import. This is quite an accurate formula for domestic consumption; however, there are some limitations. If a country has a lot of own production and exports – in this case, the fluctuation of export inventories could change annual consumption numbers to be biased up or downwards. As Risi data were available, they were compared to estimated FAO statistics up to 2007. There were some minor differences, but in general, they were rather close to each other. A decline in Russian newsprint demand in Figure 5-9 during the period 2008-2017 has been significant and dramatic, but most probably it is a real situation too.

5.4. Mixed models used in the simulation

One of the important problems in the development and creation of complex technical systems is the study of the dynamics of their functioning at various stages of design, testing and operation. Complex systems consist of a large number of interconnected and interacting elements that have complicated mathematical descriptions. These types of systems can be contrasted to the simple systems, which have a simple structure and can be easily described mathematically with formulas. The category of complex systems includes large technical, technological, energy, and industrial complexes. When designing complex systems, the task is to develop systems that meet the proposed specifications. For this purpose, the specific models can be used, as a simplified analogue of the real system, representing the laws of behaviour of the parts in the system and their connection (Sovetov and Yakovlev, 2012).

On the whole, models can be classified in various ways (Lychkina, 2014). Unfortunately, none of these is satisfactory, although each serves a specific purpose. It is possible to indicate some typical groups of models that can be the basis of the classification system (Rodionov, 2019; Sovetov and Yakovlev, 2012):

- static and dynamic;
- deterministic and stochastic;
- discrete, continuous and discrete-continuous (mixed models).

Static models describe the state of the system at a certain point in time (a one-time cut of information on this object). Examples would be the classification of animals, the structure of molecules, the list of planted trees, a report on the examination of the state of students' teeth at school and so on. *Dynamic models* describe the processes of change and development of the system (changes in the object over time). Examples include a description of the movement of a body, the development of organisms, and the process of chemical reactions. The oil port model is also dynamic, because it simulates the time behaviour of individual system objects: the movement of tankers in the port waters, the movement of tanks on the quay, the level of oil in storage tanks.

In *deterministic models*, all parameters have a point estimate value, while in non-deterministic or *stochastic models*, the influence of probabilistic characteristics is taken into account. Thus, deterministic modelling displays the processes in which the absence of random effects is assumed, while stochastic modelling takes probabilistic processes and events into account. Therefore, in the latter types of models, the value of parameters is set with the help of probability theory, e.g., different types of distributions. For example, in the model of an oil port, the exact moments of arrival for tankers to the port cannot be determined. These moments are random variables, because this model is stochastic: the values of the model are variables, which depend on the realizations of random variables, thus becoming random variables themselves (Studfiles.net, 2019).

It should be noted that the real physical objects do function in continuous time, and to study the many problems of physical systems, their models should be *continuous*. The state of such models changes continuously in time. These are models of movement in real coordinates, models of chemical production, etc. The processes of the movement of objects and the processes of pumping oil in the models of the oil-loading port are continuous. At a higher level of abstraction, for many systems, models are adequate, if transitions of the system from one state to another can be considered instantaneous, occurring at discrete points in time. Such systems are called *discret*e. An example of an instant transition is a change in the number of bank customers or the number of customers in a store. Obviously, discrete systems are an abstraction; processes in nature do not occur instantaneously. A real customer takes time in entering a real store and may get stuck in the doorway, hesitating to enter or not, and there is always a continuous sequence of his position during his passage through the store's doors. However, when designing a store model for evaluation, for example, the average queue length at the cash register for the given customer flow and the cashier's known customer service characteristics, it is possible to ignore these secondary phenomena and consider the system as discrete.

In many cases, both types of processes (discrete and continuous) are present in real systems, and if both of them are essential for analyzing the system, then, in the model, some processes should be presented as continuous and others as discrete. Such models with mixed types of processes are called *mixed or hybrid*. For example, if in analyzing the functioning of a store, not only is the number of customers significant, but also their spatial position and customer movement, then, the model, in this case, should be a mixture of continuous and discrete processes, and therefore, it is a hybrid model. Another example is the functioning model of a large bank. The flow of investment, obtaining and issuing loans in the normal mode, is described by a set of differential and algebraic equations, thus the model is continuous. However, there are situations, such as a default (discrete event), which result in panic among the population, and from that moment on the system is described by a completely different continuous model. Below, an example of another mixed model (inventory management) will be studied in more detail. Discrete events in this model are the generation of a new order, the checking of the inventory level and possible ordering of the goods, the arrival of the order from the supplier, and the occurrence of demand for goods from the buyer. Stock levels are described by continuous variables.

The above-mentioned types of models can be realized in the *physical, analytical or computer simulation* form. Physical (full-scale) models are reduced and simplified copies of real objects or systems. Examples of *physical models* are a wind tunnel, dam model, etc. The basis of building physical models is the principle of a geometric and physical similarity between the model and the real object. In *analytical modelling*, the processes of functioning of the system under study are written in the form of algebraic, integral, and differential equations and logical relations, and in some cases, the analysis of these relations can be performed using analytical transformations. The simplest mathematical models are algebraic relations, and the analysis of a model is often reduced to an analytical solution of these equations. Some dynamical systems can be described in a closed form, for example, in the form of systems of linear differential and algebraic equations to obtain a solution analytically. This is why such modelling is called analytical. Modern tools for supporting analytical modelling are MS Excel spreadsheets (Sovetov and Yakovlev, 2012).

However, the use of purely analytical methods for modelling real systems encounters serious difficulties; classical mathematical models, which provide an analytical solution, are not applicable to real-world problems in most cases. For example, in the oil port model, it is impossible to build an analytical formula for estimating equipment utilization, because there are stochastic processes in the system, priorities in processing requests for resource use, internal parallelism in processing subsystems, work interruptions, etc. In these cases, simulation modelling can be applied.

Simulation modelling is often used in decision-making in situations which are too complicated for analytical analyses or in cases where experiments with real objects are virtually impossible or impractical (Kobelev, 2003). *Simulation modelling* is the development and execution on a computer of a software system reflecting the structure and functioning (behaviour) of a simulated object or phenomenon over time (Garina, 2013). This software system is called a simulation model of this object or phenomenon. The objects and entities of the simulation model represent the objects and entities of the real world, and the connections of the structural units of the modelling object are reflected in the interface connections of the corresponding model objects. Thus, a simulation model is a simplified similarity of a real system, either existing, or one that is supposed to be created in the future. A simulation model is usually represented by a computer program, the execution of which can be considered as an imitation of the behaviour of the source system over time. In many cases, simulation modelling is the only way to get an idea of the behaviour of a complex system and analyze it.

There are different approaches or so-called paradigms for the simulation modelling of complex systems (Korovin, 2012; Plotnikov and Sokolov, 2007; Ekyalimpa et al., 2016). On the whole, there are currently four main approaches in the classification of simulation modelling paradigms:

- System dynamics;
- Discrete-event modelling;
- Modelling of dynamic systems;
- Agent modelling.

System dynamics, in accordance with the definition of Akopov (2014), can be identified as follows: this is an approach that is based on the description of a system at a high level of abstraction, including streams, accumulators, auxiliary transient and internal models with their elements. The development of this method by the American engineer Jay Forrester began in the 1950s, and today system dynamics is being developed in foreign companies and research centres. There is even an international system dynamics community. The *discrete-event* approach is based on discrete streams and is associated with the use of system elements: resources, queues, delays, and transitions on events. It is most often used to model queuing systems, i.e., systems that serve incoming applications according to certain algorithms.

Modelling of dynamic systems is based on the approach that the system of a specific mathematical model, as in system dynamics, is described using a set of variable states and algebraic differential equations. A distinctive feature of this simulation modelling paradigm is the fact that state variables have a physical meaning, i.e., have coordinates, speed, etc. The modelling of such systems belongs to the continuous type of modelling and has a very low level of abstraction. At the same time, the feasibility of its use in building simulation models of economic and social systems is the least appropriate (Korovin, 2012; Garina, 2013).

The recent and considerably new approach is *agent-based modelling*, which examines the behaviour of decentralized agents and the entire system. Agents with this method can be different elements: people, social groups, the state, industries, companies, cars, helicopters, robots, and various other ecosystem agents. The difference between this approach and system dynamics is that the behaviour of each of the agents separately is determined first, and at the global level, the behaviour arises as a result of the activities of many agents, i.e., bottom-up processes.

All approaches to simulation modelling can be realized in the AnyLogic programme (Anylogic.ru, 2019). The AnyLogic package supports the description of both continuous and discrete processes, as well as building mixed models, in fact, at any level of abstraction (detail). This software will be used to build mixed models so as to choose the necessary strategy for inventory management, depending on the different nature of demand, inventory levels, delivery conditions and other factors.

The detailed description of the strategies and their parameters is provided in sub-chapter 6.4. In the current sub-chapter, these strategies will be analyzed and compared with each other in different scenarios as well as in integration within one supply chain (Lukinskiy and Panova, 2017). To make a choice in favour of a particular inventory management strategy in the considered supply chain it is advisable to simulate the operation of each of them and make a comparative evaluation using the following indicators: total deficit, average stock level, and costs associated with the implementation of this strategy (Lukinskiy et al., 2012, Lukinskiy et al., 2016; Ivanov, 2016).

Developed models, which, as a rule, describe periodic and continuous approaches to inventory management, simplify the analysis of the effectiveness of their use in specific conditions. In addition to the four inventory management strategies reviewed by the authors (Ivanov, 2016; Lukinskiy et al., 2016), three combined strategies will be studied below, under the circumstances of sensitivity analysis (Lukinskiy and Panova, 2017).

Firstly, periodic strategies (t, q) and (t, S) have been considered. Partial models were built in sub-chapter 6.4 based on the book of Ivanov (2016), excluding combined strategies that were modelled personally. Here, all of the strategies are optimized. In the AnyLogic software, periodic inventory management strategies were described and then rational parameters for checking the inventory level and ordering the right amount of goods (economic order quantity), and the maximum desirable inventory level were found based on the minimization of costs associated with storage, shortage, order fulfilment and an acceptable service level of 95% (Figure 5-10).

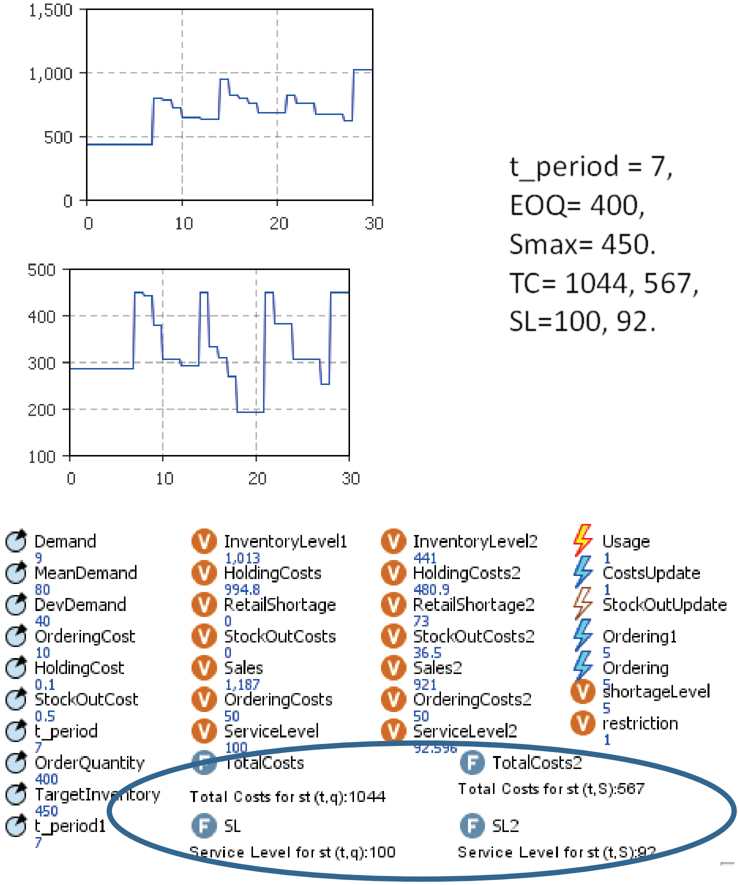


Figure 5-10. Output of the periodic inventory management strategies.

As can be seen from Figure 5-9, the strategy (t, q) implies higher total costs (TC) with the higher service level (SL) compared to strategy (t, S) with the lower total costs and service level. With the help of the optimization experiment, the parameters of the model have been improved (Figure 5-11).

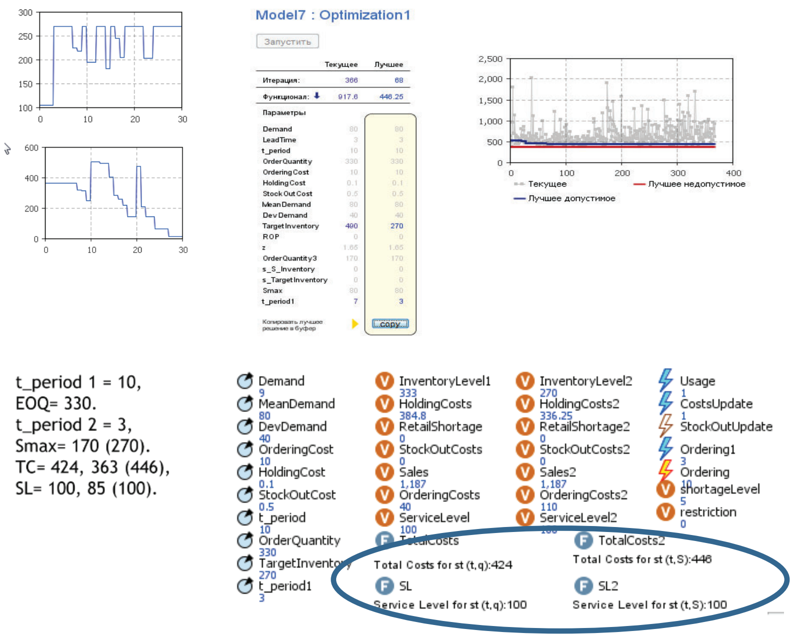
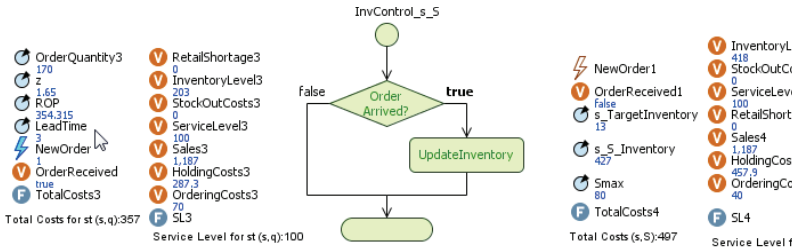
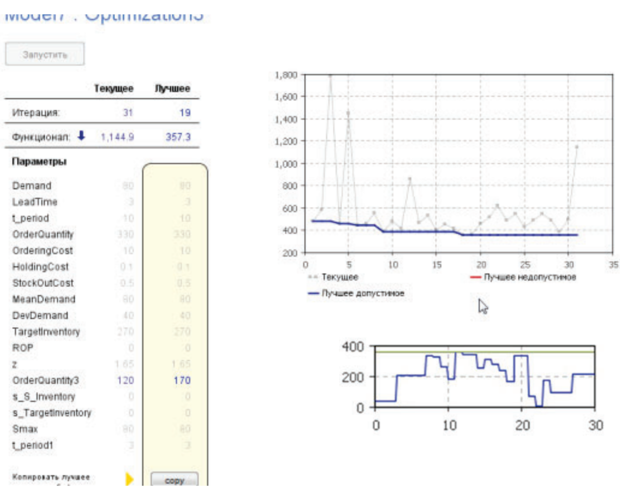


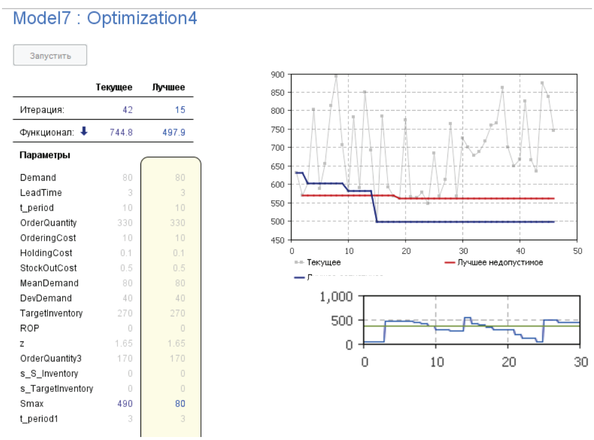
Figure 5-11. Optimized output of the models with periodic strategies of inventory management.

Figure 5-11 shows that total costs decreased in both strategies due to the changes in the EOQ, the target inventory level, and the period of inventory replenishment with the restrictions set in the optimization experiment (a service level that should not be lower than 95%) and the objective function for the minimization of total costs. Similarly, other inventory management strategies (with the order point and combined) were modelled, for which, under the optimization conditions, the best parameters were found, based on the principle of adherence to the “cost/service balance” (Figure 5-12).

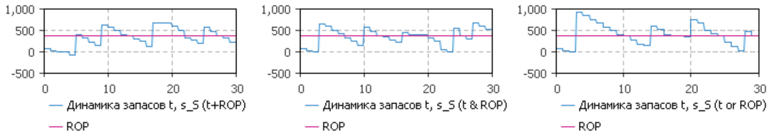




EOQ= 170, TC= 357, SL= 100.



Smax= 80, TC= 497, SL= 100.



Smax1= 300, t_per1=2; Smax2= 120, t_per2=4; Smax3= 200, t_per3=11.

Figure 5-12. Optimized output of the inventory management models with order point and combined strategies.

When the parameters of all strategies had been optimized, the sensitivity analysis of seven inventory management strategies were conducted. This was carried out with the help of control elements (Figure 5-13).

When the model was played, the average demand for products, the order period, and the time it was executed were changed in order to test the sensitivity of strategies to changes in the external environment. Based on the output of the models, the preferable strategies for different conditions have been identified and these were presented for the first time during the Fourth International Scientific and Practical Conference “Simulation and integrated modelling of marine equipment and marine transport systems”, in St. Petersburg in 2017 (Figure 5-14).

It should be noted that seven inventory strategies are systematized into three groups, depending on the terms of the order quantity, order interval, and order point (Figure 5-14). Previously, the classifications of four strategies (t,q; s,q; t,s; s,S) were provided in the book of Ivanov (2016), then, this figure was added including another three strategies and presented in the recent publication of the Russian Journal of Logistics and Transport Management (Lukinskiy et al., 2016b).

Due to the fact that an increase in costs associated with inventory management is not only typical for individual logistics systems, a version of the inventory management in the supply chain, consisting of retailers with individual strategies and a distributor, will be considered below. Such an approach requires integrated inventory management. From the point of view of an integrated approach, it is important to take into account the inventory management strategies for different participants in their interaction so that the total costs in the whole supply chain are minimized.

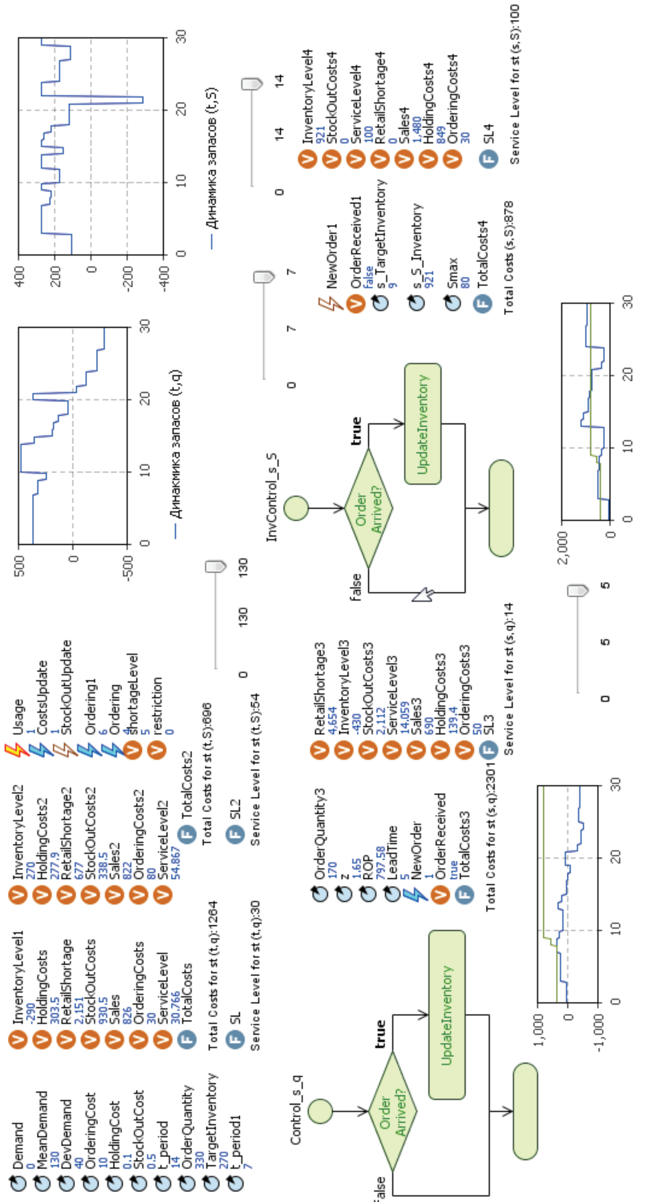


Figure 5-13. Sensitivity analysis of inventory management strategies.

