UNIVERSITY OF THE AEGEAN

GLOBAL SUPPLY CHAIN MANAGEMENT

Trends and Challenges

Business Administration
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Global Supply Chain Management

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Abstract

The main purpose of this thesis is to delve into the Global Supply Chain Management and face some of the challenges and problems that global supply networks have to deal with. In order to achieve that, the first part of our analysis is dedicated to familiarizing the reader with the concepts of management science, operations management, logistics and supply chain. Subsequently, are presented the global supply chain management and some challenges that occur in decision making. It is analyzed, as well, some of the major decisions have to be taken in every global supply network, along with some tools and models to work with, from the stage of building facilities until the distribution of the end-product to the customer. In the second part, we examine the linear single-commodity minimum-cost flow problem and specifically the case without capacity constraints. With the help of Matlab software, we create a unique generalized model, using linear programming, to solve every problem of this type. It is about an interactive and dynamic model with an open code which can easily change form in order to be able to solve more complex problems. Finally, we solve a real case of NTN to help the reader master the solution and test our model, which gives exactly the same results in numbers and in diagraphs as the original solution to the problem.

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Chapter 1

1.1 Management Science

In management science, there are no typical definitions to be used by everyone, but there are some that are quite acceptable. In 1980, the American Management Association formulated the following definition about management: *"management means getting things done through other people".* While a more recent definition assumes that *"management is working with others and through others to achieve the goals of the business and its members".* It seems that there are three differences between the two definitions.

- The first one is that in the more recent definition there is a better focus on human resources inside the company.
- The second is that the more recent definition also focuses on goals that have to be achieved.
- The third and last one is that the second definition makes clear the perception that the achievement of the goals of the labor force has to be incorporated into the goals of the company.

Managers have to plan, organize, provide personnel, coordinate, motivate, inspect. Robert Katz classified the skills of managers in three divisions: technical skills, human skills, and conceptual skills. While all three divisions are equally important, they are used in different hierarchical levels as shown in the following figure.

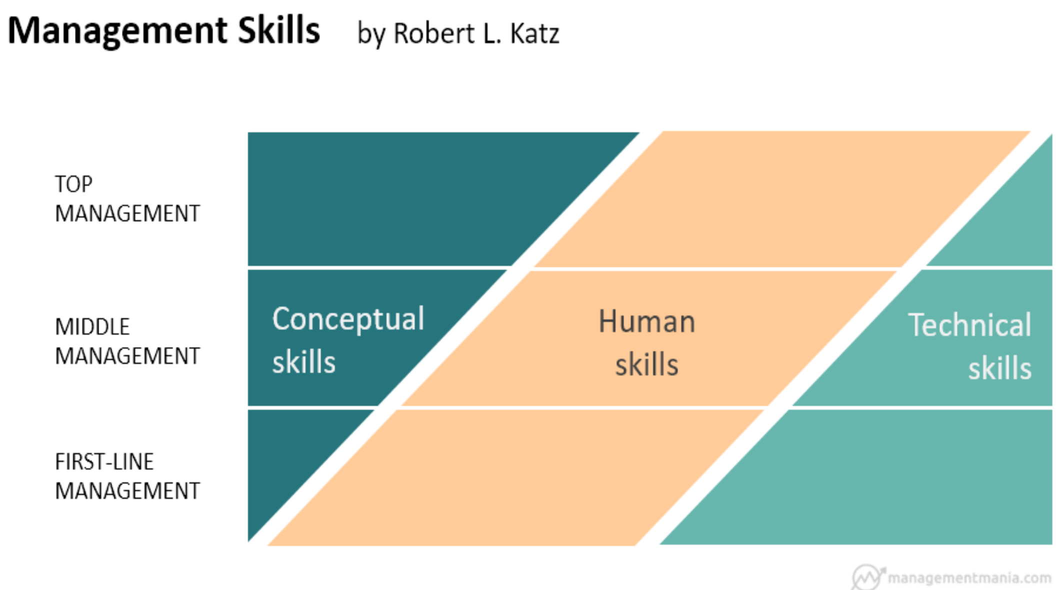


Figure 1: Management skills by Robert L. Katz[1]

Management is changing over the years. Information and technology are now top priorities for every organization. Technical skills are important for managers, but there is more and more necessity for human skills and for continuous education of the workforce.

1.1.1 History of management science

Some of the first management papers are dated at the beginning of the Industrial Revolution. Some of the first authors like Charles Babbage, though that it was necessary to study the management of employment and the standardization of operations, in order for the companies to adapt in a more competitive reality. But at that time neither the management thinking nor the available technology was mature enough to do that.