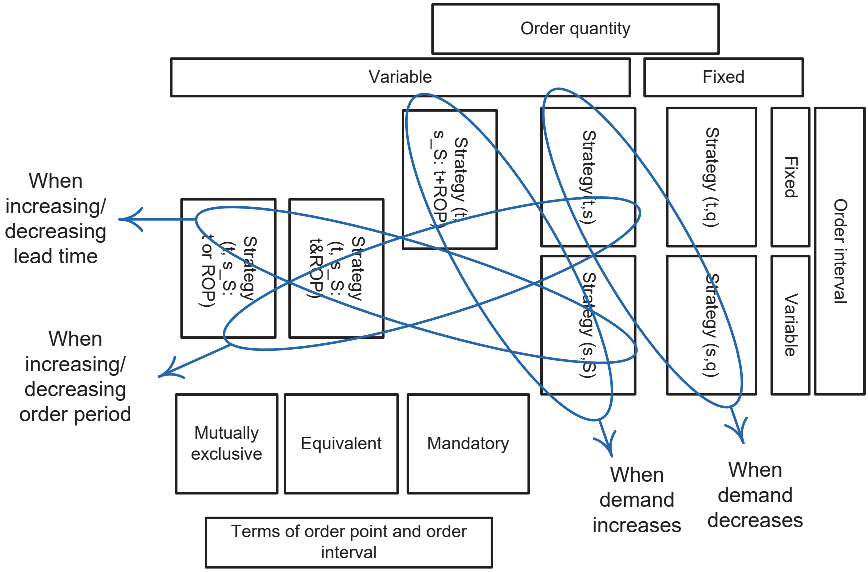


Figure 5-14. Strategies, which are suitable for different changes in the environment. Source (modified): Lukinskiy et al. (2016b)

For this purpose, it is necessary to describe the mechanics of the supply chain, in which individual units are represented by clients, retailers and the manufacturer. By doing so, the designed supply chain will be in compliance with existing definitions of this term. According to Sergeev et al. (2013), the *supply chain* is three or more economical units (organizations or individuals) directly involved in the external and internal flows of products, services and/or information from the source or origin to the end user.

According to Malikov (2014), the supply chain is a chain or network (depending on the complexity) of independent organizations related to the overall objective of profit maximization. It is achieved through the most effective co-operation, joint coordination and management processes related to ensuring all the necessary resources, manufacturing and sales of finished products in agreement with the principles of the general theory of systems and business logistics.

In the described system, the processes will be more complicated than in the previous systems, where only one inventory management approach in each system was taken into focus. In the example, the number of retailers was set to five, each of which has its unique inventory management strategy, i.e., two are periodic, two are "with order point", and one is combined. Therefore, an application of integrated inventory management will facilitate the reduction of costs across the whole supply chain.

Due to the difficulties in managing such a complicated system, adverse effects can sometimes appear. In inventory management, this phenomenon is called the *bullwhip effect* (a small two-stage version of this was introduced in sub-chapter 4.2). The causes of this phenomenon are rooted in the traditional approach to managing the supply chain. In contrast to the integrated management of supply chain elements, manufacturers and suppliers are considered individually and interact insufficiently with each other. This leads to the fact that they function as independent units, having their own plans for purchasing, sales, customer relationships, logistics flows, and inventory management strategy, and separate criteria for performance evaluation as well as being guided by their own goals and objectives (Zakharov and Tretyakov, 2013; Meschankina, 2005).

The bullwhip effect (BE) refers to increasing swings in inventory in response to shifts in customer demand as one moves further up the supply chain. The concept first appeared in Jay Forrester's Industrial Dynamics (1961) and it is thus also known as the Forrester effect. The bullwhip effect was named by the way the amplitude of a whip increases down its length. The BE can be measured by the given ratio coefficient of variances of the order to demand (Sergeev et al., 2013).

The bullwhip effect is higher when the parties in the supply chain make actions independently, with a minimum sharing of information among them. The influence of the bullwhip effect is reflected in the reliability of the supply chain as one of the basic criteria for assessing the quality and performance of the supply chain. Apparently, poor quality and failure to perform the functions by at least of one of the participants lead to a reduction in the quality of the functioning of the whole supply chain, further reducing its economic efficiency (Vokhmyanina, 2013).

The bullwhip effect is closely related to the *reliability* term. It has been mentioned as an issue in many publications in the sphere of logistics and supply chain management, but only some of these define its core concepts. One of the first works in which particular attention was paid to reliability in the functional areas of logistics, is a monograph of Inyutina (1983), where the author draws attention to the lack of a precise definition of the reliability of procurement, despite its frequent use in the economics literature of that period. In recent years, there has been increased interest in the study of the reliability of the supply chain, as evidenced by the growing number of publications, in particular the works of Bochkarev, A.A., Grigoriev, M.N., Dorofeeva, E.A., Ivanov, D.A., Lukinskiy, V.S., Lukinskiy, V.V., Pletneva, N.G. Malevich, Y.V., Sergeev, V.I., Uvarov, S.A., Shurpatova, I.G., and Zaitsev E.I. (Sergeev and Dorofeeva, 2010). According to the authors, reliability is one of the most significant indications of the supply chain work, which takes into account the constant changes in the external and internal environment. Therefore, the reliability of the supply chain is used in relation to the phenomenon of the bullwhip effect. In particular, minor changes in the external environment (in the demand of the final consumer or the order fulfilment time) can lead to much higher deviations in demand at all stages of the supply chain, creating a deficit or surplus of goods. Many resources are spent on the solution of related problems, both temporal and financial (Glatzel et al., 2009; Brom, 2008; Dybskaya, 2012).

The bullwhip effect, as a rule, decreases when the parties in the supply chain exchange information, not like the case of a break in a telephone conversation (it is a telephone turn effect of disinformation), but rather the lack of more precise information. By distributing constantly detailed information, the bullwhip effect can be decreased. In practice, it is achieved by the application of a specific system for inventory management, called the Vendor Managed Inventory (VMI). It is a business model in which the buyer (it can be a retailer or manufacturer) does not place an order with the supplier of a product, but provides certain information relating to the demand of the clients to a supplier (vendor) of that product. And the supplier takes full responsibility for maintaining an agreed inventory of the material, usually at the buyer's consumption location (usually a store). Thus, the supplier will not receive an order from the buyer, but only a preferable level of inventory with upper and lower levels. A third-party logistics provider can also be involved to make sure that the buyer has the required level of inventory by adjusting the demand and supply gaps.

In order to simulate the bullwhip effect, the model was expanded (an additional action chart was introduced). It helped to characterize the supplier and manufacturer strategy of inventory management depending on the retailers' inventory policies and demand of clients. On the basis of experiments with the expanded model, the "whip effect" was recorded as a result of an increase in the end-customer demand by half, on the 20th day after the model's initialization, for which the duration of the run corresponds to 100 days (Figure 5-15).

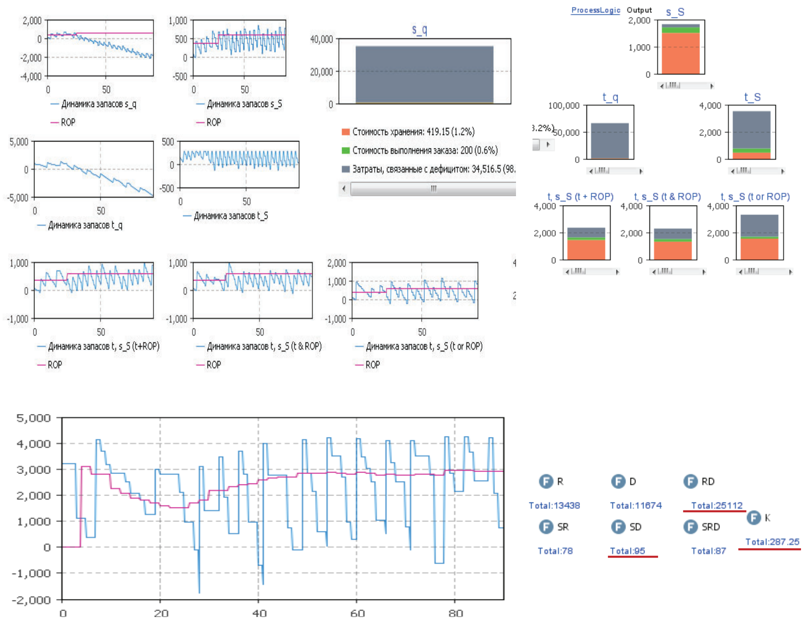


Figure 5-15. Simulation modelling of the bullwhip effect.

With the changes in demand, the cost (RD) totalled 25112 with an average service level (SL) of 87%, the ratio of RD to SD equalled 287 (Figure 5-15). In order to minimize the bullwhip effect and, consequently, reduce costs in the supply chain, an additional experiment was conducted that reproduced the VMI-based approach to inventory management in the supply chain. In accordance with this approach, the volume of supplier stocks is not determined by the level of orders received from retailers, but by the nature of the end-customer demand. As a result, the bullwhip effect was minimized, costs being reduced by 5% compared with the baseline scenario (Figure 5-16).

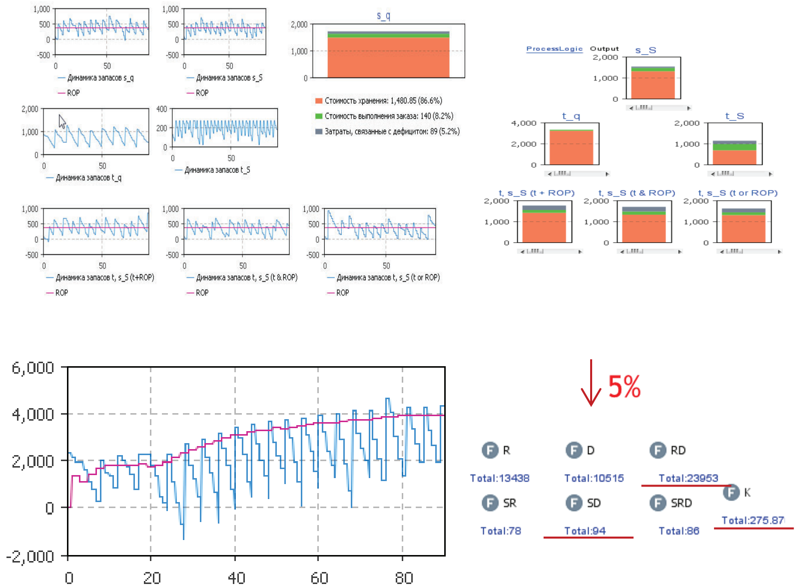


Figure 5-16. The bullwhip effect minimization based on the integration of the information flows via VMI.

Additionally, a basic scenario of VMI in the supply chain was modelled. This is the scenario without a bullwhip effect realization (risk-free scenario, Figure 5-17).

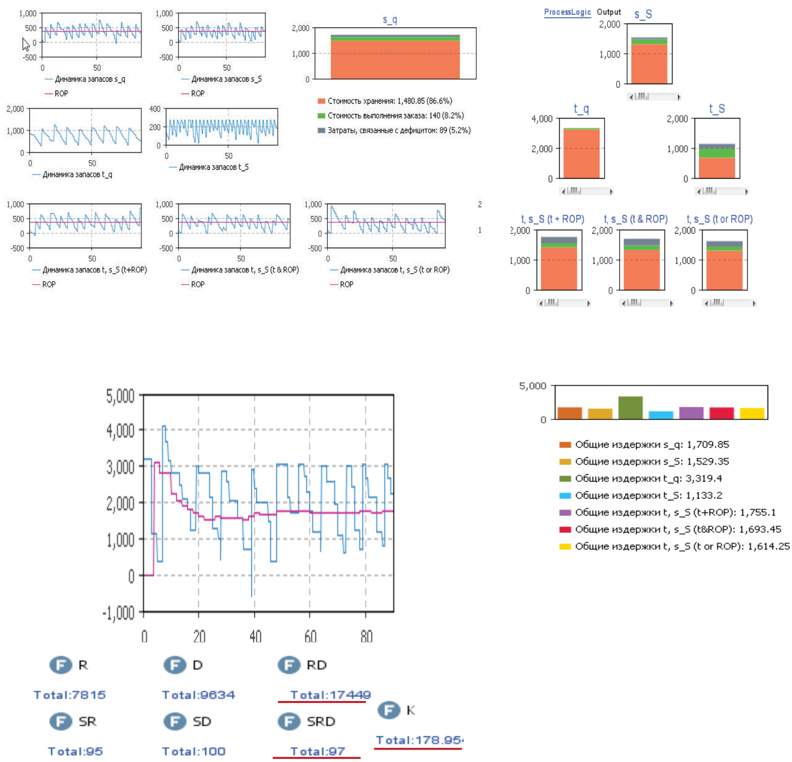


Figure 5-17. Simulation of inventory management in the supply chain within a risk-free environment.

In risk-free conditions, i.e., in the absence of changes in the external environment, the greatest cost reduction (11%) was observed in the supply chain with the VMI approach (Figure 5-18).

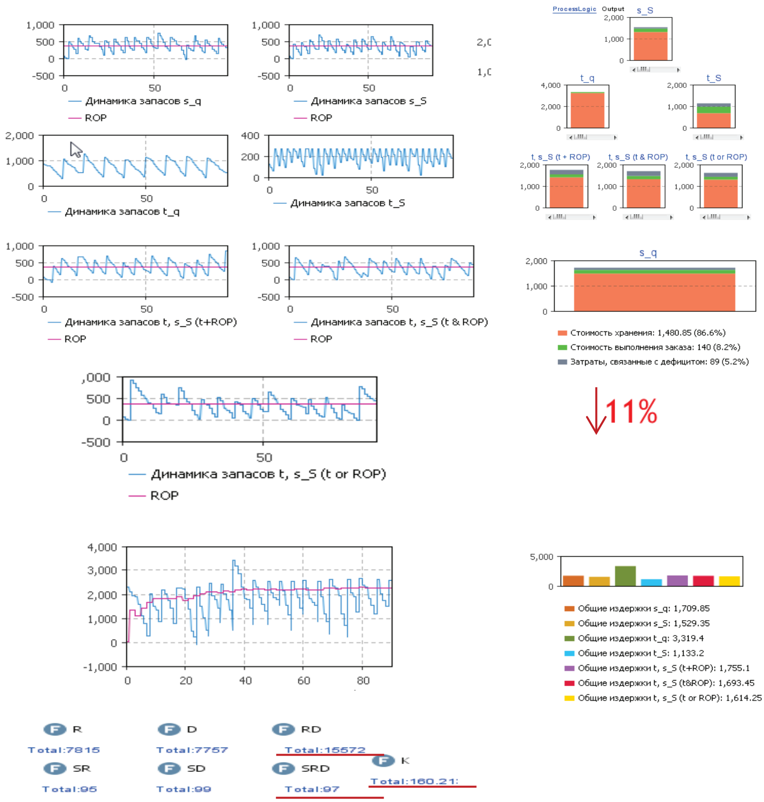


Figure 5-18. VMI-based supply chain management.

In summary, it should be noted that despite the development of logistics and supply chain management, theoretical and practical problems of the reliability of supply chains are still unresolved. This study applied a computer simulation of mixed models that allowed the description and analysis of inventory management strategies. The associated costs and service levels have been assessed in different inventory strategies. It was found that changes in the conditions of external parameters can lead to financial losses and a decrease in the effectiveness of the strategy as a whole, negatively influencing the capital of the company.

On the whole, the application of mathematical models and computer simulation of mixed models allows the amplifying of the evidence of cause and effect relations. With the created computer models, the analysis of the inventory strategies' performance under various external parameters has been provided. Moreover, with the help of computer models, the bullwhip effect was simulated. Thus, computer simulation can be considered as a convenient environment for studying practical problems: performance indicators, a comparison of variants of design and algorithms of systems as well as the control of stability conditions of the system under the variation of input variables.

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CHAPTER SIX

SIMULATION EXPERIMENTS AND CASE STUDIES

YULIA PANOVA

6.1. Technical aspects of transport nodal point design

One of the critical nodal points of intermodal traffic is dry ports that, as a rule, are located along international transport corridors (Monios and Lambert, 2013). This term was described in sub-chapter 2.4. In this section, attention will be paid to the technical aspects of transport nodal point design. Many works have been devoted to the design and development of warehouses and cargo terminals (Zhuravlev and Malikov, 2006; Bolotin et al., 2009; Malikov, 2003; 2005; Malikov et al., 2015). In the books of specialists of logistics and supply chain management (Lukinskiy, 2007; Lukinskiy et al., 2016; Mirotin et al., 2002; Mirotin and Sergeyev, 2000), problems of the optimal location of warehouses in supply chains, and inventory management of warehouses are considered. Kuznetsov (2011) investigated primarily the operation of marine container terminals and their parameters, port types, the capacity of storage areas of terminals, planning stages, the delivery of containers through port terminals as well as issues on the simulation modelling of marine container terminals. Problems of simulation modelling of the operation of inland intermodal terminals are less investigated (Roso, 2009; Lättilä, 2012; Korol, 2015; Sherbakova-Slyusarenko, 2016; Henttu, 2015; Panova et al., 2016). In Russia, for example, the concept of dry port development is considered to be relatively new, despite the fact that the country has a favourable circumstance for their allocation (Korol, 2015; Panova, 2012; Sherbakova-Slyusarenko, 2016; Panova, 2016).

When choosing the characteristics of inland terminals, it is necessary to take into account many factors, the mutual influence of which is not always obvious. Therefore, the use of the mathematically simple calculations (e.g., spreadsheets) that certainly provide some static evaluation, is not always sufficient. The use of computer simulation is becoming increasingly popular in this regard. Simulation is a method of research that is based on the construction of a generalized computer model with the algorithmic description of the basic rules of its behaviour. The developed models with sufficient accuracy describe the systems under study, allowing a simulation of the behaviour of those objects, especially when experiments with them are impossible or dangerous. Thus, the simulation models are created to answer questions of the type "what if ...?", i.e., to investigate possible scenarios for the development of systems (Karpov, 2005). The use of simulation modelling allows the describing of complex processes, the finding of cause-and-effect relationships and on the basis of technical and economic analysis the choice of the most rational modes of operation of the terminal.

Further on, as an example, the simulation of scenarios, i.e., the organization of truck flows in the intermodal terminal, is considered. The terminal is used to provide the transfer of containers from one mode of transport to another with the most efficient transshipment operations in order to minimize the downtime of transport (Abdikerimov et al., 2013; Lee et al., 2006). For the description of complex processes, such as the working process of the intermodal terminal, the most suitable method of modelling was chosen. This is the discrete-event approach, which, according to studies performed, was the most common in the field of production and business (Jahangirian et al., 2010).

The modern software AnyLogic can be applied as the simulation environment. The first version of the program was released in 2000. At the root of its creation was a group of scientists from St. Petersburg State Polytechnic University. Their successful research initiated the establishment of the Russian company XJ Technologies with its headquarters in St. Petersburg, Russia. The network of the company consists of 27 distributors on six continents from Australia to North America, with more than 15,000 users in 60 countries (XJ Technologies, 2012). The reason for the high demand for this simulation environment is due to the possibility of creating models based on any of the paradigms of simulation. Examples include system dynamics, discrete-event, and agent-based modelling as well as their combination within a single model (XJ Technologies, 2012).

In a further example of simulation modelling application, the intermodal terminal, which is located in the port area, will be considered. The terminal is equipped for loading and unloading railroad tracks and with lifting equipment. It has selected areas for loading/unloading containers to/from rail transport as well as road transport points of entry. Emphasis is placed on the organization of intermodal truck flows, i.e., internal trucks that are used to provide the transshipment of containers between two modes of transport (sea and rail). The containers are delivered by truck from three port terminals (container terminals A, B, and C) through the two gates to the areas of loading/unloading of rail wagons located at the intermodal terminal. For the purpose of the effective interaction of transport modes (reducing downtime), the organization of truck flows needs to be considered properly (Lee et al., 2006; Panova et al., 2016).

To achieve this, a simple model in Anylogic can be built in order to find the parameters of the terminal (mainly, the amount of handling equipment, depending on the intensity of the truck flow and the normative time prescribed for processing operations). In addition, technical parameters will be identified (the average time that a truck spends at the entrance, under loading/unloading operations and the total time in the system of the intermodal terminal, min; the average length of a queue at the entrance and under the operations, trucks, etc.). Below, the description of the simulation model development will be provided.

Phase № 1. Adding the plan of the intermodal terminal and drawing shapes of networks

- To create a new model:

1. Close the welcome page and then create the new model by selecting **File|New|Model** from the AnyLogic main menu. Drag the **Image** shape from the **Presentation** palette on the graphical diagram. This is the easiest and most common way to add an element to a diagram. Choose the file that will display the image (Figure 6-1).