In 1886, Henry Towne participated in a meeting of the American Society of Mechanical Engineers and he requested the research of project management. Frederick Taylor and his colleagues accepted this challenge and began the establishment of the theory of management. Management theory uses the knowledge of other

[1] managementmania.com

scientific sectors such as Economics, Mathematics, Sociology, Psychology, Philosophy, and others. Management science as an individual sector started to be developed in the 1940s.

1.1.2 Management Theories

1.1.2.1 Theory of Frederick Taylor

Frederick Taylor, the father of management science, thought that economic prosperity could only be achieved if workers could achieve the best level of efficiency possible. Furthermore, he thought that in order to achieve that, it was necessary to re-engineer work methodology and to get workers and leadership to work together as a team. After thousands of measurements, he divided every task into smaller parts and for each one he found the only best way to be performed. As a result, workers became far more efficient than before and Taylor obtained the title of the "father of management science".

1.1.2.2 Theory of Henry Gantt

Henry Gantt, an associate of Frederick Taylor, contributed to the optimization of time planning and work inspection. He thought that the lack of efficiency was due to unrealistic standards of management. He also thought that in order to achieve efficiency and realistic models, work standards had to be set after measurements with scientific defined data. The most popular achievement of Gantt was the chart of time scheduling or Gantt chart. Moreover, in order to maximize the productivity of the labor force, he created financial incentives for the workers, which are used until now.

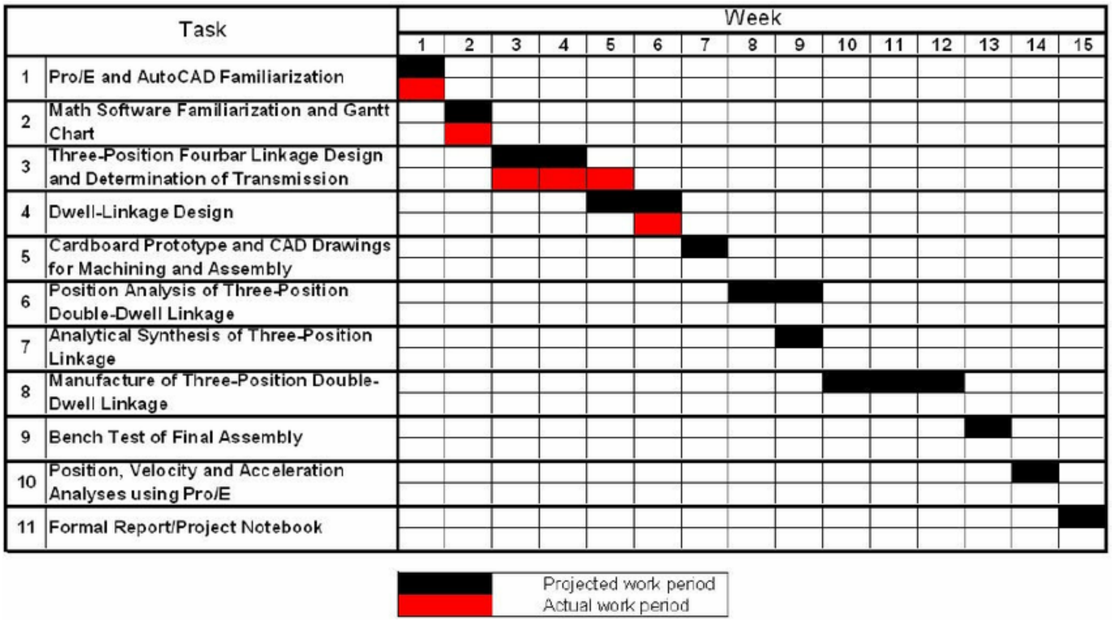


Figure 2: Gantt chart[2]

1.1.2.3 Theory of Henri Fayol

Henri Fayol, a French engineer, worked on the efficiency and effectiveness of the whole organization. His work was recognized as Administrative Theory, which contains four important elements.

1. The first is the differentiation between inspection and management level, giving more importance to the management level.
2. The second is the creation of management functions which are used until now and include
    - Planning
    - Organizing
    - Commanding
    - Coordinating
    - Controlling
3. The third is the establishment of general principles of management.

[2] www.researchgate.net

4. The fourth is the thought that managers can learn how to manage, which was contrary to the established thought until then, that managers are born and cannot be made.

1.1.2.4 Theory of Douglas McGregor

Douglas McGregor studied the behavior of the workers and created the X and Y theory. According to theory X, people don't like working, so they have to be forced to. Most workers lack spiritual capabilities and just a few are creative. Finally, they don't like responsibility and they prefer to do what they are told to.