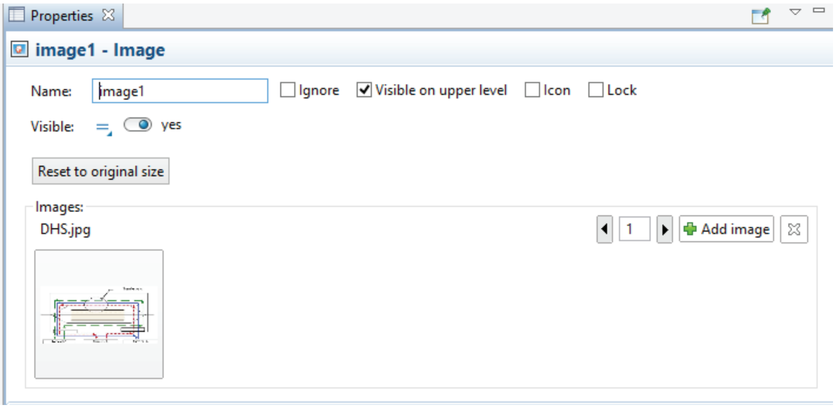


Figure 6-1. Image properties.

2. On the **General** page of the **Properties** view, in the **Image** area, click **Add image**.

3. Choose an image (the plan of the organization of truck flows at the terminal) and **open** it.

4. For the convenience of users, AnyLogic provides an opportunity to reduce the sensitivity of the individual figures to mouse clicks during the graphical editing of the other figures. For the simplification of drawing the network figures over the plan (background image), it is possible to lock it temporarily.

5. On the **General** tab of the **Properties** view, select the **Reset to original size** checkbox to use the image's original size and **Lock** the checkbox to lock the image.

6. The locked image is reflected in the **Projects** view with a lock icon. Once the object is locked, its sensitivity to the actions of the mouse is turned off. If necessary, it can be activated by clicking on the symbol of the object in the model tree (**Projects** view).

7. Mark the outline of the truck flow (all important areas and routes over the plan) by using shapes from **Presentation** palette (Figure 6-2).

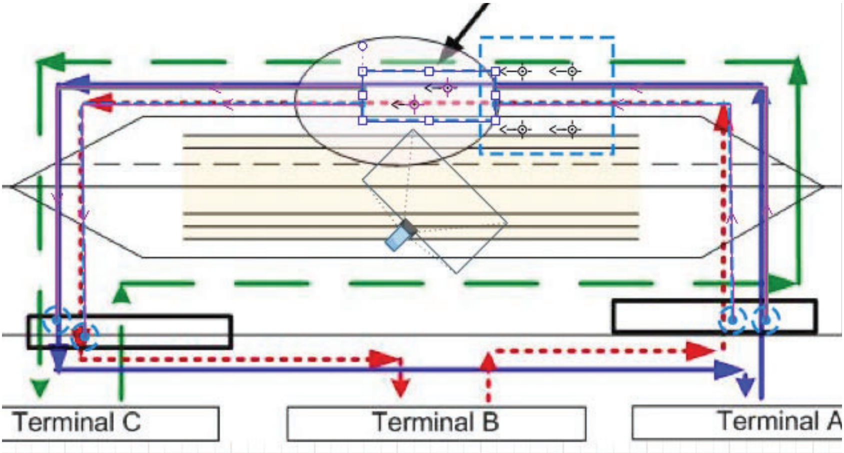


Figure 6-2. Shapes of the transport network (the fragment shows the topology of the network for trucks that come from the Marine Terminals A and B). Source (modified): Lee et al. (2006)

8. Draw the technological areas of the terminal by **Rectangle Node, Path, Point Node, and Attractors** from the **Process modelling library (Space Markup)**.

9. Add the **Camera** and **3D Window** from the **Presentation** palette on the central part of the picture to view the animation in 3D space (Figure 6-2).

10. In the case of using older versions of AnyLogic, the technological areas of the terminal and additional nodes are drawn by **Rectangle** shapes from the **Presentation** palette; and the routes between zones and nodes are drawn with the help of **Polylines**.

11. Add all the figures in the group NetworkGroupA**.**

➢ To group one or more figures:

a) Select all the elements in series by clicking on them while holding the Ctrl-key, or by dragging the mouse over the area with the shapes.

b) After selecting the shapes, right-click (Mac OS: Ctrl+click) them, choose **Grouping|Create Group** from the popup menu, and then name the group NetworkGroupA.

c) Groups of figures in AnyLogic have their start-coordinate tension other than the geometric centre of the grouped shapes. When a group is selected, its origin appears as a small purple circle. The origin group is the centre of rotation of the group and the origin for the combined figures.

➢ To add a shape to an existing group:

a) Right-click on the figure and choose **Grouping|Add to an existing group**. Available groups will be presented in the form of a small purple circle.

b) Click on a group to which a shape should be added.

12. Create a **Variable** object by dragging it to the diagram from the **General** tab of the Palette view and name it as meter.

    This variable will set the ratio between pixels of presentations and meters of the simulated space. To set the initial value of the variable, it is necessary to use the **Advanced** tab of the **Properties** view of the **Image** to determine the parameters of the image in pixels.

    In the **General** tab of the **Properties** view of the **Variable**, set the initial value taking into account the scale (for example, the initial value 10 is set if 1 metre is equal to 10 pixels of presentation).

Phase № 2. Creating a network of resources of the intermodal terminal

A **Network** object defines the topology and network settings and manages network resources. These resources are mainly represented by the used mechanisms (e.g., cranes). A group of **Enterprise Library** objects with the common **Network** prefix is for network and layout-based modelling. Their blue icons can easily distinguish them from other groups of objects.

1. Add a **Network** object. Go to the object properties and specify the name: networkA and the Group of network shapes, NetworkGroupA. Here, NetworkGroupA is the name of the group,

which was established in phase № 1. It contains rectangles and polylines that define the structure of the network.

2. Add a NetworkResoursePool object to define a set of network resource units. In this case, the object represents rail-mounted gantry cranes (RMG). In the properties of the object set the following parameters (Figure 6-3).

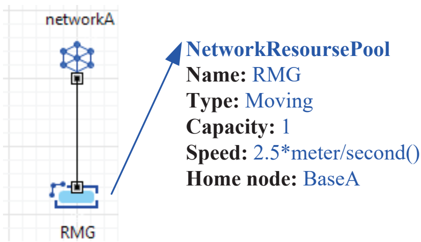


Figure 6-3. Topology and Network settings.

The velocity of the rail-mounted gantry cranes is installed with the introduction of the variable metre (Figure 6-4). It is always recommended to use variables such as second (), minute (), hour (), day (), etc., in numerical terms, which represented time intervals. In this case, it is possible to change the unit of time measurement freely, i.e., without changing the settings of the model. Therefore, the most important characteristic of these functions is that the expression used in them is completely independent of the setting units of simulated time: expression is always calculated in accordance with the current time intervals.

3. In the new version of the program, network resources can be easily created with **New agents** from the **Process Modelling Library (Agent palette)** by the drag and drop principle**.** One agent is a **Resource type** for cranes of the terminal and the other is an **Agent type** for trucks. Rename the first agent as **Truck,** and the second as **Crane.** Add pictures to animate trucks and cranes. These pictures with corresponding names are used for the modelling and animation of entities (trucks) and network resources (cranes) of the intermodal terminal (Figure 6-4).

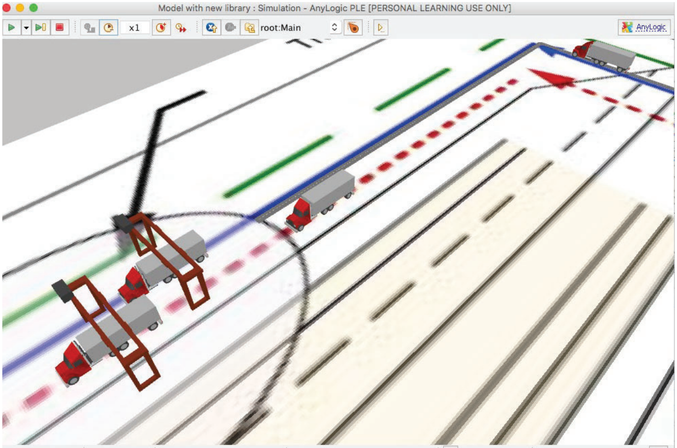


Figure 6-4. Animation of the intermodal terminal model.

Phase № 3. Development of a fragment of a discrete-event model of an intermodal terminal

As an example, the design of a model, which describes the flow of trucks coming from marine terminal A, is considered. By the end of this phase, the simple model, describing the inflow, processing and disposal of entities, can be developed using the **Enterprise Library** palette (Figure 6-5).

➢ To develop the fragment of the model:

1. Add a **Source** object to generate entities (to simulate trucks, which go from a marine terminal to the intermodal terminal), and set its basic properties:

   Arrivals defined by: Rate

   Arrival rate: 0.1/minute()

   New entity: new Truck()

   On exit: entity.type = 1;

   It is necessary to create a new Java class for the formation of new entities **new** Truck () which are with advanced functionality. By default, the entities that are processed by the models have the class

Entity. To add an entity with specific functions, features, and statistics collection, create a Java class Truck:

a) Right-click on the top item **Main in the Model tree** and select from the popup menu **Create|Java class**.

b) Enter the name of the class Truck, which is inherited from the base class Entity. Then click the **Next** button.

c) Fill in the three fields of the class Truck:

Name: type Type: int Access: public

Click on the **Finish** button to close the wizard of a new Java Class. Then, the designer of the Java class will be automatically opened. It can be closed because there is no need for editing.

In the main properties of the **Source** and all subsequent objects of the fragment of the model install **Entity class:** Truck.

If the model is created in the latest version of the Anylogic programme, then the new Java class can be created with the help of the **Agent palette** (described earlier).

2. To simulate a checkpoint (gate) of the terminal, use **Queue** and **Delay** objects. In the **General** properties of the **Queue,** set a queue length equal to 20-30% of the average daily flow of trucks.

3. Select the **Delay** object and adjust its **General** properties:

   Delay time: triangular (0.5, 1.5, 2)

   Capacity: 1

4. Add a **SelectOutput** object for the distribution of entities (trucks) to the prescribed directions (created by the network topology). In the properties of this object set the following selection mode – by the condition: entity.type == 1

   If the model is created in the latest version of AnyLogic, then the condition would look like this: agent.type==one

5. For a **NetworkEnter** object, which adds the incoming entity to the network and places it in the specified node, set the following **General** properties:

   Network: NetworkA

   Entry node: EnterA

   Speed: 4.5*meter/second()

6. A **NetworkMoveTo** object moves the entity to a specified place in the network. With this object, trucks will move from the entrance of the intermodal terminal to the transshipment zone (transfer point). For this purpose, specify the following **General** properties:

   Entity move to: Destination node

   Node: TransshipmentPoint

7. A **NetworkSeize** object captures for a given entity the required number of network resources. In the model, the resources are represented by handling mechanisms. Therefore, the object has the following **General** properties:

   List of resources: {RMG}

   Send captured resources: Select a checkbox.

   Entity move to: Destination node

   Node: TransshipmentPoint

8. In a **Delay1** object**,** which detains entities for loading/unloading operations, set the following **General** properties:

   Delay time: uniform (transshipment TimeMin, transshipment TimeMax)

   Capacity: 1

9. Add two **Parameters** named as transshipmentTimeMin and transshipmentTimeMax, respectively. Set the lower bound of time required for the loading/unloading of containers from the truck, according to the performance handling equipment. This is the

Default value of the first parameter. In the **Default value** of the second parameter specify the maximum time (e.g., 5).

10. In a **NetworkRelease** object set the following characteristics:

    Release: All resources

    Portable resources: Return to the base location.

12. In a **NetworkMoveTo1** object set the **Destination node:** ExitA

13. A **NetworkExit** object eliminates the entity from the network, if modelling the transport networks is provided. A **Sink** object is commonly used as the endpoint of a discrete-event model.

14. Run the simulation of a fragment of the discrete-event model (without the use of either figure animation) (Figure 6-5).

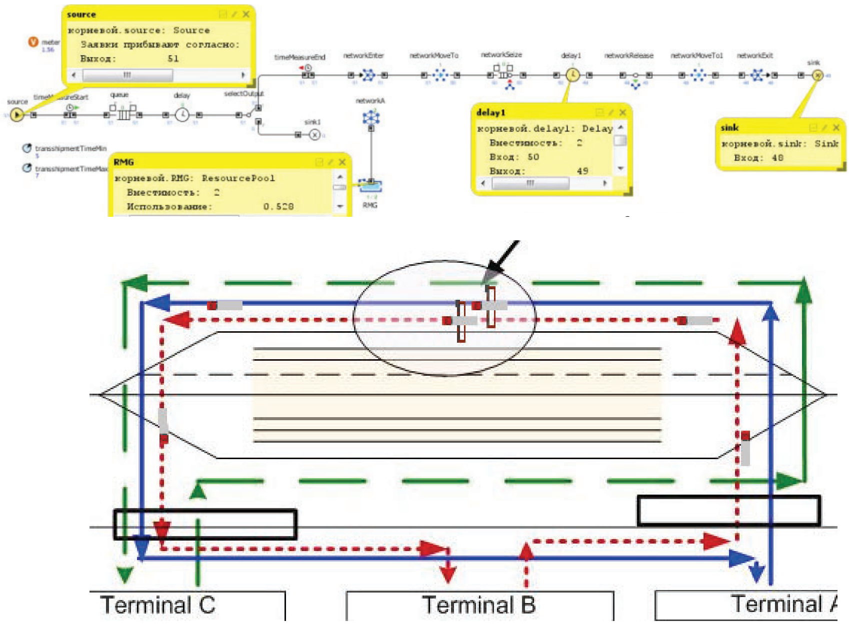


Figure 6-5. Fragment of a discrete-event model during the experiment (2D), describing the arrival, processing and disposal of trucks (from maritime terminal A). Source (modified): Lee et al. (2006), Panova et al. (2016)

Phase № 4. Designing of a "test stand" for the experiment and the collection of statistics about the model

- To collect statistics from the model, follow the next steps:

1. Create two objects **TimeMeasureStart** and **TimeMeasureEnd** (Figure 6-5), adding a code {timeMeasureStart} in the **General** properties of the last object. TimeMeasureEnd with TimeMeasureStart is a pair of objects that allows the measuring of the time that the entity spent between two points of the process diagram. Usually, with the help of these objects, the time spent by the entities is measured in the system or some sub-processes. Examples would be the average time that the truck was delayed at the entrance of the intermodal terminal.

2. Drag the **Histogram** from the **Analysis** palette onto the diagram. The **Analysis** palette has elements that store some simulation outputs and calculate statistics (data set, statistics, etc.). It also contains several charts (bar chart, time plot, histogram, etc.) for visualizing the data.

3. In the **General** tab of the Properties view of the **Histogram** set the Name: An average delay time of the truck at the instance, using **Code:** timeMeasureEnd.distribution

4. Add the required number of objects (**TimeMeasureStar**t, **TimeMeasureEnd,** and **Histogram)** so as to collect the statistics on the average time the truck spends at the different technological zones of the terminal. For example, it can be data about the average time the truck spends at the entrance of the terminal, under the loading/unloading operations and in the system as the whole (Figures 6-5 and 6-6).

5. To analyze the efficiency of the processing of entities in the system, the average queue length that occurs per day (playing time model) can be considered. As a matter of fact, in the **Project**s view, select the item **Simulation**. In the **Property** view of the **Simulation-Experiment** in the tab **Model time** set the following options:

   Stop: At the required time

End time: 1224

6. Add a **Variable** that will store the simulation output of the average queue length of the trucks at the entrance.

7. On the General properties of the **Queue** fill in the following fields:

   On enter: variable++;

   statistics.add(variable);

   On exit: variable--;

   statistics.add(variable);

8. Create an object **Statistics** from the **Analysis** palette to calculate basic statistics (average queue length) for a sequence of measured values of the type double.

9. Add the required number of **Statistics** and **Variable** objects in order to collect the data about the average length of trucks in different zones and the terminal as a whole.

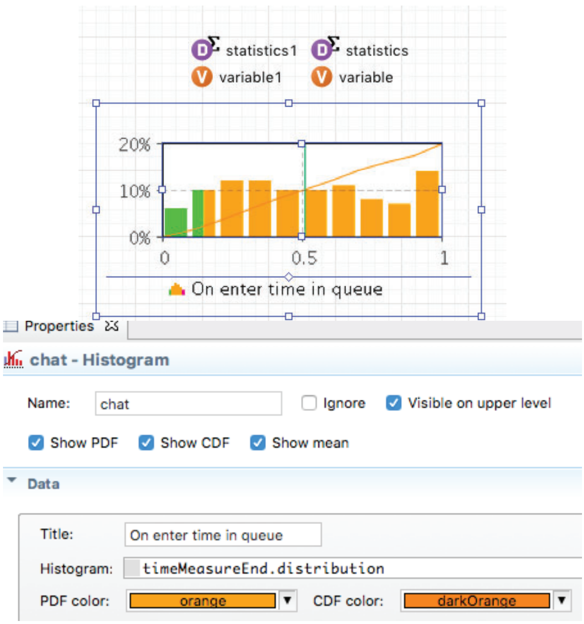


Figure 6-6. Objects used to gather statistics from the performed experiments.

It should be noted that by adding new flows of trucks from terminals B and C, the model will be gradually extended. In Figure 6-7, the model includes the second type of truck flow from terminal B, therefore, several blocks (Source, Queue, MoveTo, and Sink) are doubled compared to the model from Figure 6-5.

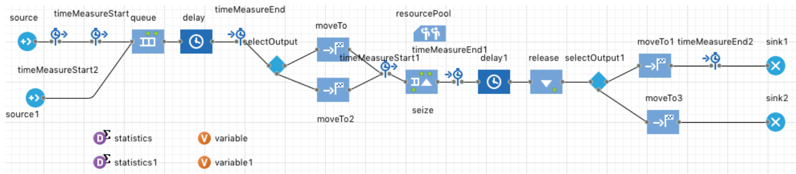


Figure 6-7. Discrete-event model, describing the arrival, processing and disposal of trucks (from maritime terminals A and B).

The model in Figure 6-7 also differs from that of Figure 6-5 due to the design of the main objects. The reason is that the latter model is created in the newer version of the Anylogic programme. Despite the different appearance of the blocks, their functional characteristics remain the same. Statistics from the objects can be collected in the same way. Particularly, to gather information about an average queue length of trucks under loading/unloading operations, it is necessary in the general properties of the **Seize** object to fill in the relative fields (Figure 6-8) that are similar to the **Queue** object described in the previous stage.

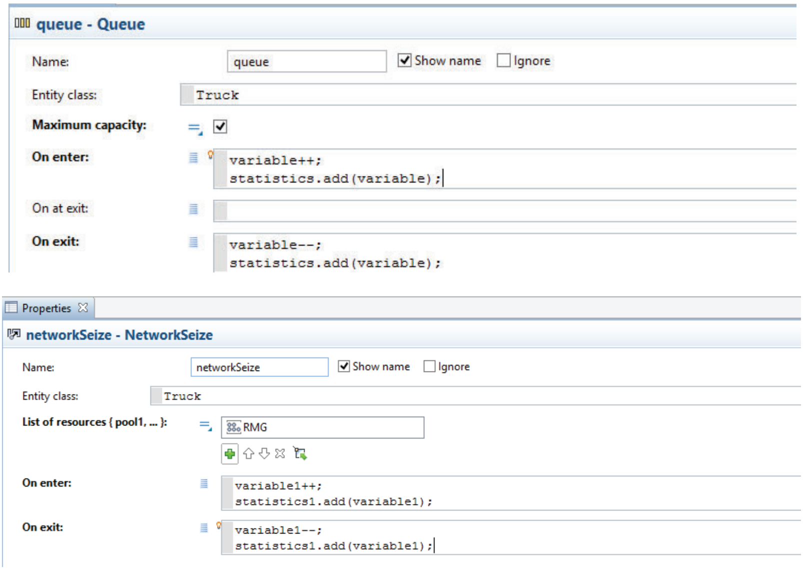


Figure 6-8. The filled-in general properties of the **Queue** and **Seize objects** for the statistics collection concerning the queue length.

Optionally, the block NetworkSeize (or Seize) can be used to collect statistics on the number of lost orders/entities. To do so, it is required to set the Timeout in the **Properties** of this block, after which the orders will be pushed out from the system via the block **Sink** (Figure 6-9). The timeout can be set, depending on the maximum normative time for the crane to serve a truck.

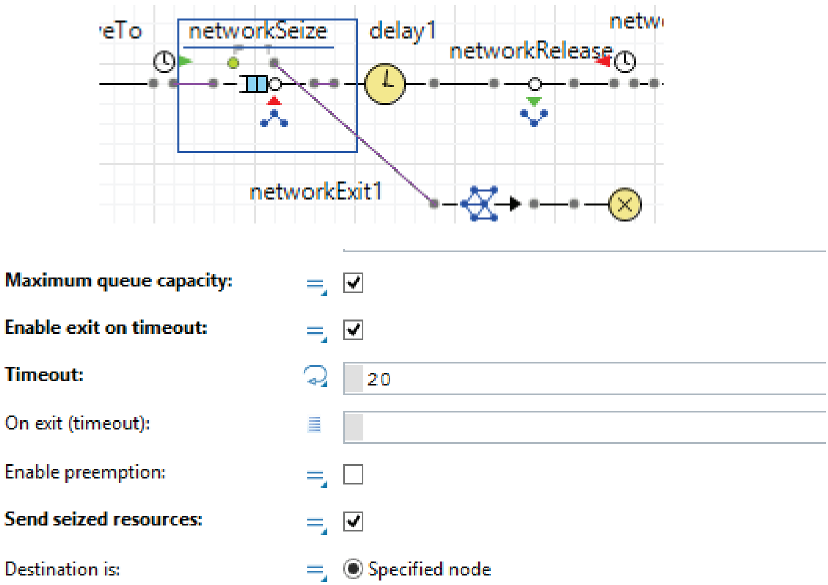


Figure 6-9. Properties of the block Seize for counting lost orders.

Additionally, the **Resource Pool** block (Figure 6-10) from the latest version of Anylogic can be used to collect statistics on the utilization of resources (e.g., cranes). To do so, it is required to drag **Time Plot** on the diagram from the **Statistics** palette and add one more **Parameter** from the **Agent** palette. In the **Default value** of the parameter, specify the number of cranes (e.g., 2) and use this parameter to specify the number of cranes in the general properties of the ResourcePool (Figure 6-10).

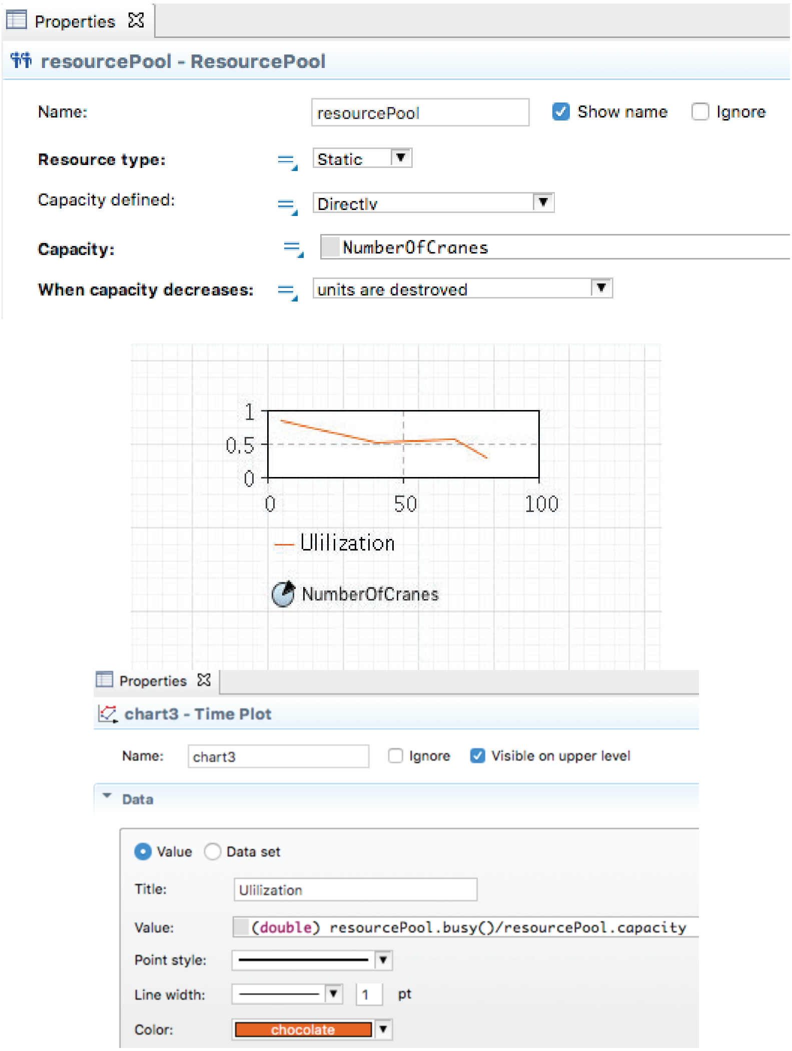


Figure 6-10. The filled-in general properties of the **ResourcePool** and **Time plot** for the analysis of resource utilization.

Mouse clicks are often used for navigation in the user model. Programmers create a text or graphics that are combined in logically-separate groups. These groups represent them in the various view fields of the model. For example, one viewport can contain animation models, while another might contain the output of the model. To design the simple viewing areas and the navigation between them, create hyperlinks:

10. Drag the **View area** object from the **Presentation** palette in the area, where the background image of the intermodal terminal is placed.

11. On the **General** property page of the **View area** set:

    Name: viewAnimation

    Title: Animation

    Align to: Left corner

    Scale: Adjust to the window

12. Create another **Viewing area** for the representation of the model output.

13. On the **General** property page of the second **Viewing area** set:

    Name: viewOutput

    Title: Output

    Align to: Left corner

    Scale: Adjust to the window

14. In the first field of view, create two **Text** elements (from the **Presentation** palette) "Animation" and "Output" (set their font size to 16, bold).

15. Set the colour of the text "Output" to lighter text.

16. In the **Dynamic** property page of the **Text** "Output", write the following code in the field **On click**: viewOutput.navigateTo ();

17. Draw a lighter line under the text «Output», to make it look like a hyperlink.

18. Select both texts "Animation" and "Output", and the lighter line. Ctrl+drag the selection (Mac OS: Cmd+drag) to create a copy of the shapes.

19. Drag the copy downwards to the second view area.

20. Set the colour of the second "Animation" text to lighter, and "Output" – to black.

21. Move the lighter line from "Output" to "Animation" and extend it to match the text.

22. Cut the code from the **On click** field of the **Dynamic** property page of the second "Output" text to the same field of the "Animation" text and change it to viewAnimation.navigateTo ();

23. Run the model. Click the hyperlinks that were created.

The lighter texts in this example are click-sensitive. Their actions **On click** call the method navigateTo() of the two view areas, which displays the corresponding part of the canvas.

To create a complete model of truck flow in intermodal terminal (Figure 6-13), add the appropriate blocks to specify:

- Network topology (Figure 6-2),
- Network resources (Figure 6-3),
- Animation of the model (Figures 6-4, 6-5),
- Additional fragments of the discrete-event model (Figure 6-7),
- Statistics shapes (Figures 6-6, 6-8, 6-10).

The created objects should reflect the arrival, processing and disposal of entities (trucks) that are related to the other two marine terminals (B and C, Figure 6-11). For this purpose, use similar steps from phases 1-4.

Figure 6-11. Discrete-event model of an intermodal terminal and statistics of its work (taking into account trucks, arriving from three marine terminals A, B, and C). Source (modified): Panova et al. (2016)

Phase № 5. The analysis of system statistics

The discrete-event model developed in AnyLogic describes scenarios of truck flow organization. This model is designed for the visualization, analysis and selection of stable parameters of the system.

Therefore, perform two experiments with the model:

- First experiment: the entities (trucks) arrive at the intermodal terminal with an intensity of 0.1, 0.15, and 0.2 from marine terminals A, B, C, respectively,

- Second experiment: increase the intensity of the arrival of entities twofold.

Then, determine the required number of loading and unloading mechanisms (RMG) for processing the incoming trucks. The optimal number of cranes can be found with the help of the optimization experiment (Figure 6-12).

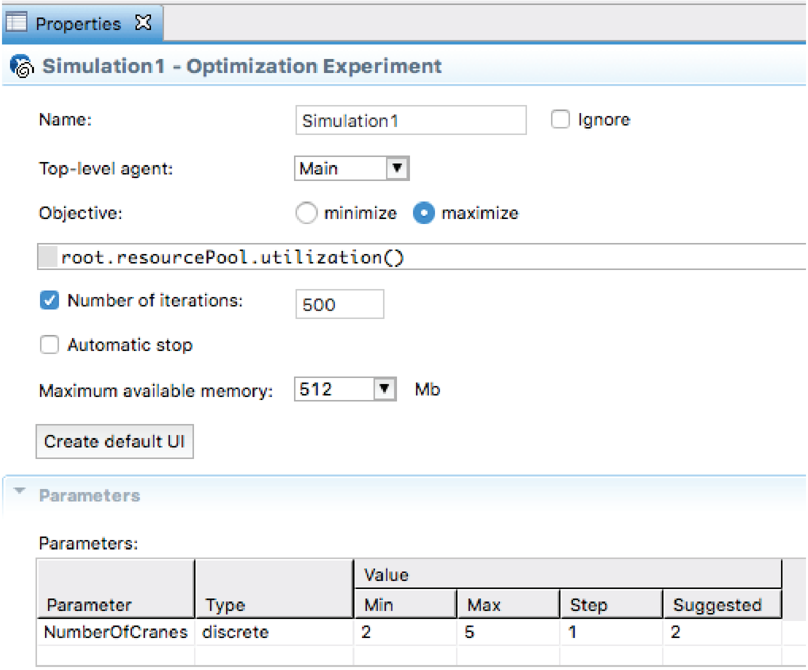


Figure 6-12. General properties of the optimization experiment.

As seen in Figure 6-12, the objective function of the model is root.resourcePool.utilization(). It will be maximized. Additional parameters include the minimum and maximum numbers of cranes and the step of the optimization experiment, which is equal to one crane. The sufficient number of iterations is 500. On the whole, on the grounds of the model, the values of additional parameters can be found:

- ✓ Average time that a truck spent at the entrance, in minutes (Histogram 1 for measuring time connected with the block timeMeasureEnd);
- ✓ Average time that a truck spent under loading/unloading operations, in minutes (Histogram 2 for measuring time connected to the block timeMeasureEnd1);

- ✓ Average time that a truck spent in the system of the intermodal terminal, in minutes (Histogram 3 for measuring time connected with the block timeMeasureEnd2);
- ✓ Average length of the queue at the entrance, in trucks (Statistics object);
- ✓ Average length of the queue under the operations, in trucks (Statistics1 object);
- ✓ Number of arrived entities, in trucks (Source object);
- ✓ Number of lost entities, in trucks (Sink object connected to the Seize object, Figure 6-9);
- ✓ Number of processed entities, in trucks (Sink object at the end of the whole process diagram);
- ✓ Number of entities in the process (WIP) can be found analytically, by subtracting from the number of arrived entities the number of lost and processed entities;
- ✓ Service level: (Number of processed entities – Number of lost orders)/Number of processed entities*100),%;
- ✓ Number of lanes for the processing of trucks at the entrance of the terminal;
- ✓ The number of resources (RMG), cranes.

After conducting experiments with the developed model, further on it can be applied to the analysis of the financial parameters required for the economic assessment of the construction project of the terminal, which will be described in the next sub-chapter.

6.2. Economic assessment of construction projects

The construction projects of inland terminals belong to investments with a long payback period (Panova, 2016). Therefore, their development can be realized in phases (Panova, 2012). In the below scenario, it is assumed that the terminal will be developed in three stages in regard to the growing truck flows (Table 6-1).

Table 6-1. Truck flow intensity.

Year	**1**	2	3	**4**	5	6	7	**8**	9	10	11	12	13	14	15
Truck flow intensity (trucks/min)	**0.1**	0.2	0.3	**0.4**	0.4	0.4	0.5	**0.6**	0.6	0.6	0.6	0.6	0.6	0.6	0.6

The capacity of the terminal will be increased discretely, despite the fact that the truck flow will increase more or less continuously during the settlement period of 15 years. Therefore, for each type of average intensity of truck flows, e.g., 0.1/minute, 0.4/minute, and 0.6/minute, the amount of handling equipment, the length of tracks, the required capacity of the container yard and related investments should be assessed. If the expenses related to the capital investments to the terminal are calculated three times, the operational costs should be calculated for each year, depending on the service level and proposed equipment for the terminal, i.e., the opportunity cost, WIP cost, backlog cost, expenses on the fuel of reach stackers and on wages, including various employee supplements. Keeping in mind that equipment will only be changed three times, while traffic will be more or less dynamic over 15 years, the AnyLogic model will additionally help to figure out operational costs that can increase due to the shortage of equipment and increased backlogs, WIP and lost orders. For the calculation of the profitability or return on investments (ROI), depreciation costs and taxes can also be found.

Only capital-intensive investments will be taken into account in the calculations. An assessment of real construction projects would require a more detailed specification with a large number of estimations. In the current example, investments that are related to the acquisition of new lifting equipment and the expansion of the container yard will be considered (Malikov et al., 2015).

Technical parameters

The capacity of a container yard:

$$YC = Np*d/z* \Delta S,$$

where *Np* is the number of orders processed per day, trucks;

d is the average retention cycle of containers, days (2-5);

z is the average number of containers in the stack (3);

Δ S is the required space to accommodate 1 TEU with allowance for the technical equipment of the terminal (12-20 m^2/TEU).

The length of rail track:

$$L = Np/n* Lw,$$

where n is the average number of containers on a flat rail wagon;

Lw is the average length of a flat rail wagon.

The service level:

$$SL = (Np-LO)/Np*100,$$

where LO is the number of lost orders per day.

A number of lost orders can be calculated automatically in the model with the help of the function of the Seize object. The option of pushed out orders should be checked in the general properties of this object. Lost orders could be collected from the Sink object.

Financial parameters

Investments:

$$I_t = I_l + I_{he} + I_{cy} + I_{rt}\ ,$$

where I_l is the cost of the land, RUB (2 4000 per 1 m^2);

I_{he} is the cost of handling equipment, RUB;
I_{cy} is the cost of coating a container yard, RUB;
I_{rt} is the cost of laying railway tracks, RUB.

$$I_{he} = n*C_{he}\ ,$$

where n is the amount of handling equipment (loading and unloading machines, e.g., reach stackers), units;

C_{he} is the cost of one unit of handling equipment, RUB (25 000 000).

$$I_{cy} = S * C_{cy}\ ,$$

where S is the container yard area, m^2;

C_{cy} is the cost of coating 1 m^2 of the container yard, RUB (3 200).

$$I_{rt} = L*C_{rt}\ ,$$

where L is the length of railway track, m;

C_{rt} is the cost of laying 1 km of railway track, RUB (71 m).

Exploitation (or operational) costs:

$$E_t = E_{dt} + E_{oc} + E_{wf} + E_f + E_{wip} ,$$

where E_{dt} is the costs related to the unproductive downtime of vehicles or backlog costs;

E_{oc} is the loss of income (loss of sales or opportunity costs);
E_{wf} is the wage fund;
E_f is the cost of fuel consumption by loading and unloading machines of cyclic action;
E_{wip} is the cost of WIP orders;
E_{lo} is the cost of lost orders.

$$E_{dt} = t_{dt} * C_{dt} * N * 365,$$

where t_{dt} is the average time of vehicle downtime, waiting for loading and unloading operations, h;

C_{dt} is the unproductive downtime costs, RUB/h (1000).

N is the average number of trucks in the queue.

$$E_{oc} = LO * 365 * C_{lo.},$$

where LO is the number of lost orders per day;

$C_{lo.}$ is the cost of a lost order, RUB/order (1800).

$$E_{wf} = \sum N_i * S_i * 12 * (1 + ECH/100),$$

where N_i is the number of employees;
S_i is the average monthly wage per employee per month;
ECH is the unified social tax (e.g., since 2015 it has been 30.4% in Russia).

$$E_f = N_{equip} * W_{en} * q_т/p * k * T_{act} * C_{fuel},$$

where N_{equip} is the number of machines of the same type, units;

W_{en} is the installed capacity of the internal combustion engine, kilowatt (320);
q_{T} is the specific fuel consumption, kg per 1 hp in hour (0.21);
p is the density of diesel, kg/m^3 (0.85);
k is the coefficient of the utilization of electric power (0.8);
T_{act} is the actual value of the work of the equipment for a year (7400), h;
C_{fuel} is the cost of one litre of fuel, RUB (33).

$$E_{wip} = WIP * 365 * C_{wip.},$$

where WIP is the number of orders in process, per day, which can be found by the formula: *Na -Np-LO*, where *Na* is the number of arrived orders per day.

$C_{wip.}$ Is the cost of the WIP order, RUB/order (1200).

Depreciation costs:

$$D = MF * \frac{a_{dep1}}{100} + Ccy * \frac{a_{dep2}}{100} + Ct * \frac{a_{dep3}}{100},$$

where MF is the value of fixed assets (of all handling equipment);

$a_{dep1,2,3}$ is the rate of depreciation of the handling equipment, container yard (3%) and rail tracks (4%), respectively, in %.

$$a_{dep1} = \frac{100\%}{T},$$

where T is the useful life of handling equipment (7).

Revenues:

$$R_t = Np*365*r,$$

where Np is the the number of orders processed per day;

r is the revenue from processing a single order, RUB/order (1800).

Taxes:

$$T = R_t \times 18/118 + 0.2 \times (R_t \times 100/118 - E_t) + \frac{2.2 \times I_t}{100},$$

where R_t is total revenues;

E_t is total operating expenses, RUB/year;
18/118 is the coefficient for calculating the value-added tax of 18% (% rate of VAT/(% rate of VAT+100);
100/118 is the coefficient for calculating the revenues without VAT;
0.2 is the profits tax in absolute measure (or 20%);
2.2 is the property tax.

Profit based on the free cash flow:

$$P = Rt–Et+D–T$$

Based on the intermediate calculations (i.e., technical and financial parameters), it is possible to define the preferable option of terminal development (its technical state) by the *profitability ratio* (e.g., through simple comparisons of the *ratio of net profit to capital investments* (P/I_t*100%). By doing so, the most suitable technical state of the terminal can be defined (1^{st}, 2^{nd} or 3^{rd}, which respectively corresponds to the capacity of the terminal with an average intensity of truck flows of 0.1/minute, 0.4/minute, or 0.6/minute).

Further on, the calculations can be continued in the Vensim programme, where the project performance indicators can be found (NPV and DPP) in regard to the favourable scenario of terminal development (for the state of the terminal, which is previously defined). In the given example, it is assumed that the favourable technical state of the terminal is the third one (when the terminal works to its planned maximum capacity, which is reached by the end of the settlement period). For calculations of the NPV and DPP of the construction project, a simple system dynamic model in Vensim should be built (Figure 6-13).

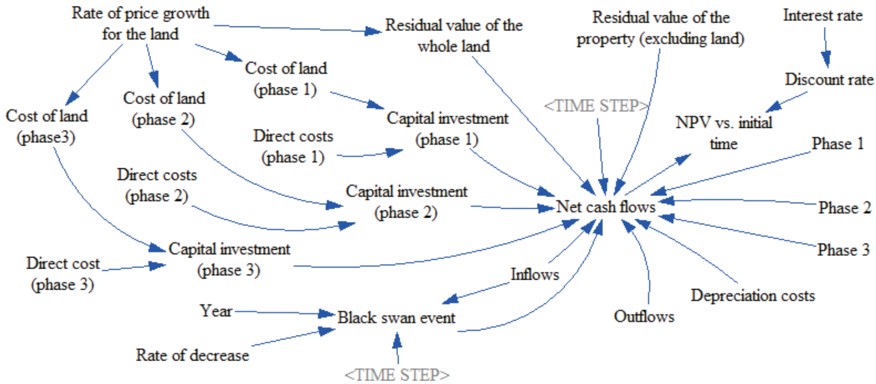


Figure 6-13. Model for an economic assessment of container terminal development.

The proposed model is useful for the analysis of the project's realization under the influence of risks. In order to receive an outcome from the model (risk analysis of the investments), the following scheme has been properly considered:

- ✓ Formulation of the parameters (factors) affecting cash flows of the project;
- ✓ Generation of the probability distribution for each parameter (factor).
- ✓ Combination of the values of risk factors with the parameters (factors), which are not expected to change (for example, the tax rate or the rate of depreciation). With this point in mind, net cash flows are calculated for each year. Based on the net cash flows, the discounted payback period and net present value are computed;
- ✓ The above steps are repeated many times (typically 500 simulations), allowing a probabilistic distribution of the DPP and NPV to be built;
- ✓ The results of the simulation are complemented by a probabilistic and statistical analysis.

The influence of risk factors (political, operational, and economic) having an effect on financial cash flows is estimated via Monte Carlo simulations. They are accessed in the form of the NPV and discounted payback period fluctuations. Each type of risk is represented by the particular parameters. For example, an interest rate is used to simulate the political situation. Due to the fact that, as a rule the evaluation of projects in countries with high political risks increases the required rate of return, it can be assumed that the interest rate will fluctuate (Figure 6-13). The absence of sufficient information on how the interest rate may change over the settlement period can be mitigated by the use of the uniform distribution.

The next risk factor is related to the operational situation. Sale prices for services can be volatile as the result of a crisis or another black swan economic event. Knowing Benford's Law and its application for examining a list of the heights of the 60 tallest structures in the world by category, it is possible to suppose the financial situation in the next years. The theory is that the soaring ambition of an overheated economic boom expresses its peak through the construction of the world's tallest skyscraper, meaning the economy is due for a correction. With the construction of a new skyscraper in China (the 2,749-foot-tall building in Changsha), the world might be on the verge of a new financial crisis. However, the construction of this project, due to start in either June or July of 2014, was delayed. Meanwhile, there is another project underway to build the world's tallest skyscraper, Saudi Arabia's Kingdom Tower (also called Jeddah Tower), which is scheduled for completion in 2021. However, there have also been various delays since construction began in 2013, and these might take place again later (CNN.com, 2018). Could there be a financial crash between now and then? Although it is often not possible to precisely predict when such events will occur, it is supposed that a “black swan event” could happen within this period with the use of the distribution function for the specific factor (Figure 6-13). The year of a black swan event occurrence can be modelled with the triangular distribution. The rate of price decrease should be modelled with the help of the normal distribution based on the analysis of historical data.