On the other hand, theory Y presents people who like working and try to accomplish the company's goals. Furthermore, workers have capabilities that must be found by management, they are creative and they can handle responsibilities.

By making these assumptions, McGregor pointed out the need for redefining the way that managers face human resources and the design of working positions.

1.2 Operations Management

One of the basic elements in management is the creation of added value. Operations management is responsible for the creation of that value and furthermore for matching supply and demand. According to Sanders (2012) *"Operations management (OM)—or ''operations''—is the business function responsible for producing a company's goods and services in an efficient and cost-effective way. It is the function responsible for transforming a company's inputs, obtained by the sourcing function, into finished goods and services, which marketing sells to final customers".* That means that products and services cannot be created without operations management. This makes OM a core function for every company. As a core function, it is responsible for planning and managing all the resources a company needs for production and deliver products and services to customers efficiently and effectively.

Another definition by Branch (2008) says that *"sales and operational planning has been defined as the translation of upstream demand data into an actionable operational plan and that rapid product commoditization, shorter product lifecycles, high product mix, and higher product volatility are all putting pressure on margins and accelerating the importance of planning".* So it is important to integrate the scheduling of workforce management and match it to the operational planning process.

1.2.1 Evolution of operations management

Figure 3: The evolution of Operations Management

3

Operations management has evolved over time. Prior to the 1950s, the function was named "Production management". It was a supportive tool of back office that was all about producing. Until the 1980s the function was named “Production and operations management” and had more organizational role than before. After 1980 it took its final name as “Operations management” and its role became strategic. The level of today’s competition has made operations management a core function with critical importance. Companies try to become more efficient and satisfy customer needs in the best way possible. The optimization of this tool is crucial for companies to survive in a global market which becomes more complex and competitive day by day.

1.2.2 Impact on Supply Chain Management

Companies of the same supply chain have to coordinate and link their operations in order for the whole supply chain to be effective and efficient. When operations function is not managed as it should, then there will be an increase of several costs for all members of the supply chain. If suppliers have poor operations function, then production resources will be late or not in the right form and quality, which will result in production delays and in worse quality of the end-products compared to the prototype. If retailers and distributors have poor operations function, products may not be delivered to customers on time or they may be

[3] Nada R. Sanders, 2008, Supply Chain Management: A Global Perspective, John Wiley & Sons, Inc., pp. 126

damaged. As a result, sales are about to be reduced and all parts of the supply chain will lose their confidence.

Globalization of the market had as a consequence the creation of global supply chains. This resulted in the globalization of operations strategies. Other factors that contributed to this result was the development of technology, political and macro-economical factors. Globalization also brought higher levels of competition, which resulted in the formation of agile supply chains that focus on individual end-customer demand satisfaction.

1.2.3 Manufacturing versus Service operations

Operations management differs in manufacturing organizations compared to the service sector. The main difference appears in the physical form of the end-product. On the first corner, in manufacturing the end-product is tangible, which means that it can be produced in large quantity and stored before use. On the opposite direction, in the service sector, the end-product is a service, which is intangible and cannot be stored. A second important difference is that in manufacturing companies, customers rarely are present in the production of goods, while in service companies, services are created in presence of customers and many times the process is interactive. However, in some cases, differences are not that clear. These cases appear when manufacturers provide services as part of their business and when service firms manufacture physical products they use during service delivery or other functions.

1.3 Logistics – Supply Chain

Sometimes the terms logistics and supply chain management are used interchangeably. This confuses people and they think that it is the same thing. The truth is that these are different terms and they are analyzed below.

1.3.1 Logistics

Let's present some definitions of logistics term in order to be clear what it is.

According to Waters (2003), logistics is *"a single, integrated function that is responsible for all aspects of the material movement. With this broad view, logistics includes all the activities that are needed to ensure a smooth journey of materials from original suppliers, through supply chains and on to final customers."*

The Institute of Logistics (1998) presented logistics as *"the time-related positioning of resources or, the strategic management of the total supply-chain."*

The next presented definition by the USA Society of Logistics Engineers defines logistics as *"the art and science of management, engineering and technical activities concerned with requirements, design and supplying, maintaining resources to support objectives, plans and operations."* (Waters, 2007)

Finally, the Council of Supply Chain Management Professionals (2006) described logistics as the function that *"plans, implements and controls the efficient, effective forward and reverse flow and storage of goods, services and related information between the point of origin and the point of consumption in order to meet customers' requirements".*

1.3.2 Supply Chain

Now let's have a look in some definitions about supply chain and then about supply chain management.