The last but not least, important risk factor that could be considered in the built model is related to the economic situation. The risk of land prices changing dramatically can be high. The rate of price growth for the land (Figure 6-13) should be estimated based on past trends. Once all the parameters of the model are set, with the help of the Monte Carlo simulation, the influence of each type of risk and their overall effect on the project can be identified. The obtained mean value of the NPV and DPP from the model can be used to represent the expected values of the given financial indicators of the project assessment, while the standard deviation of both indicators can serve as an indicator or characteristic of risk.

During the construction of inland terminals, additional financial aspects (e.g., sources of profit) can be considered. An example would be the diversity of the services provided by the inland terminal, depending on the specifics of processed freight flows. For instance, in Russia, the level of containerization in the export direction is very low, because the export flows are represented by raw materials. Containers of cargo arrive from abroad, while in the export direction the containers leaving are empty, causing a non-desirable empty run of containers. Despite an increase in the level of filled-in returnable containers with the growth of bulk cargo (fertilizers or scrap metals) in export flows, about 30-40% of the containers are still sent back empty from Russia (Korovyakovsky and Panova, 2011). One of the solutions to the above problem may be the use of additional equipment on the territory of the inland rail terminal, which will allow the use of containers for the transportation of various types of cargo, thus, increasing the profitability of the port terminal from the offer of services for the reloading of cargo into containers (Panova et al., 2012).

Such technologies, for example, include flexible polymer reservoirs – *flexitanks and drainers* – installed in large-capacity containers for transporting petrochemical, agricultural, and food products. Flexitanks are used for liquid cargo, such as wine materials, juices, food or technical oils, non-aggressive liquid chemical products; and dry liners – for dry, powdery, granular, pulverized, and dry grain cargo. Such technologies have been used in the world for over 30 years. The main purpose of creating and using flexitanks and dry liners is to increase the efficiency of delivering liquid and bulk cargo in general-purpose containers compared to standard methods for transporting these goods in metal or plastic barrels, specialized tanks, tank containers, soft low-tonnage containers, and other types of transport packaging.

Therefore, the inland terminals can be additionally equipped with special technologies for loading/unloading general-purpose containers using flexitanks or dry liners. This equipment includes bunkers for storing bulk products, pumps and pneumatic lines connecting storage tanks for cargo to flexitank/dry liner throats. Equipping dry ports with such equipment is advisable in areas of industrial enterprise that have constant volumes of shipment of the same type of cargo for export. Thus, the operation of the inland rail terminal will not be limited to servicing the sea port, according to the general concept of dry ports. Rather, the new services of the inland terminal should be considered so as to identify additional sources of company revenue (Table 6-2).

Table 6-2. List of inland rail terminal services.

Type of service	The approximate cost of services, USD	
	TEU	FEU
1. Container transportation as part of a container block train in the direction of the "sea port – dry port" (distance 84 km)	81 (subject to loading two 20-foot containers onto one rail platform in one direction)	175
2. Additional payment for security at the terminal	20	20
3. Customs inspection (10%)	190	380
4. Storage		
Imported loaded		
Free storage	0 days	
From day 1 to 4 days	6	12
From 5 to 8 days	9	18
From 9 days or more	15	25
Loaded exported		
Free storage	5 days	
From 6 to 11 days	9	18
From 12 days and more	18	36
Empty imported/exported		
Free storage	5 days	
From 6 to 11 days	6	8
From 12 days or more	7	10
5. Reloading of cargo from the container to the truck	100	130
6. Cargo reloading from container to warehouse	80	100
7. Container stuffing	80	100
8. Weighing	10	
9. Coating the inside of the container with paper	40	70
10. Installing a Flexitank/Dry liner	30	60
11. Cleaning of the container	10	15
12. Washing and drying the container	30	60
13. Loading/unloading an empty container	30	30
14. Loading/unloading a loaded container	50	50
15. Container repair	At the request of the principal	
* Fees are subject to 18% VAT		

The average cost of container handling in the sea port of St. Petersburg (Russia) is 325 USD. According to Table 6-2, the potential income from the processing of a container increases by three times, if additional services are provided. Thus, the inclusion in the supply chain of an inland rail terminal equipped with specialized technologies leads to an increase in revenues by expanding the list of logistics services. If the logistics services are completely new for clients, it is essential to consider their diffusion among potential clients. As a rule, in the theory of the spread of innovations, the two most well-known diffusion models by E. Rogers and F. Bass are applied (Solomina, 2009). The essence of the mathematical model of F. Bass, published in 1969, is that new products are spread by the influence of two effects (advertising and interpersonal communication).

During the first stage of the product life cycle, the advertising effect prevails, since many people do not know about the product and, accordingly, cannot purchase it. As the duration of advertising influence increases, the number of consumers also increases. In turn, the effectiveness of advertising gradually decreases. The model can clearly reflect the principles of increasing feedbacks, when the number of product consumers determines the growth of the flow of new consumers due to the effect of interpersonal communication.

As an example of the spread of innovation, the technologies of flexitanks and dry liners can be studied. For this purpose, the simulation model can be developed on the basis of the system dynamics approach in the Vensim environment (Figure 6-14).

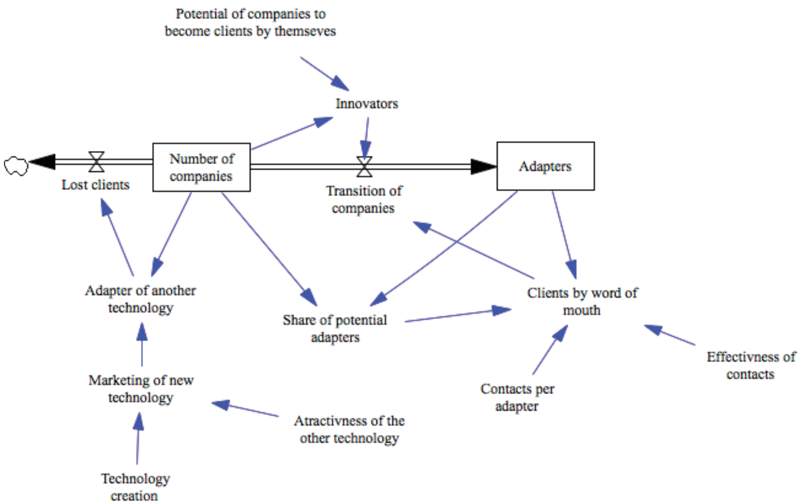
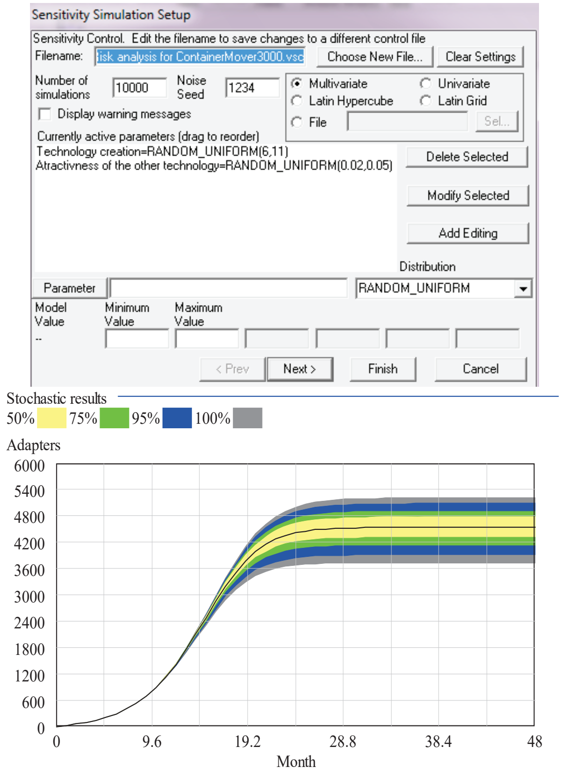


Figure 6-14. Simulation model of the spread of innovation. Source (original; modified to the English language from Russian used for the internal journal of the university): Panova and Hilmola (2015)

The following assumptions were made to build a simulation model of diffusion according to F. Bass: the number of potential clients (companies) is assumed to be 7,500 of which approximately 300 are railway operators and 5,500 are trucking companies. On average, 0.4% of potential companies come to the decision to purchase equipment under the influence of its advertising. Sales due to "word of mouth" are modelled on the condition that the number of contacts of the innovator company is three potential client companies per unit model time (months). If the first category of companies contacted the second, the latter became clients with a probability of 0.1, that is, due to the effect of "word of mouth" advertising (Figure 6-14).

Risk parameters have been set in addition to the existing Bass innovation diffusion theory; in particular, the emergence of a competitive analogue technology 6 or 11 months after the initial distribution of the technology by the considered terminal. The probability of such an event reduces the number of potential customers by an average of 2%. Depending on the characteristics of a new competitor, the negative effect may be increased by 2% to 5%. These risks were modelled using a uniform law of probability distribution and estimated on the basis of the Monte Carlo method. The number of iterations of the experiment is 10,000 (Figure 6-15).



Statistics

Variable	Count	Min	Max	Mean	Median	StDev	(Norm)
Adapters sensitivity results at time 48 Runs:		Stochastic results					
Adapters	10000	3730	5213	4540	4559	315.1	.06941

Figure 6-15. Outcome of the model.

The simulation model developed in the Vensim environment visualizes the process of diffusion of innovations, which is displayed as an S-shaped curve (theoretical and practical studies converge in this concept). With the accepted initial data, the market will be saturated in 3 years and 1 month. Due to the presence of the risk of the emergence of competitive technology, the number of adapter companies of flexitank/dry liners will decrease by 21%

(from 5800 to 4540) with a 50% probability and with a deviation from the average of 315 companies (according to the normal distribution law). With a probability of 68%, the number of adapter companies will be within [4225; 4855]. Approximately 95% of observations fit into the area with a double standard error, that is, the number of user companies can fluctuate between 3910 and 5170. The best scenario of market saturation that can occur with a minimum probability will lead to the emergence of 5213 adapter companies of flexitank/dry liners.

6.3. Inventory management and control policies

Once the design of the inland terminal has been planned and its economic assessment conducted (sub-chapters 6.1-6.2), the construction project can be implemented into the existing supply chains. In particular, the design of the supply chain will be considered further so as to define the best locations for the bonded warehouses that belong to the dry ports or the inland container terminal. These warehouses are, as a rule, required for cross-border trade between neighbouring countries. As an example, China-Russia cross-border trade will be analyzed (Panova and Hongsheng, 2019). Chinese companies occupy up to 90% of the market in the neighbouring e-commerce cross-border partner, the Russian Federation. Meanwhile, nowadays, Russian people on average wait up to 20-25 days for the delivery of parcels from China (Logisticstime.com, 2018).

The bonded warehouse model can help to deliver products from abroad to final clients in a shorter time. Investors may set up a warehouse in a reasonable location so that goods will then be transported and stored temporarily within the warehouse under the customs supervision before they are delivered to domestic customers. In this case, the delivery time can be reduced to 5 days, compared to the direct shipping model that requires 7-30 days for delivery (China-brifing.com, 2016). The reason for long deliveries is that under the direct sale model, foreign manufacturers maintain warehouses in their home countries and send goods to customers after they have made orders online that involve a relatively more complicated custom clearance procedure.

With these points in mind, decision-making concerning the warehouse location will be done below with the help of Greenfield Analysis (GFA) and network optimization experiments carried out in the simulation environment. In order to identify the favourable location of bonded warehouses in Russia for doing e-commerce business with China, the locations of customers were set in 100 places, and the demand was set proportional to the density of population in the considered locations. For the experiments of greenfield analysis and network optimization, an Anylogistix environment was chosen (AnyLogistix.ru, 2018). In the greenfield analyses, the best location of the warehouses was identified for a certain quantity of facilities, satisfying the demand of all customers with minimized transport costs. In total, three experiments have been done with the set number of sites for warehouses (varying from one to three). The larger number of warehouse sites allowed the reduction of the service distances (Figure 6-16).

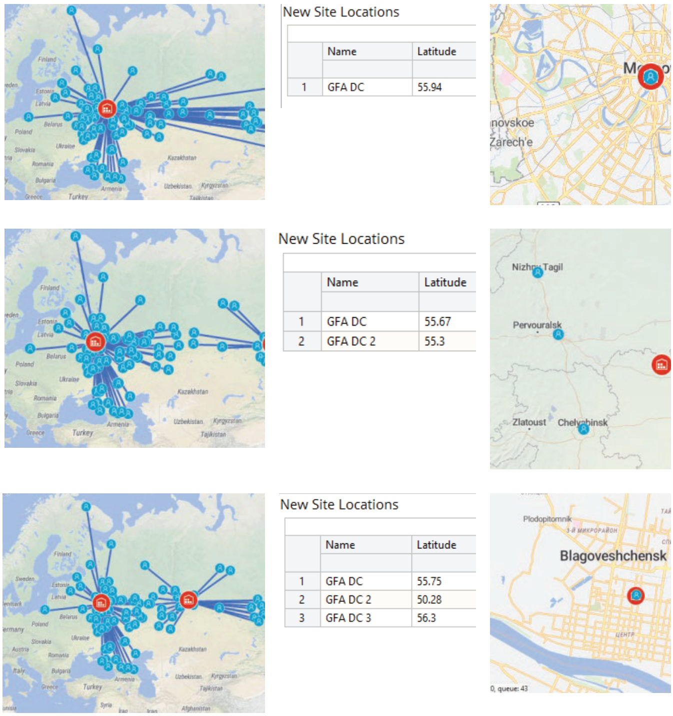
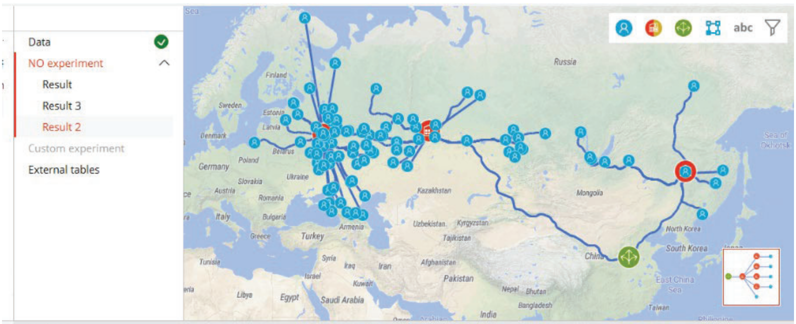


Figure 6-16. Outcome of greenfield analysis experiments.

On the whole, the locations of three warehouses correspond to Moscow, Blagoveshchensk and a place between the cities of Tyumen, Kurgan, Chelyabinsk and Pervouralsk (Figure 6-16). It should be noted that GFA did not take into account roads, cities, peculiarities of geographical areas, etc., which is why after the experiments their locations were double-checked. For example, the best suggested location for the first distribution centre (DC) was near to the central Kremlin square in Moscow. Its location was manually shifted out of the city centre to a place behind the third Ring Road in Moscow.

In the next step of the analysis, additional data were added, such as revenue, outbound processing costs as well as the location of the source in China (Zhengzhou). This source was connected to the three identified warehousing sites; therefore, the additional transportation costs were considered (i.e., supply costs) based on roads that are actually available. The optimal number of chosen sites to process the production flows was found on the grounds of the network optimization experiment in Anylogistix. According to Figure 6-17, profits will be generated in the case of using all of the warehousing sites. The use of only two locations for warehousing sites results in losses.

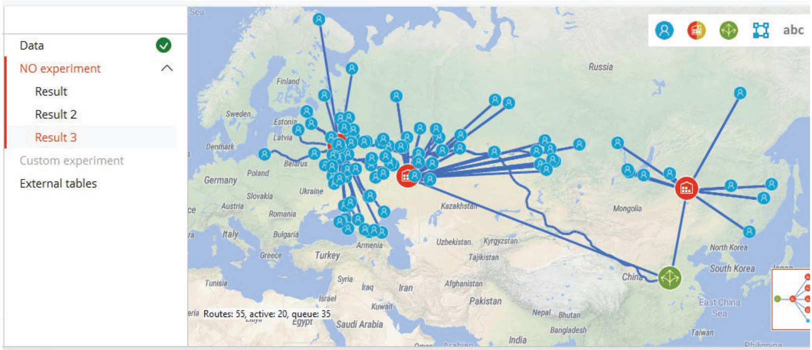


#	Sites	Profit (NetOpt)	Flows Amount
1	Iteration 1: GFA DC, GFA DC 2, GFA DC 3	194,911,104,014.483	8,911,007,070
2	Iteration 2: GFA DC 2, GFA DC 3	-14,979,424,915,123.555	2,853,447,944
3	Iteration 3: GFA DC, GFA DC 3	-1,417,382,585,941.369	8,293,082,510
4	Iteration 4: GFA DC, GFA DC 2	-5,490,887,965,906.109	6,675,483,686
5	Iteration 5: GFA DC 3	-16,591,718,605,079.406	2,235,523,384

Figure 6-17. Outcome of the network optimization experiment, considering the optimal number of sites for warehouses named as GFA DC, GFA DC2 and GFA DC3.

The final step of the network optimization experiment was related to the evaluation of other potential locations for warehouses. Assuming that bonded warehouses should be positioned close to the Russian border with China, new alternative sites were added to the map (Ussurisk, Zabaikalsk for serving the GFA DC 2 group of 11 customers; and Pervomaisk, Novosibirsk for serving the GFA DC 3 group of 26 customers). The alternatives for Moscow (GFA DC), serving the largest group of customers

(63) were not set. The results of the optimization experiment showed that the network of warehouses should consist of sites located in Moscow, Novosibirsk and Zabaikalsk (Figure 6-18).



#	Sites	Profit (NetOpt)	Flows Amount
1	Iteration 1: GFA DC, Ussur, Pervomaisk	-7,103,181,655,861.961	6,057,559,126
2	Iteration 2: GFA DC, Zabaikalsk, Pervomaisk	110,394,755,731.021	8,911,007,070
3	Iteration 3: Zabaikalsk, Pervomaisk	-15,063,941,263,407.016	2,853,447,944
4	Iteration 4: GFA DC, Zabaikalsk, Novosibirsk	214,008,113,218.503	8,911,007,070
5	Iteration 5: Zabaikalsk, Novosibirsk	-14,960,327,905,919.535	2,853,447,944

Figure 6-18. Outcome of the network optimization experiment, considering the optimal number of sites for warehouses named as GFA DC, Novosibirsk, Zabaikalsk, Pervomaisk, and Ussurisk.

The positioning of warehouses in Moscow, Zabaikalsk and Pervomaisk in terms of financial benefits is less advantageous among all the alternatives, including those considered in the first optimization experiment (Figure 6-17). Now, it is worth summarizing the findings. By the greenfield analysis, the best location of warehouses for serving the demand, proportional to the density of the population in Russian regions, has been identified based on the principle of minimization of total transport costs. The potential number of customers was set to 100, and transportation costs were calculated propositional to the distance between warehouses and customers, and their demand. The outcome of GFA experiments showed that the best locations of three warehouses correspond to Moscow, Blagoveshchensk and the place between the cities of Tyumen, Kurgan, Chelyabinsk and Pervouralsk (Figure 6-16). However, in GFA, the roads, cities, and peculiarities of geographical areas were not taken into account. Therefore, further analysis was done in the framework of network optimization experiments, in which the optimal quantity of facilities with the allowance of the actual roads was identified. The number of warehouses was chosen based on the principle of profit maximization. This is why additional parameters were set, such as revenues, outbound processing costs as well as the location of the source of products in China (Zhengzhou). In this regard, the supply costs for delivering the products from the site in China to the alternative warehousing sites in Russia were also considered. The potential sites for warehouses have finally been identified on the map (two are close to the Russia-China border, Novosibirsk and Zabaikalsk, and one is in Moscow; Figure 6-18).

In the examples below, different operational tasks that arise after the implementation phase of the construction project will be considered. Their management can also be carried out with the help of simulation modelling. One of the most important aspects in the logistics system is related to the maintenance of inventories at a level that ensures the uninterrupted supply of all participants with the necessary material resources or final products with allowances for the balance “cost/service”.

On the whole, inventories are essential for different companies due to various reasons; that is, the stochastic demands on material resources; imbalanced demand and production capacities; long distances between suppliers and customers; low reliability of deliveries; and speculative intentions and inflation expectations. Thus, the functions of inventory are objective (Lukinskiy et al., 2016a). First of all, inventories allow the increasing efficiency of production systems, specifically, stocks allow the reduction or elimination of the downtime of the process equipment. Secondly, stocks ensure the uninterrupted service to consumers, in particular, stocks can compensate for seasonal and random fluctuations in demand. Thirdly, stocks can serve the investment function: stock levels allow the maintenance and even an increase in the amount of cash resources of the companies under favourable market conditions, when the value of stocks may grow faster than the bank interest on the company’s deposits.

Therefore, inventory is one of the most expensive and important current asset items for many companies (Wood and Horner, 2010). Managers have long recognized that good inventory control is crucial. Inventory management implies a closed loop structure, encapsulating four stages:

1. Planning on what inventory to stock and how to acquire it;
2. Forecasting of components/product demand;
3. Controlling inventory levels;
4. Feedback measurements to revise plans and forecasts.

Inventory management should be seen from the systems point of view. The process of inventory management includes different levels. Firstly, phase one will be discussed. This stage is about the strategic level of inventory management that requires the settlement of goals, tasks and analysis of nomenclature or assortment of the inventories. It is essential since it can help to define the right controlling inventory policies and levels depending on the specific characteristics of items in the inventory. The structure or assortment analysis can be based on different methods: that is, ABC, FSN, and XYZ analysis (Devarajan and Jayamohan, 2016; Lukinskiy et al, 2016a; Scholz-Reiter et al., 2012). In ABC analysis, inventory items are divided into three groups following the Pareto principle (an Italian philosopher and economist). Criteria for the classification can be the volume of the sold items, the income received from them, margin levels, and sales volume. However, it is not the only metric that weighs the importance of an item. Also, the impact of a stock-out onto the business of the client should influence the inventory strategy.

According to the Pareto principle, 20 per cent of the items that make slightly above 80 per cent of the sales volume can be included in category “A”. The level of the sales volume or income that makes up 6 average levels (AL) and more (<AL*6) should be included in group “A”. If the level is twofold lower than average (>AL/2), then this type of goods should be included in group “C”, and the rest of the cargoes should be related to category “B”.

How is the XYZ-category determined for materials? Class X materials deviate by up to 10% of the average or a coefficient of deviation <0.5. Class Y materials deviate by 10~25% (or the coefficient of variation equals 0.5<CV<1). Everything above 25%, or when the CV is >1, is considered to be a sporadic demand that belongs to Class Z materials (Scholz-Reiter et al., 2012). In inventory management, groups of cargo can be consolidated in the groups combined from both methods (Table 6-3).

Table 6-3. The classification matrix of ABC-XYZ analysis.

AX	AY	AZ
BX	BY	BZ
CX	CY	CZ

Various approaches to inventory management should be used for the different types of cargo. Specifically, group A has a significant part (80%) of funds bound in stock (or this group accounts for a large share of the profits or other metrics on the basis of which analysis was conducted). For example, for the items included in the AX group it is advisable to find an optimum size of order and consider the application of the just-in-time principle that decreases inventory levels to the bare minimum without even the provision of safety stock levels with frequent delivery cycles, because the volumes of sales of these items are relatively stable over time. While AZ groups would require frequent control policies (checking the inventory levels every day) along with high safety stock levels due to the sporadic demand of products in the Z category.

For CX, CY, and CZ groups, there is no need for strict and tight inventory control policies. The inventory levels in the warehouse can be checked (that is, control reports) every month or every four months (quarterly), with a delivery cycle of six months; these principles are determined by the fact that these reserves “freeze” a relatively small part of the funds, because fluctuations in demand for these positions are significant. Therefore, the control effort is minimal compared to the first AX group, where the control effort is at the maximum level.

In inventory management, apart from strategic tasks (setting goals, forecasting demand as well as providing ABC-XYZ analysis of inventory nomenclature) that belong to the first and second stages of inventory management, there are tasks at the tactical level. These include choosing the inventory control policy, which implies the calculation of the parameters of the considered inventory management strategy. Examples of these parameters would be economic order quantity levels, the maximum and minimum levels of stocks in the warehouse as well as safety stock level computations, and also setting normative service levels of servicing clients. The parameters prescribed at the tactical level can be used as the referenced ones for the next operational levels of inventory management. In other words, the actual results computed on the grounds of the existing operations can be compared to the normative levels defined at the tactical level.

The fourth phase of the inventory management process can be associated with the operational level. It is based on the analysis of the balance sheets, accounting for the movement of inventory operations (income, consumption, and balance levels) from the records of the orders issued. Additionally, calculations of the economic parameters are provided, such as gross profits, gross margin return on inventory, the cost of goods sold, sales revenue, etc. In general, profitability measurements are assessed during this phase, after which the inventory control strategies and systems can be re-engineered or corrected in relation to the current environment or identified problems.

So, further on, we will look at different levels of inventory management practices (strategic, tactical, and operational levels). These levels formulated the closed-loop structure of this process, which in turn helps to improve the effectiveness of companies. In particular, for example, according to Professor Lukinskiy in St. Petersburg, who is famous in Russia in the logistics and supply chain management sphere, the application of the existing theory of inventory management has led to financial benefits for many companies: manufacturing, fast food chains, and trading companies. The companies are diverse, because the inventories are represented by different types. Examples would be manufacturing inventories that include buffer stocks, safety stocks, and merchandise stocks, which in turn can be divided into distribution inventories, belonging to wholesalers and trade inventories of retailers. Other types can be seasonal inventory, speculative stock, work in process, finished goods, or even dead stock, raw materials and so on.

In order to make a decision on choice or re-engineering for the improvement of the existing inventory management policies, it is essential to start from the analysis of the inventory reports, balance sheets, and economic indicators; that is, the operational level of inventory management. Indicators of the efficiency of inventory management policies include such parameters as *average and average weighted level of inventory, provision of stocks in days, stock out level, and duration of inventory turnover* (Lukinskiy et al., 2016a). It should be noted that an acceptable value of stockouts is up to 5%, however, in any case, the stockouts indicate the shortcomings and errors in inventory management policies.

On the whole, indicators/metrics of the average and average weighted level of inventory or stockouts, the provision of stocks in days, constitute the group of indicators showing the availability or provision of inventories in the company. The general metrics, the amount of money spent on inventory management or the level of service would be included. The level of service can be found by the ratio: the number of performed orders from a total number of orders multiplied by 100%. The level of service at 95%, means that in 95 cases out of 100, the needs of the clients in terms of material resources can be met by the inventories on hand. The other 5 cases represent a risk of stockout.

The next group of indicators shows the efficiency of inventory usage. These are the *stock turnover, duration of stock turnover,* which can also be *deviations from the actual ordering cost from the normative ordering costs, and actual volumes of the inventories from the normative volumes.* The turnover can be calculated by two formulas. The first is the annual demand as the numerator and the average inventory as the denominator. The second is the cost of goods sold divided by the average inventory cost on hand (average inventory for the quarter or for the year).

It is generally accepted that the carrying costs alone represent approximately 25% of inventory value on hand. Inventory turnover is calculated as the cost of goods sold divided by the average inventory. If, for example, the values are respectively $250,000 and $25,000, then inventory turnover is 10. The duration of inventory turnover can be converted into days by dividing 365 by the inventory turnover measured in time: 365 by 10, which is 36.5. This means that inventory turns 10 times a year and is on hand for approximately 36 days. In other words, it takes 36 days to turn over an entire inventory in sales.

The norm of inventory turnover is the time in days that the company prescribes. It is a period during which the stock should be sold out so as to consider the sales as profitable. According to the estimates (Lukinskiy et al., 2016a), the average length of turnover for supermarkets varies depending on the type of item. If it belongs to category “C” then the duration of turnover in days is approximately 30 days. As a rule, the duration of turnover for category “A” is 10 days, and for category “B” it is 20 days. A low turnover implies weak sales and, therefore, excess inventory or inefficient work. A high ratio implies either strong sales and/or large discounts. The speed with which a company can sell inventory is a critical measure of business performance. In general, the authors think that the rate of inventory turnover should be 25-30 times per year for the companies to make a considerable profit (Lukinskiy et al., 2016a). The duration of turnover or the time within which the stock should be out is 12-15 days.

Apart from the two groups of indicators, the provision of inventories and efficiency of inventory usage, there is a third group of indicators. This is the metric of the *efficiency of investments in inventories* which includes the *cross profits in absolute and relative terms, in %, as well as gross margin return on investments (GMROI).* Since 60-80% of a typical retailer’s investment is tied into inventory, it therefore becomes essential for a retailer to know how much return he or she is getting on invested money in the inventory. GMROI should provide quick feedback to assess how many gross margin dollars are earned on every dollar of inventory investment. It is calculated based on the ratio: gross profit to the average inventory on hand. Gross profit, in turn, can be found by subtracting the cost of goods sold (COGS) from the sales revenue.

If the company has a GMROI of 0.75, it earns revenues of 75% of its costs and has an unfavourable GMROI. Another metric, similar to the GMROI, is the Turn/Earn index (*T/E Index*) which can help to balance turnover and profits. It is calculated by multiplying inventory turns with the gross margin percentage. The higher the T/E Index, the better. It highlights situations where high margins can compensate for low inventory turns. For example, if turnover of the inventory of an item is four times a year, and it earns on average a 30% gross margin, it will result in a T/E Index of 120. It is possible to get the same return on investment value, if turning the inventory of an item only occurs twice, but it makes an average gross margin of 60% on every sale (Schreibfeder, 2013).

On the grounds of the performed analysis, the other critical tasks of inventory management can be solved. These tasks are related to the tactical level, and concern first and foremost:

1) Defining the optimal level of reserves of material resources, and its main components:
    a) Base stocks or cycle stocks, which comprise the main part of the manufacturing and trade stocks, and are considered as dynamic, and provide the continuous production process and formulate the sales of finished products between the two orders;
    b) Safety stocks;
    c) Buffer stocks – the stocks in the preparation of the product for shipment to the buyer or to the release into production (continuity, regularity and the rhythm of production processes).
2) Organization of the control of principal stocks (including the timing for stock reports – quarterly, monthly or weekly) and their timely replenishment of the inventory levels.
3) Determining the optimum size of the order for the replenishment of stock levels as well as rational replenishment periodicity (this was discussed previously, concerning different specifications; for group C, it is the 6-month delivery cycle, three months for products of category B and weekly for category A).

One of the complicated tasks is related to the computation of the economic order quantity, EOQ (optimal size of the order). The formulas for defining the EOQ are diverse and were firstly defined by Harris (1913)/Wilson (1934):

$$EOQ = \sqrt{\frac{2 * D * Co}{C_h}}$$

D stands for the demand or annual consumption depending on the annual (demand) of production (e.g. 4000 units/year). C_o is the cost of ordering or purchasing one lot (placing an order, receiving an order from suppliers, inspecting the parts and putting them on the shelf), e.g., 10 rubles/lot; C_h is the costs associated with the holding of stocks (the cost of the inventory holding, including the cost of obsolescence, cost of insurance, damage, pilferage, handling and so on), e.g., 2 rubles/item. So, if all of this is put into the equation, Q = 200 units. The number of orders then, would be 4000/200 = 20. This means that the order will be placed 20 times during the year and 200 units will be received at a time. The replenishment periodicity (the time between two orders) can be found by dividing the total number of days 365, or working days at 260 per year, or 52 weeks, by 20 (e.g., 365/20 = 18 days or 2.6 weeks). So, by delivering the lot size of 200 units, the total costs (TC) will be at the minimum level:

$$TC = \frac{Q}{2} C_h + \frac{D}{Q} C_o$$

If assuming another lot size, the costs would be higher (Figure 6-19).

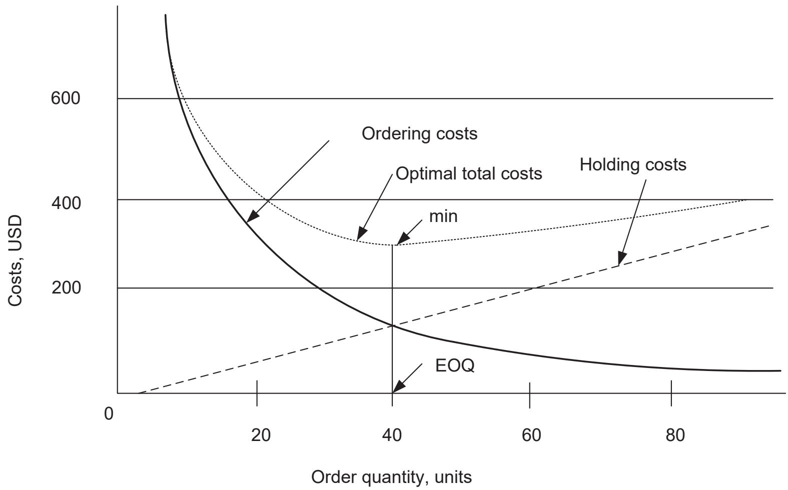


Figure 6-19. Relation between logistics costs and order quantity.

In order to visualize the EOQ model, simulation modelling in AnyLogic can be used (Ivanov, 2016). All of the models below have been built based on guidance from the book by Ivanov (2016). The following parameters were set (Demand and Order Quantity) as well as variables, the Inventory Level, and event, Ordering, describing the principle of change in the inventory level (e.g., once a day, Figure 6-20). According to the EOQ model, change in inventories is a linear function of demand. As a result of the simulation, a clear picture of change in the current inventory levels in the warehouse was obtained (Figure 6-20).

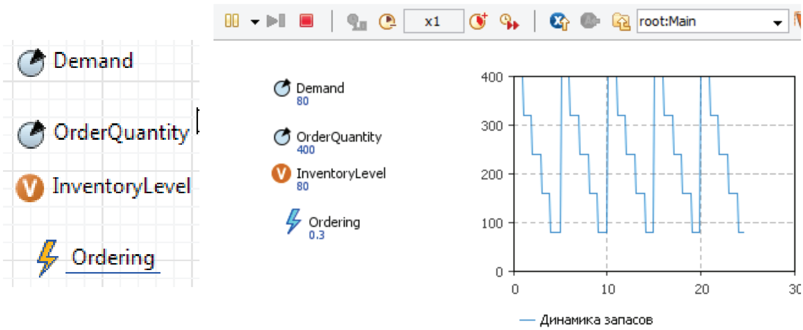


Figure 6-20. Dynamics of inventory levels.

According to the specified parameters, demand was equal to 80 units, the size of the order (q) = 400 units, and the duration of the simulation was set to 30 days. As shown in the graphic, at the beginning of the fourth day, the inventory level was equal to 80, on the fifth day, in order to avoid a deficit, an instantaneous replenishment of order quantity, 400 units, was provided (Figure 6-20).

The formula for identifying the EOQ is very simple and straightforward, but problems may arise in companies when they define their holding and purchasing cost of inventory. EOQ model assumptions are the following:

- Only one product is involved;
- Annual demand requirements are known;
- Demand is even throughout the year;
- Lead time does not vary;
- Each order is received in a single delivery;
- There are no quantity discounts;
- Replenishment is simultaneous;

- There is only one type of stock considered (that is, the cyclic stock, without taking into account the safety, buffer stocks and so on).

At the same time, most practical situations differ from the ideal scheme; since in reality, there is the uncertainty caused by various reasons, mostly the random nature of demand and the replenishment cycle. The randomness of the main supply and demand parameters, as well as logistical risks, are reasons for having safety stock (Figure 6-21).

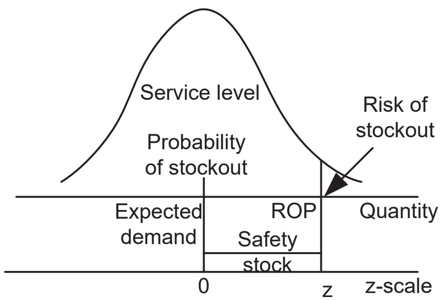


Figure 6-21. Safety stock.

The stockout can bring one of the significant costs of companies:

- ***Holding (carrying) costs***: cost to carry an item in inventory for a length of time, usually a year;
- ***Ordering costs***: costs of ordering and receiving inventory;
- ***Shortage costs***: costs when demand exceeds supply.

Due to the probabilistic nature of the environment, the ideal formula for calculating the order size and the time between two orders defined by Harris/Wilson cannot be used everywhere, since it has limitations. It requires modifications. For example, one option is to consider in the Q computation, not the mean demand, but e.g., d = 2 000/365 = 6 (d_{mean}) + standard deviation (σ_d), e.g., 2 units, thus the EOQ model would include the demand of 8*365 = 2920 units. It is also essential to consider the safety stock, which can be found by the formula of Fetter:

$$SS = z * \sigma_{dLT},$$

where z is the number of standard deviations and sigma stands for the standard deviation of demand during the lead time. The lead time is the time interval between ordering and receiving the order (Figure 6-22).

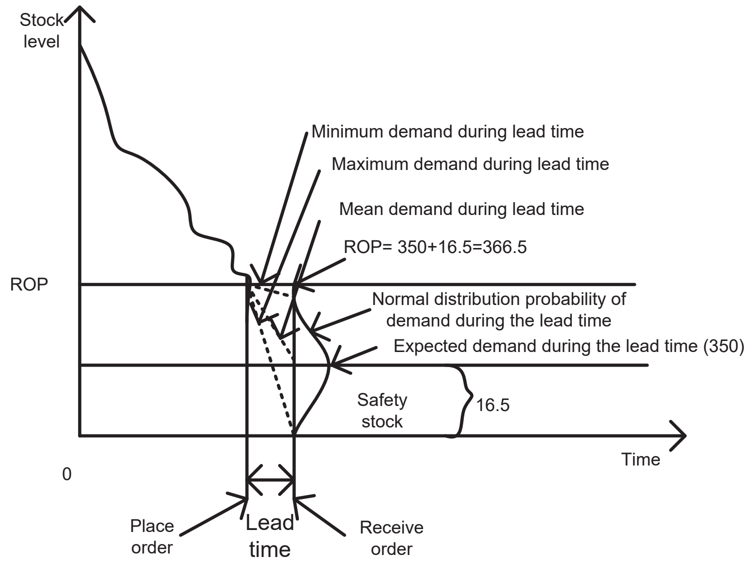


Figure 6-22. Probabilistic nature of the demand considered in inventory management.

The SS is included in the formulas of the reorder point (ROP), which are described below in the text. In the given example of Figure 6-22, it is assumed that demand is variable and the lead time is constant. However, when the lead time is variable, then, the standard deviation of the lead time should be taken into the formula, as shown in the forthcoming text, to define the correct value of ROP. When both demand and lead time are variables, then, two standard deviations, respectively, are encapsulated into the formula.

The z value can easily be determined from the table of normal distribution. It should be noted that the higher the service level that a company wants to provide to the clients, the larger the stock level should be. In particular, in the table of normal distribution, the higher level of service corresponds to a higher level of the z value. The calculations of SS can vary for different conditions: when demand is variable and the lead time is constant, or when daily demand is constant and the lead time is variable or when both demand and lead time are variable (Lukinskiy et al., 2016a). In the last case, the safety stock will have larger values, which is natural. Higher volumes of inventories are required to mitigate stochastic or uncertain demand and lead time.

It should be noted that studies in the UK showed that in the price of the product delivered to the final consumer, more than 70% of the prime cost is related to the costs of storage, transportation, packaging and other operations. Therefore, by reducing the prime cost, companies can make the prices of the products more competitive. Thus, by optimizing the size of the replenishment order, the costs can be reduced.

But identifying the right order quantity is not a standalone task and depends on different strategies of inventory management. The development of inventory management strategies foresees the continuous supply of the consumer by the material resources, raw materials or finished products through the implementation of an inventory control system to maintain the stock size in the required limits. Experts identify the following three groups of inventory management strategies/policies (Lukinskiy et al., 2016a; Ivanov, 2016): a) Periodic strategies, b) Strategies with the order point, and c) Combined strategies. The first two groups were described in the book by Ivanov (2016), while the third group was discussed in the book of Lukinskiy et al. (2016a). However, these issues were also discussed long ago in the book of Tersine (1985).

Periodic strategies (t, q; t, S) imply that the order for replenishment is done in a certain, pre-set time (the period between orders – is a constant). Monitoring the level of stocks in the warehouse is carried out only at the time of placing the order. In the (t, q) strategy, the order is the same and the time between orders is constant. Therefore, it is sufficient to define the EOQ and replenishment periodicity by dividing 365 by the number of orders.

In the second periodic strategy (t, S), the time between replenishments is constant, while the order size is variable, which can be found by subtraction from the maximum size of the target inventory level of the inventory at the time of placing the order. The maximum inventory equals the cyclic stock plus (+) a safety stock. The cyclic stock can be found by multiplying the replenishment periodicity (the time between two orders), say 12 days, by the daily demand, which is 8 units, resulting in the cyclic stock of 12 * 8 = 96. Safety stock can be found by the Fetter formula (z * the standard deviation of the demand during the lead time, e.g., 23). Therefore, the maximum stock (MS) would be 96 + 23 = 119 units. Instead of the EOQ, in the (t, S) strategy, the order size should be found as MS - Stock on the balance during the time of placing the order (SONB, e.g., 98). If the order is replenished simultaneously, in other words, there is no lag between the ordering and procuring of materials, then this formula is final (MS - SONB). If the lead time is included or considered in the model, then the order size has to be enlarged by the demand during the lead time (e.g., 3 days): Order size = 119 – 96 + 8 * 3 = 47 units. These strategies are useful when the schedules for making the orders are prescribed and when demand is more or less stable. Meanwhile, when the demand is variable it is better to use strategies with an order point.