The Institute of Logistics (1998) presented supply chain as *"a sequence of events intended to satisfy a customer. It can include procurement, manufacture, distribution and waste disposal, together with associated transport, storage and information technology".*

According to Sanders (2012), a supply chain is *"the network of all entities involved in producing and delivering a finished product to the final customer. This includes sourcing raw materials and parts, manufacturing, producing, and assembling the products, storing goods in warehouses, order entry and tracking, distribution, and delivery to the final customer".*

The next definition from Waters (2003) says that *"A supply chain is the series of activities and organizations that materials – both tangible and intangible – move through on their journeys from initial suppliers to final customers".*

Finally, Ivanov, Tsipoulanidis and Schönberger (2017) described supply chain as *"a network of organizations and processes where in a number of various enterprises (suppliers, manufacturers, distributors and retailers) collaborate (cooperate and coordinate) along the entire value chain to acquire raw materials, to convert these raw materials into specified final products, and to deliver these final products to customers".*

Below are presented two definitions of supply chain management, in order to clarify the differences between that and logistics.

The first definition by Sanders (2012), says that *"Supply chain management (SCM) is the design and management of flows of products, information, and funds throughout the supply chain. It involves the coordination and management of all the activities of a supply chain. As such, SCM may appear deceptively simple. In fact, it is a complex business concept that is far-reaching in the nature and type of decisions involved".*

The second definition by Ivanov, Tsipoulanidis and Schönberger (2017), claims that *"Supply chain management (SCM) is a cross-department and cross-enterprise integration and coordination of material, information and financial flows to transform and use the*

SC resources in the most rational way along the entire value chain, from raw material suppliers to customers. SCM is one of the key components of any organization and is responsible for balancing demand and supply along the entire value-adding chain".

1.3.3 Supply Chain Management versus Logistics

As mentioned earlier, Supply chain management and Logistics are not the same. Supply chain management promotes the collaboration of all parties across the supply network, in a way that the maximum level of competitiveness can be achieved. It is also a strategic concept which is managing many flows, including inventory. Logistics, on the other hand, is about moving inventory all through the supply chain. It is a support function to supply chain management that involves order processing, inventory management, transportation, and packaging.

1.3.4 The rise of supply chain management

When SCM started to evolve in the 1990s, was presented the concept that reduction in order fulfillment time linked to customization would lead to a significant competitive advantage, which offered by SCM. The rise of SCM was the result of information technology development, which provided data across the whole supply network. Also, the thought that optimized planning and managing of the supply chain can bring tons of savings, has contributed to the rise of SCM, along with a reduction in transportation costs, which have resulted by improvement in transportation modes. Before that, order processing was too long. The average time to process and deliver an order ranged from several weeks to months. Processing steps were too many and as a result, a lot of them were performed inefficiently and with many errors. Sometimes stock was not enough to cover the market, so companies raised the stock level, which in turn raised inventory cost. In the 1990s, the SCM revolution has begun. Companies started to offer customized products, they reduced response time and the need to design competitive supply chains showed up.

Technology development and the internet provided information across the whole supply network very fast. Customers gained the power to demand customized and high-quality products. As a consequence, companies are focusing on improving their products, customization process and delivery time.

1.3.5 Logistics evolution

In the 1980s, it was found that logistics costs were too high, by constituting about 15-20 percent of a firm's total cost. In order to change that, it was tried to improve separate activities of logistics, like procurement, warehousing, transport and others. While this effort failed, in the 1990s firms understood that competition is up to the supply chains and not between individual companies anymore. Furthermore, they found that they could not make changes just to one activity, because all activities were interconnected and changes in one had consequences to others. Respond to that, was the formation of logistics strategies, consisting of long-term decisions and plans to reduce logistics costs and improve the overall efficiency, by combining all related activities into a single integrated function. Critical success factors were the improved communications which offered better information flows, globalization which unified the market and the need to remain competitive in order to survive in the global market which led to improvements in operations.

1.3.6 The service supply chain

Service supply chains differ from manufacturing. The main differences can be found in the role of customers and in the delivery process. While manufacturing companies focus on the production of tangible products, service companies focus on interaction with the customer. A service provider produces the service with the customer in an interactive process, without the buffer of retailers and distributors. This shows the difference between service and manufacturing in terms of distribution and enhances the quality of information flow between parties. A further critical difference seems to be the fact that in service companies there are no safety stocks to help them be more flexible. This is the reason why they tend to rely on their supply chain to deliver customers the best value they can, in order to remain competitive.