In inventory management strategies with an order point (s, q; s, S), the order is made when a stock reaches a certain level or reorder point (ROP), which is a constant. The value of the ROP can be calculated by three different formulas, depending on the characteristics of the demand and lead time, whether they are variable or not (Lukinskiy et al., 2016b; Ivanov, 2016; King, 2011).

When demand is variable and lead time is constant:

$$ROP = d \times L + x \times \sigma_C \times \sqrt{L} \quad .$$

When daily demand is constant, while lead time is variable:

$$ROP = d \times L + x \times \sigma_C \times \sigma_{в} \quad .$$

Both demand and lead time are variables:

$$ROP = d \times L + x\sqrt{L \times \sigma_C^2 + d^2 \times \sigma_{в}^2} \quad .$$

The inventories at the warehouse are monitored continuously (t, q; t, S). For the left-hand strategy, the order size is constant and can be defined by the formula of Harris/Wilson. In the right-hand strategy, the order size is not constant and can be calculated by the same formula as in the (t, S) periodic strategy. If the order is replenished simultaneously, in other words, if there is no lag between the ordering and procuring of materials, then this formula is final (MS - SONB). If the lead time is included or considered in the model, then the order size has to be enlarged by the demand during the lead time. And if demand is not constant, in the order size, the additional parameters should be taken into account: (demand + standard deviation of demand) × lead time. The order size is then: 119 – 96 = 23 + (8+2) × 3 = 53.

This strategy can be modelled with the Anylogic program. To set the variable values of demand and lead time, additional parameters have been added to the previously described model (Figure 6-20). By doing so, the classical inventory management strategy (t, q) was transformed into a strategy with an order point. Therefore, instead of the code InventoryLevel + = OrderQuantity; in the cyclic event, the new law code describing the random variable distribution was written. Additionally, the code which determines the replenishment principle by an order point, was set.

The adjusted model thus reflected the inventory management strategy (s, q), where the time between the change of inventory levels is 5 days, the order point was set to 240 units, and the lead time (without deviation) was 3 days (Figure 6-23). The model also gained several parameters and variables, which helped to analyze the inventory management system: Holding Cost (0.1 USD per day per unit), Ordering Cost (10 USD for one order), and Stockout Costs (0.5 USD per unit). The effect gained from the applied inventory management strategy was estimated by the use of additional parameters – Service Level, Total Sales, and Retail Shortage. The accounting of cost was carried out by a new cyclic event, Costs Update. The costs associated with the storage of inventory were calculated according to the average level of inventory (Inventory Level/2) through the cyclical event, Costs Update. At the same time, the costs associated with a deficit were calculated through the second event, StockOut. The results were updated at the end of the calculation period, i.e., on the 29th day. To reflect the level of service and the level of the deficit, additional time plots were used (Figure 6-23).

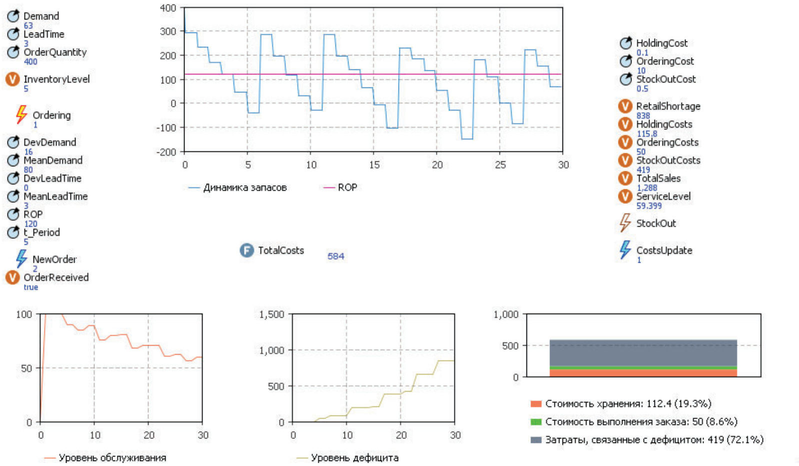


Figure 6-23. Output of the model describing the (s, q) – inventory management strategy.

In accordance with the output of the model, the total costs amounted to 584 USD, while the service level by the end of the model time equalled 59.4% with the level of the deficit at 838 units. In order to improve the output of the model, the safety stock was calculated and introduced as the parameter of the model. Based on the table with a cumulative normal distribution (when z >0) for a given z, the value of the service level can be determined. According to this table, the service level of 95% corresponds to z = 1.65, while for the value of 99%, z = 2.33. Further on, this value was applied to the formula of the ROP, when daily demand is constant, while the lead time is variable: ROP = 80 + 3 × 1.65 ×18×√3 = 240 + 52 = 292 units, where 52 units are the amount of safety stock. The amount of the EOQ was found by the Harris/Wilson formula:

$$Q=\sqrt{\frac{2\times 2400\times 10}{3}}=127\times 3=381\ \ units.$$

where 2400 (80*30) is the demand during the month (model time), 10 is the ordering cost, including the cost of transportation (e.g., rubles/unit), and 3 is the holding cost, rubles/unit. By setting in the model, which describes the (s, q) – inventory management strategy, the value of the EOQ (381 units) and the ROP (292 units), its output improved. The overall costs reduced to 431 USD compared to the first experiment (584 USD). The level of service also increased from 59.4% to 95% at the end of the month; and the goods deficit decreased from 838 units to 103 units. To avoid cases of deficit in the EOQ model, the deviation of the demand (80 +18 = 98) can be taken into account:

$$Q = \sqrt{\frac{2 \times 2940 \times 10}{3}} = 140 \times 3 = 420 \ \ units.$$

By setting this value in the model, the deficit became zero, and the costs were reduced to 420 USD.

Finally, the combined strategies of inventory management will be described (t, s_S: t+ROP; t, s_S: t&ROP; t, s_S: t or ROP). In these strategies, the order is made with the allowance of two criteria; that is, the period between orders and the ROP. In the first combined strategy (t, s_S: t+ROP), the order size is variable and calculated similarly to (t, S or s, S) strategies. Meanwhile, the order is made at the pre-set period only when the ROP is reached. For example, if the inventory level does not reach the minimum level or the so-called ROP at the pre-set period, the order is not made. The orders are made only when the pre-set time is matched with the level of inventory, which is lower than the ROP. This strategy helps to optimize the number of orders in situations when demand is decreased. In the second inventory management strategy (t, s_S: t&ROP), the order size is also variable, and the order is made when the inventory level reaches the ROP and the order is also made during pre-set time periods. This strategy allows the avoidance of stockouts in situations when the demand increases significantly. In the 3rd combined strategy (t, s_S: t or ROP), the order is made either in the pre-set time or when the ROP is reached. For example, the order should not be placed, if the order was recently received due to the alternative rule, e.g., when the level of the inventory became lower than the ROP, and vice versa. So, in order to define which strategy is better, a comparative analysis should be provided based on the mentioned former indications from the operational and tactical level; that is, the level of stockouts, the average inventory level, and the total costs associated with each strategy. This analysis was done in sub-chapter 5.4.

6.4. Manpower and resource control policies

The role of manpower is very important in inventory control policies as well as in other spheres of logistics and supply chain management. Nowadays, the top management of a company can no longer guarantee a company's success, therefore it is necessary to have a team of competent associates. In connection with this, the basis of a logistics business and each company is its personnel potential that should not only meet modern requirements, but also constantly evolve as the external environment changes. Skilled personnel should be advanced so the process of development and improvement of logistics is not disrupted or slowed down. The position of a logistician is honourable and useful, and, at the same time, implies a high level of responsibility. The reason behind this is that the logistician is a specialist who plans, organizes and coordinates the efficient and effective movement of goods, services and related information from the point of origin to the point of destination of the final consumer for the purpose of meeting customer requirements at an acceptable and competitive price. It is becoming increasingly difficult to find competent professionals in the field of logistics, despite the fact that training is conducted both on the basis of universities and business schools, and as corporate training (Panova and Shishkina, 2015).

For example, in Russia, especially in the north-west region, labour market needs in the field of logistics and procurement were 10 times higher than the number of graduates from the profiled universities (Lukinskiy and Noskova, 2013). The reason is understandable as the education of logisticians in Russia was started in universities relatively recently, during the year 2000. Since that time, education in the specialty of "Logistics and Supply Chain Management" was initiated in more than 40 technical universities (Vende, 2015). In the beginning, there were only seven leading economic universities of Russia, including St. Petersburg State Engineering and Economic University and St. Petersburg State University of Economics and Finance.

Changing the standard of education in Russia has created conditions for the formation of the bachelor and master degree levels of high professional education in compliance with the European educational space. Nowadays, there are three levels in universities: the first level is the bachelor degree programs, the second is the specialist and master degree programs, and the third is postgraduate studies (State Duma, 2012). Thus, specialists and masters ceased to be a full professional higher education, while the concept of "post-doctoral research" started to belong to the science sphere (Table 6-4).

Table 6-4. Descriptors defining levels in the European Qualifications Framework (EQF) in correspondence with the Russian Education system. Sources: State Duma (2012); Ec.europa.eu (2015)

Level	Qualification (in the EQR called knowledge)	Number of Years to Study	Former Russian Education System	Market-oriented Education System	Skills	Competence
6	Knowledge in an advanced mode in a field of learning, knowledge of methods and principles and critical reflection (Bachelor)	1 2 3 4	Specialty (engineer-logistici-an)	Knowledge in an advanced mode in a field of learning, knowledge of methods and principles and critical reflection (Bachelor)	Advanced skills, demonstrating mastery and innovation, required to solve complex and unpredictable problems in a specialized field of work or study	Manage complex technical or professional activities or projects, taking responsibility for decision-making in unpredictable work or study contexts Take responsibility for managing the professional development of individuals and groups

7	Highly specialized knowledge in a field of learning. Knowledge in new insights and academic research (Master)	5		Highly specialized knowledge in a field of learning. Knowledge in new insights and academicals research (Master)	Specialized problem-solving skills required in research and/or innovation in order to develop new knowledge and procedures and to integrate knowledge from different fields	Manage and transform work or study contexts that are complex, unpredictable and require new strategic approaches Take responsibility for contributing to professional knowledge and practice and/or for reviewing the strategic performance of teams
		6	Postgraduate studies (candidate of technical sciences or PhD)			
	(Master of Business Administra-tion)	7		(Master of Business Administration)		
		8				
8	Knowledge in a field of learning on the highest level (PhD)	9	Postdoctoral research (Doctor of technical sciences)	Postgraduate studies (candidate of technical sciences or PhD)	The most advanced and specialized skills and techniques, including synthesis and evaluation, required to solve critical problems in research and/or innovation and to extend and redefine existing knowledge or professional practice	Demonstrate substantial authority, innovation, autonomy, scholarly and professional integrity and sustained commitment to the development of new ideas or processes at the forefront of work or study contexts including research
		10				
		11				

The hierarchical levels of education (Table 6-4) can easily correspond with the hierarchy of organizational management levels (Wünsche et al., 2014). A set of qualifications, skills and competencies described in Table 6-4 could stand behind each management level. The European Qualifications Framework assists in allocating specific skills and competencies to a position on a particular management level (Wünsche et al., 2014). For example, EFQ level 8 and partly level 7 (Table 6-4) are associated with positions at a top-management level, since the level of top-management decisions requires insights and specialized knowledge in different areas as well as authority and accountability. Therefore, the highest top-level management is represented by the top managers, who are responsible for making critical and strategic decisions that determine the development of the entire company. At university, top-management positions are represented by the rector, the president of the university, and the vice-rectors.

The upper management level (also EFQ level 7 and partly level 8; Table 6-4) contains the head executives of major business units (i.e., departments, units or divisions). They are responsible for the practical implementation of the strategic plans developed by the top-management level. The role of the upper management level in the development of companies is extremely high. Typical positions of upper managers are represented by the directors of major departments; at the plant – department heads; in commercial networks – the director of stores; and in hospitals – the deputy chief of physicians. At universities, deans could be partly considered as the representatives of the upper management level, despite the fact that officially they are related to the teaching staff (Ministry of Health and Social Development of the Russian Federation, 2011).

At universities, the lower management level (EFQ levels 6 and 7; Table 6-4) could be associated with the head of a department, provided that officially the head of a department is also regarded as teaching staff (Ministry of Health and Social Development of the Russian Federation, 2011). A particular characteristic of this level of management is that managers themselves often have to perform a variety of production tasks, combining the functions of managers and executives.

It should be noted that the EFQ provides the only general competencies related to the different levels of education. Meanwhile, the skills expected of professionals in different spheres of the economy can vary significantly. However, in Russia, for example, standards that define basic professional competence in the field of logistics have not yet been introduced, while, in contrast, Belarus has already progressed so much in this direction, despite the fact that the teaching of logistics in universities started five years (2005) later than in Russia. In 2013, the decision of the State Standard of the Republic of Belarus № 61 was approved and put into effect as standard 2345-2013. It is called logistics activities – the requirements for the professional competence of the staff-performers of logistics services and certification procedure – and entered into force on 1 July, 2014 (Vernikovskaya, 2015). As professional standards for employees of the logistics area have yet to be enacted in Russia, the following research was conducted. Around 100 advertisements within the two most popular Russian sites for job seekers were analyzed for the period of one month to determine the expected generic competencies that are in demand in the Russian sphere of logistics (HeadHunter.ru, 2015; Rabota.ru, 2015).

The following conclusions can be made based on the analysis of competencies for the allocation of professional groups in the field of logistics. Professional experience, basic computer knowledge, and knowledge of a foreign language are more important competencies for a qualified person (logistics manager). A high learning ability and advanced knowledge in the field of information and communication technology (ICT) were more common for the position of an assistant logistician. Dispatcher-logisticians need to have, first of all, basic computer knowledge and professional experience. The highest, yet less popular position of a top manager in logistics requires all of the competencies mentioned above (e.g., professional experience, advanced knowledge in ICT, and knowledge of a foreign language), as well as the ability to conduct business negotiations and competently express their thoughts orally and in writing (Panova and Shishkina, 2015).

A similar study was carried out in Germany (Wünsche et al., 2014). The authors indicated that professional experience and a basic knowledge of computers are increasingly in demand for skilled workers in the field of logistics rather than for a specialist (a university degree or professional education or a professional education with experience and advanced training) and expert (a university degree). The scale of occupational categories reflects the classification by the GFLMA, which includes the expert, specialist, skilled worker, and unskilled worker (Wünsche et al., 2014). Also, very limited demand was identified for cross-cultural experience and the "flexibility of experts". The reason for such a finding, according to the authors, is hidden in the ethnocentric orientation of logistics companies, i.e., the management strategies of transnational corporations, in which the overall management of the corporation is the most concentrated in the headquarters of the company in the homeland.

On the whole, the requirements for logisticians in the modern labour market are defined by companies rather than standards that, as a rule, lag behind the forever and fast-changing business environment. Companies develop the competency model in terms of personnel design in manpower and resource control policy. The process of personal design in the company includes five steps (Aksenova, 2008):

1. Analysis of the mission and objectives of the company.
2. Analysis of the external environment and scenarios for the development of the situation.
3. Development of the organization's development strategy.
4. Specification of the organization's competencies.
5. Translation of the organization's competencies into the personnel competence model.

In the organization, the competencies can be assessed based on three types of methods:

- *Quantitative methods* that are the most objective, since all the results are recorded in numbers (rating, points).
- *Qualitative (descriptive) methods* that define employees without the use of quantitative indicators (e.g., matrix method; 360-degree method).
- *Combined methods*.

The assessed competences, in turn, are divided into three clusters:

1. *Corporate (general corporate, key) competencies* that can be applied to any position in the organization. Examples of such competencies would be Focus on results, Flexibility, and Responsibility.
2. *Managerial (managerial) competencies* that can be applied to a manager at any level who has a group of employees in line or functional subordination. Such competencies include Effective administration, Management potential, and Systems thinking.
3. *Professional (technical) competencies* for specialists of a group of specific positions or functions. An example of such competencies can be Knowledge of legislation, Skill of working with an electronic trading platform, etc.

Usually, the number of levels is from 3 to 4, and the total number of competencies in a model varies in companies, from 10 to 30. Their number is determined at the stage of developing a competency model. The more competencies that a model contains, the more difficult it is to implement in corporate practice. The model of competencies is included in *the Balanced Scorecard (BSC*; Kaplan and Norton, 2001). The BSC discloses a strategy of the company in the form of a set of strategic goals on the plan of four components: the internal business process, learning and growth, finances, and customers.

The basic principle of the BSC, which, in many respects, became the reason for the high efficiency of this control technology, is represented by the statement that “you can’t manage what you can’t measure”. At the level of business processes, the control of strategic activities is carried out through the so-called *Key Performance Indicators (KPIs).* A KPI is a measure of the attainability of goals as well as a characteristic of the effectiveness of business processes and the work of each individual employee. The place and role of assessment and development of competencies of employees in the organization's development strategy are shown in Figure 6-24 that was drawn in the lectures of the City Business School (E-mba.ru, 2018).

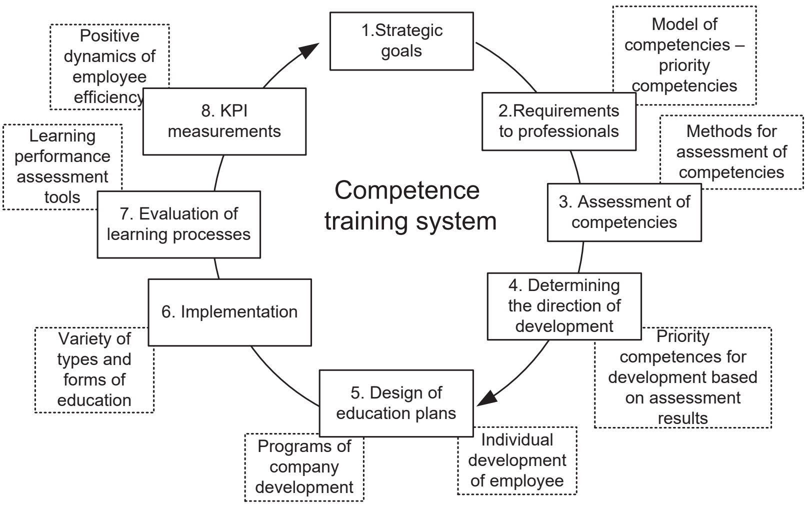


Figure 6-24. The interrelation of the assessment and development of competencies with key performance indicators and enterprise development strategy.

One of the examples of applying a competency model in a balanced scorecard would be the experience of the company MC-Bauchemie Muller Gmbh & Co. (MC), which was established in Germany in 1961 (E-mba.ru, 2018). The main activity of MC is the development, production and distribution of building materials. The mission of MC is expressed in the company's motto: “Innovations, competence and effectiveness”. With reference to the strategy of the company, the system of evaluation indicators was created in regard to the four main components of the BSC: competency, innovations, internal processes, and financial results. Corresponding to technological and employee competence, the indicators included employee qualification and employee training time as well as a number of sales with special solutions for consumers.

Management of the labour force requires special approaches, because manpower flows are significantly different from the financial, resource, service and information flows in logistics. The basis for human resource flows is people that can be characterized by a high level of self-organization. Therefore, logistics management can be less appropriate for manpower control in the organization. At the same time, the professionalism of employees influences the customer service level in the company. The provision of enterprises with labour resources, their rational use, and a high level of labour productivity are very important for the successful development of an enterprise, the growth of profits, reduction of the cost of services and improvement of a number of other economic indicators. In this regard, another case will be considered further on. This is the freight forwarding company Orbis, which consists of eight structural units with a total staff of 39 people. The distribution of workers in Orbis by structural units is presented in more detail, in Table 6-5.

Table 6-5. Distribution of workers of Orbis company by structural units.

Position	Structural subdivision	Number of staff	The proportion of staff employed in each of the structural units, %
General director	Administration	1	15.38
Director of Development	Administration	1	
Deputy CEO	Administration	2	
Assistant of General Director for External Relations	Administration	1	
Contract Inspector	Administration	1	
Chief Accountant	Accounting	1	10.26
Chief Accountant's assistant	Accounting	1	
Accountant	Accounting	2	
Forwarder	Forwarding	9	5.13
Senior freight forwarder	Forwarding	3	
Human resources department inspector	General	1	7.69
Director of Prospective Development	General	1	
Secretary-Assistant	General	1	
Head of Railway Transportation	Railway Transportation Department	1	2.56
Head of Multimodal Transportation Department	Multimodal Transportation Department	1	15.38
Deputy Head of Multimodal Transportation Department	Multimodal Transportation Department	1	
Logistics specialist	Multimodal Transportation Department	4	
Road Transport Specialist	Multimodal Transportation Department	1	

Position	Structural subdivision	Number of staff	The proportion of staff employed in each of the structural units, %
Specialist of Foreign Economic Activity	Multimodal Transportation Department	2	
System Administrator	Information and Technology Department	2	2.56
Economist	Commercial Department	1	5.13
Commercial Department Specialist	Commercial Department	1	
Total	-	39	100,00

After analyzing the data of Table 6-5, it can be seen that 12 people, i.e., 30.8% of the total staff, work in the freight forwarding department. This is necessary, because they are engaged in the registration of all of the certificates and permits relating to unloading cargo from vessels as well as controlling the unloading directly into the area, sealing cars and obtaining clearance passes in the port. From the presented Table 6-5, it is also clear that the administrative and managerial staff of Orbis company makes up 15.38% of the total number working in the enterprise, due to the need to process a large amount of information in the process of the company carrying out its activities, namely searching for and negotiating with potential customers and making relevant contracts and agreements, and the organization of joint activities with enterprises that provide the necessary services.

The Orbis company case study will be considered in terms of the improvement of the quality of customer services, partly based on training and staff development, which form one of the main positions in the balanced scorecard (Domaseva and Panova, 2015). The improvement of the quality of logistics services can be achieved by motivating employees, providing new, additional types of services, information, and technical support. This strategy was considered as part of the four dimensions: customer relationships, finances, business processes, training and staff development (Figure 6-25).

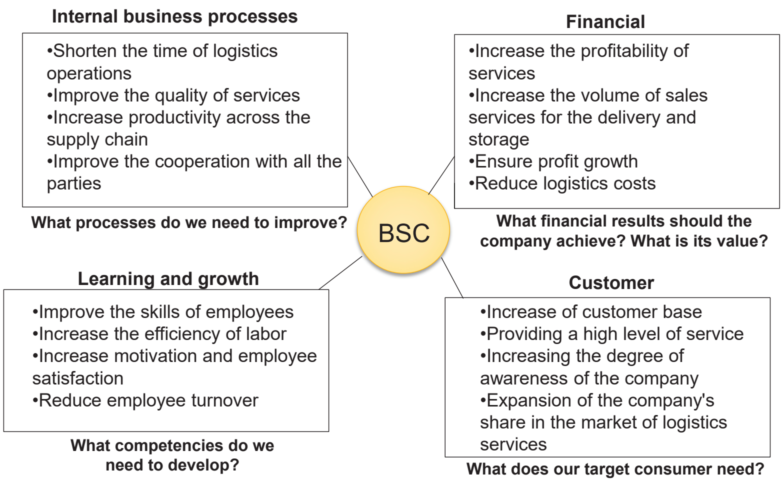


Figure 6-25. Strategic goals in the "4 perspectives" approach. Source (original; modified with questions): Domaseva and Panova (2015)

To judge the progress towards the goal presented in the four positions (customer relationships, finances, business processes, training and staff development, Figure 6-25), performance indicators have been considered for the manpower and internal process components of the BSC (Figure 6-26).

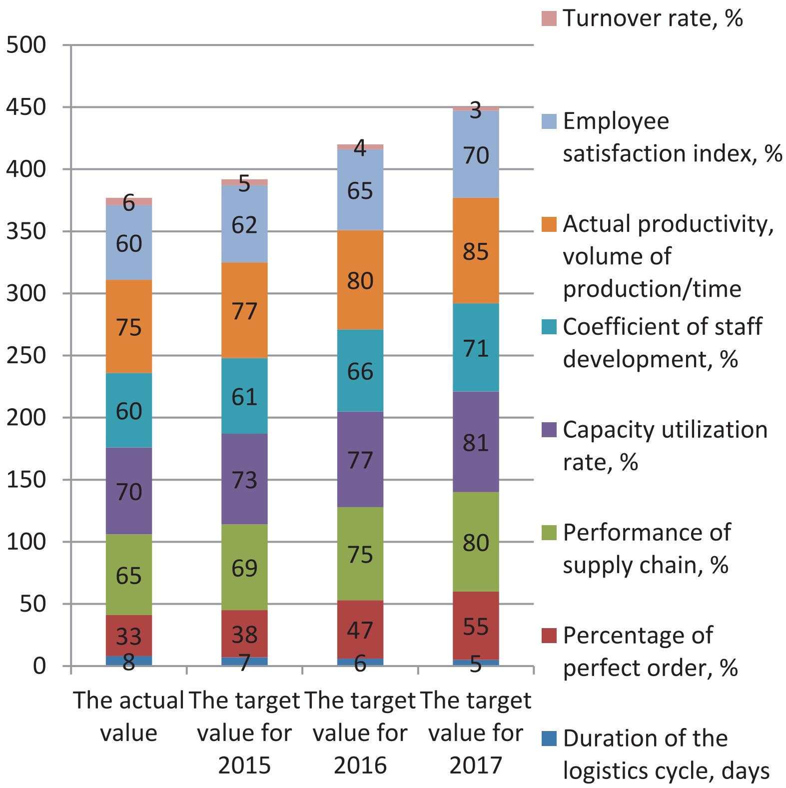


Figure 6-26. Key performance indicators for internal business processes, and the learning and growth perspective.

The strategic goals of the company (Figure 6-25) are closely related to the key performance indicators (Figure 6-26). Specific measures for the internal business processes and the learning and growth perspective, which are presented in Figure 6-26, are intended to progress the realization of the following strategic goals: reduction in the lead time of logistics operations;

improvement of the quality of services; increased productivity across the supply chain; development of the skills of employees; growth in the efficiency of labour; increased motivation and employee satisfaction; and and reduction of employee turnover. It should be noted that one of the critical success factors in the implementation of the company's strategy is the allocation of responsibilities in the achievement of the goals and targets (Table 6-6).

According to Table 6-6, planned activities related to the HR and staff training department, include the following activities: the development and application of a "social package" for employees, the organization of special courses, seminars earmarked for the education and training of employees; training personnel to work with new technologies and techniques; and a system of positive motivation (awards and praise). For the latter system, the experience of Sberbank could be taken into account. The new remuneration system in Sberbank was introduced at the beginning of 2011, and was the first step towards the unified and centralized material motivation of employees (Report-sberbank.ru, 2013). The basic philosophy of the new wage system is grounded on payment for results, not activity, and the encouragement of self-improvement, customer orientation, innovation, and teamwork. The two-tier system for evaluating individual results includes two levels:

- Level 1: Key performance indicators and priority projects.
- Level 2: System "5+" (a five-point scale of employee performance evaluation).

Table 6-6. Strategic actions.

Strategic goal	Strategic goal	The period for carrying out the action	Division, responsible for implementation
Internal business processes			
To reduce the length of the logistics cycle	The introduction of information technology to speed up the processing of orders	1 – 1.5 years	IT Department
Shorten lead times for delivery	Purchase and implementation of information technology for the development of optimal routes in directions	2 weeks – 2 months	Purchasing Department
To improve the quality of services	Purchase/lease rolling stock	1 – 1.5 years	Logistics Department
	Implement special storage technology for the automation of the accounting system	2 weeks – 3 months	Purchasing Department
Learning and growth perspective			
Improve the skills of employees	*Training of personnel to work with new technologies and techniques*	*7 days 1 month*	*Staff training department*
	To organize special courses, seminars earmarked for the education and training of employees	*7 days 1 month*	*Staff training department*
Increase the Effectiveness of Labour	Implement special software to reduce the amount of manual labour	1 – 1.5 years	IT Department

Strategic goal	Strategic goal	The period for carrying out the action	Division, responsible for implementation
Reduce employee turnover	*Use a system of positive motivation (awards, praise)*	*1 month – 1 year*	*Human Resources Department*
	The one-time rewards for employees for results of the year	1 year	Accounting Department
	Development and application of a "social package" for employees	*1 – 1.5 years*	*Human Resources Department*

The "5+" rating system evaluates employees, according to the *key corporate competencies* at Sberbank Group:

- Individual performance;
- Improving professional knowledge;
- Innovation/optimization of operating processes;
- Teamwork;
- Client focus in respect of both external and internal clients.

With the implementation of the "5+" system, the activities of employees are assessed according to uniform criteria recognized by the bank as critically necessary for achieving the set of strategic goals. In turn, the rating scale of the "5+" system contains 5 gradations, denoted by the letters:

A – far exceeds expectations;
B – exceeds expectations;
C – meets expectations;
D – requires improvement;
E – unsatisfactory.

The scale is used to assess compliance with the portrait of a successful bank employee. Grade *"C"* is a *portrait of a good employee. Assessment "A"* assumes *a truly "stellar" efficiency* in most parameters. The individual coefficient of quarterly bonuses for an employee using the "5+" system depends on three criteria:

- ✓ Evaluation of the implementation of the Territorial Bank (TB) plan for profit.
- ✓ Evaluation of the implementation of the KPI of the Internal Structure Unit (ISU).
- ✓ Evaluation of personal effectiveness in the “5+” system.

With these points in mind, an example of calculating an employee’s quarterly bonus is as follows:

Employee salary × Standard coefficient × TB profitability rate × ISU KPI achievement coefficient × Coefficient “5+” = AWARD

On the whole, the above-mentioned cases show that in modern organizations, integrated management systems are becoming increasingly essential, capable of not only solving current tasks, but also implementing a developed strategy. In this regard, working with human resources of the organization will require not only operational decisions, but also strategic ones. Thus, the creation of corporate competency models interrelated with key performance indicators (KPI) and an enterprise development strategy in the form of the BSC will allow the provision of information in real time about the current state of the human resource as well as the creation of opportunities for continuous development and improvement. An effective combination of programmes for assessment, development, use and replication of the core competencies of the company and its employees will contribute to the achievement of the organization’s strategic goals and the gradual transformation of human resources into human capital.

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CHAPTER SEVEN

CONCLUSIONS

OLLI-PEKKA HILMOLA

Infrastructure projects are difficult, mostly due to their long planning, engineering, construction and implementation period (time delay), and also due to the huge capacity added to the markets at once (as completed). If larger projects could be completed in small useful increments, and in a short amount of time, they would be much less risky, and funds could be addressed to the intended purposes. Alternatively, projects could be cancelled during the process if rosy forecasts are not met. Smaller projects would also require less debt-based financing, and give flexibility for investors regarding future options and development paths as cash flow would turn into a positive in the middle of finalizing smaller increments.

However, the world is not yet ready for the incremental implementation of logistics infrastructure projects. Typically, large-scale projects are therefore implemented in periods, where there exists clarity in datasets and a common understanding that the current development trend continues into the foreseeable future. Different kinds of forecasts of traffic and usage could be made, and these are based on statistics, math and continuity of the world, as it is known a priori. The higher the confidence given by the numbers, the greater is the interest for different financing bodies to commit themselves to financing very large-scale projects. Huge projects also require low interest rates to exist (Boyle et al., 2016). However, numbers and estimates of the future do sometimes prove to be false and discontinuities could happen (even after long periods of time of favourable development). Think about the housing crises around the world in 2008-2009 – there were a number of models forecasting that a housing crisis could never ever occur in the USA. In contrast to statistical models and a vast amount of analyses, the housing market simply collapsed. One reason was some over-building in the real-estate markets, but another reason was the extensive use of debt-based finance to keep construction activity going on (Turner, 2008; Schiff & Downes, 2012).

The analogy could be seen relating to logistics infrastructure building and emerging Eurasian supply chains – building, e.g., a new airport, highway or railway will add much capacity to the markets at once, and it is funded mostly with loan-based instruments. What if there is not enough demand in the early years of built logistics infrastructure? (This was identified as especially critical in Indian highway projects, see Kumar et al., 2018.) How long could government and/or a private company carry on paying loans and continuing operations with low usage rates? Are there troubles in the month(s) or year(s) ahead? The entire project could be an economic failure, even after years of being available for use. In this case, a prolonged concession period of, e.g., a private funding body is not enough (typical in public-private partnership projects, as concluded in Kumar et al., 2018), and the government needs to take the project under its control. What are the possible alternative usage plans and financial shoulders available then? Based on previous studies in Asia, the most troublesome infrastructure investments are in the transportation and logistics area, and these commonly face severe difficulties, even when they are mostly funded by private parties (Lee et al., 2018).

We know from previous examples of the housing market, and especially from the construction of the tallest skyscrapers that basically demand never follows forecasts and it will take not years, but decades, to fill the skyscraper and have profitable operations through tenants. For example, there was the official opening in January 2010 of the Burj Khalifa skyscraper in Dubai (UAE), which was then the tallest building in the world. In 2017 it was still reported to have nearly one-third of its space unused (The Guardian, 2017). Due to the lower than expected success of Burj Khalifa (and Dubai's economy in general), local government was forced to take emergency loans in billions of USD in 2010 to keep serving the debts and other operative payments (Landon, 2010). This is one of the reasons why Burj Khalifa's original name was changed from Burj Dubai to the current one.

It should be highlighted that Burj Khalifa is not alone in the problems it faced. It took much more than two decades for the Empire State Building (finalized and opened in 1931; it was the tallest building at that time) to find usage for all of its new capacity. It had the nickname of "Empty State Building" in the 1930s, mostly as its occupancy rate was so low (around 20% was estimated for occupancy at the opening; Tauranac, 2014). Similar problems were identified (e.g. The Guardian, 2015) for the World Trade

Twin Towers (finalized and opened in 1972). Cheng (2014) reports from Malaysia that the local office market was living in challenging times after the Petronas Towers were completed (finalized and opened in 1999) – basically in 2014 the occupancy rate in the area was the same as at the opening, around 80%. Before the completion of the tallest building of its time (Petronas Towers), Klang Valley in Kuala Lumpur in Malaysia was enjoying a healthy occupancy rate of above 90%.

Making really big investments at once is not only a problem for apartments and office space, but also for shipping e.g., the last decade of deliveries of very large-scale container ships (or the over-building of dry bulk ships in the period 2008-2010) has caused over capacity and a deflationary environment (United Nations, 2017; Lun et al., 2012). Easy money policies, low interest rates and somehow a seemingly promising economy lead to *"Cantillon effects"*, where more centralized and bigger structures take competition and business away from smaller units (Boyle et al., 2016). This again is an important learning point for Eurasian supply chain development – new infrastructure is needed, but it is often very large-scale and all built at once.

As discussed in this book, logistics infrastructure investments have been difficult to manage, even in the developed world. Typically, investments are over budget (when finalized) and behind completion schedules (what was promised in the first place). Budgeting failure is caused by many factors. First of all, in the feasibility and planning phase, the overall budget is a rather rosy view of the required funds as it is politically influenced, and made by persons without a proper connection to real life. We have lived through very low interest rates for decades all over the world (of course, there are some exceptions, like hyperinflation countries), and most of the potential projects have already been found, funded and finalized.

Nowadays, it is increasingly difficult to find profitable investments, especially when economic concerns move from one country to another, bringing down currency values and stock markets. As the values of national currencies in developing countries fall against the US dollar, the inflation in these countries increases (and the amount they have to repay for loans grows even larger). The high inflation rates disrupt countries' economic stability. Examples would be a recent drop in Argentina's money value, the peso, against the US dollar (by 29% in August, and more than half by the middle of September 2018). In response, Argentina's central bank raised interest rates to a world record of 60 per cent (Aljazeera.com, 2018). Next, Turkey's currency decreased against the USD by 25%, and afterwards, the South

African currency, the rand, lost 10% of its value (Mullen and Baltaji, 2018). The currencies of India, Indonesia, and Iran also fell, resulting in economic difficulties which forced companies to leave these markets and seek new ones for potential investments. Such risky contagion could affect every country in the world, and bring about uncertainties for the mega-infrastructure projects discussed in the book.

As projects are uncertain, decision-making takes a long time. Therefore, the second, causal factor on the "over budget" issue is a time delay experienced between the initial decision-making budget, and the time of the start of the actual construction process. Again, this delay is years, if not decades. Therefore, inflation (think about what happened to raw material prices, after China started its enormous construction activity) and business cycles do their work, and even at the beginning of the construction process, it is known that the investment is not going to meet its budget. As well as a budget, keeping a schedule is difficult. One reason could be an insufficient amount of funds during the project execution period. This, in turn, causes considerable delays in the construction processes. Also, feasibility and planning phase ideas about progress in the construction could be too rosy – quality and safety requirements, e.g., for infrastructure, are increasing all the time, and causing a need for better constructs, and again possibly causing time delays in the realization phase.

A key idea behind this book was to merge modern thinking, knowledge, tools and practices to be used in Eurasian supply chains. As Eurasia is just emerging as a more common trade area, there are often applications here relating to logistics infrastructure projects. In addition, as the whole of Eurasia is an implementation environment, it is a really challenging task due to the different types of economies, cultures and countries involved. We believe that the only way to manage this environment correctly is to use bigger and more detailed quantitative models, and also use as an aid, different types of computer simulations. Different scenarios need to be built and uncertainties identified and somehow addressed in the management actions. As most of these countries are experiencing weak domestic currencies and inflation, it is extremely important to take into account the time value of money. There is a real danger that project budgets will mushroom, and that the planned amount of loans to fund a project execution and implementation period is not enough. However, this is only one possible risk. Others mentioned in this book are related to the environment, where this larger logistics infrastructure is finalized, and what kind of demand and price level exist for its provided services. Demand could be there, but a much lower price level than previously thought and this low-price environment could persist for years. Again, this is something that needs to be incorporated in the feasibility and planning phase models. How robust are plans and investments? What is the ultimate value of what we provide for customers with this investment? Are there any substitutes existing or forming?

Although Eurasian supply chains have a tremendous build-up and development phase, in many cases they are already available for users. One example is the railway hinterland connection to China from Europe. This connectivity has now been available for years, and before the Chinese direct connection, there was the connection to the end of the Russian side of Asia: Vladivostok and Nakhodka. We have evidence there have been volumes before, and already currently, they have grown to some notable level. However, growth could be much more significant. The problem in further growth is multi-faced. One issue is the total costs of transportation between, e.g., Europe and China. Another is the predictability of prices over the medium- and long-term as well as the capacity of the route (especially border-crossings and terminals). From the customer side, it is also necessary to think outside the box, and instead of long-distance and long-duration sea transports, supply chains could be built through the hinterlands with a short lead-time performance and a reasonable cost level. As illustrated in this book, the decision also contains such issues as inventory in the supply chain and the possible time-based erosion and depreciation of the goods transported (like electronics, fashion, food, etc.). Who has the liability for inventory in a supply chain? Who is paying for transports? Think about a company selling items for Chinese markets, and supplying one of the one hundred cities with a population of more than a million. If this city is not located in the coastal area, then how is the delivery transported to the customer? It depends quite a lot on who is making this decision. If a decision is localized to the customer level, and person, e.g., from this city, they might see things rather differently. Railways and direct delivery from Europe could be high on the preference list. The reason is simple as hinterland transports in China are a troublesome equation and expensive to arrange.

Thinking differently in Eurasian supply chains is not only limited to hinterland transports. Just going through Chinese OBOR investments and main sea ports in Europe would yield a totally different point of view on logistics. Chinese people seem to think that Europe is one big entity, and a singular trade partner. They also seem to think that the distance travelled is a key factor for competitiveness. In addition, Eastern Europe is seen as a very attractive investment area for logistics infrastructure. Current mainstream supply chain models between Europe and Asia are based on a time three to four decades ago; the time when Soviet rule was a fact in Europe, and it was clearly divided in every sense (and in Western Europe only sea ports in the west provided the needed and secure connectivity). Of course, this old modus operandi is not optimal. It results in long distances and long delays, and hub sea ports and surrounding areas are congested as well as over-crowded. The Chinese solution for European supply chains is to use more southern sea ports and to access European markets by hinterland transports over short distances using e.g., railways. If Europe remains as peaceful and economically united, then this approach will be fruitful in the future. It already is; readers could visit the sea port handling of containers in the Mediterranean area concerning Italy, other different country sea ports on the Adriatic Sea and in Greece. Performance after the crisis of 2008-2009 has been extremely good. This is not only due to Chinese businesses, but also due to other Asian countries (like Indian steel). People and decision-makers see things differently if they come from different continents. It could be that the Asian perspective on European supply chains is a valid one.

In Eurasian supply chains, changes are not only taking place at the European end. Asia will change greatly, if most of the new investment ideas are implemented, and if new emerging countries take a manufacturing-based lead as China did in the last two decades. Sea ports in Southeast Asia, together with India, will become major maritime transport hubs. These will not only mix local and Chinese products or demand, but also African manufacturing output, which is currently being built. Africa's strategic assets are expected to be used more actively in the forthcoming decades after the implementation of investments in infrastructure, first and foremost, by Chinese companies. African countries would export more farm products and other commodities to facilitate the struggle of repaying their debt in the long term. In return, China will receive products that are in demand as the country's purchasing power for virtually all products and services has strong potential due to the expected growth of middle- and upper-income categories to some 190 million people by 2020 (Hill and Hult, 2018). As a result, consumption will now be the driving force behind China's growth rather than foreign investments. While, for some small African nations, the export of materials that China wants would be the preferable option to repay billion-dollar loans for railroad projects that otherwise they would take many years to pay (Dierking, 2018). Such a stimulus for trade in return for infrastructure loans may change the distribution of material, financial and information flows in the world economy. This does not need big economic miracles to work and be realized – the population (the amount, growth and share of young people) in Africa, India, China, Pakistan, Indonesia and the rest of Asia is so huge that even with moderate functioning, and with a proposed increase of per capita income and an upgrade of demand, it will be the new prospering area in the world. In this new configuration, lead times by, e.g., shipping, could be considerably shorter as compared to those of today. Much of the improvement will appear due to the shorter distance. Again, a new mindset is needed.

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