1.3.7 Supply chain differentiation

When firms understand that they need to customize their products and services on market needs, differentiation seems to be necessary. It appears to be crucial when new products are introduced, when having a mix of products and supply chains in different maturity stages. To be successful, it is critical to segment the market and then apply the right supply chains to each segment. The more heterogeneous the market the bigger the need for differentiation.

1.3.8 Globalization

As a result of globalization, companies act and compete in a new market, a unified international market. Competition has shifted from individual companies to whole supply networks. Traditional technologies give their position to new disruptive supply chain technologies, local sourcing gives its position to global sourcing and the development of outsourcing gives the opportunity to companies to focus on their core competencies. Companies are trying to make their supply chains as leaner as possible, to reduce costs and waste. To achieve that, it is necessary for all parts of the global supply network to work together and coordinated in order to eliminate waste and improve their operations. Some factors that encourage global operations are mentioned below:

- E-business and optimized information systems allow better communication of organizations around the world.
- Cost differences in operations between different countries.
- The opportunity to create economies of scale for companies with stable and large-scale production.

- The empowerment of customers and their growing demands, lead them to look for the best option in global markets.
- Removal of trade barriers and the formation of free trade areas.
- The continuous development of logistics.
- The development of outsourcing that gives the opportunity to organizations to focus on their core competencies.

As supply chains get longer it is possible to deal with the issue of bullwhip effect. "*It has been observed that fluctuation and distortion of information increases as it moves up the supply chain, from retailers, manufacturers, to suppliers"* (Sanders, 2012). It is about inaccurate and distorted information, that in order to be confronted, it leads to progressively more inventory for each stage of the supply chain. To deal with it, supply chains need to optimize their information systems in order for accurate information to travel across the whole global supply network.

Chapter 2

2.1 Introduction to Global Supply Chain Management

The undeniable development of technology nowadays has created a lot of trends. Furthermore, better-sophisticated communication and transportation systems have brought the world closer. All of these had, as a result, the development of Global Logistics.

The beginning has been made by the end of the Second World War. During the effort to settle trade disputes between countries, the World Trade Organization has been established. That was an inter-government organization, whose main concern was the removal of trade barriers and the establishment of international free trade areas. With the help of the World Trade Organization, China became a global industry giant and resulted in an economic rise in the Asia Pacific region. This resulted in the transformation of tech and clothing sectors supply chains and had unprecedented effects on freight transport, which in turn attracted logistics providers that had the knowledge and the experience to support these changes.

In the 1960s the market changed from production oriented to customer oriented, which in the 1970s brought quality issues in the foreground. In the 1980s after the establishment of Total Quality Management, the development of inventory management took place. Build to Order strategy was born in the 1980s – 1990s by the need to reduce stocks and develop a flexible production system. The pioneers were Toyota in the automotive industry and Dell in the technology sector. After the changes in production, Just in Time delivery schedules came in the forefront, in order for cycle time reduction and faster inventory turnover to be achieved, plus to remove waste from the workflow processes. Just in Time also had major effects in the transportation system and positive results on the efficiency of the whole supply chain.

In the 1990s, when globalization was a fact and there were advancements in the technology sector, companies from all around the globe started to collaborate with each other. Another trend in that time was outsourcing non-essential activities to service providers that could develop them better and cost-effective. That gave the opportunity to the companies to deal with core activities effectively. In contrast to that theory, nowadays companies outsource both non-essential and essential activities and keep in house only those activities that they can make the best way and can establish a competitive advantage.

The development of less developed regions has attracted foreign companies to sell in those markets. Furthermore, as customers get more demanding and more empowered by the improvement in communication systems, local suppliers and retailers cannot fulfill their requirements. As a result, customers can search for products and services outside of their region, while organizations can do the same in order to find better sources.

These days we talk about risk management, information technology, e-commerce, supply chain agility and flexibility and of course green logistics either in terms of vehicle or type of packaging selection.

The evolution of technology has helped in reducing operational costs and in the creation of global supply chains. Especially the establishment of the Internet in the structure of today's companies helps them to reduce the ordering process time and from the aspect of manufacturers, it contributes to the reduction of order processing costs. Furthermore, the members of supply chains have the opportunity to electronically exchange information about production schedule, stock levels, statistical reviews and much more by using the latest information systems. From the transportation aspect, customers are being able to track their order and have a specific look in the whole process, from the capture of the order until its delivery.

Back to the internet, the establishment of internet traders and in general e-commerce is the main cause of the weakening of intermediaries. The main advantage of internet traders is that they do not have a physical presence. That means that they do not have to worry about infrastructure costs, front office costs and stock. The opportunity to reduce those costs and be more efficient has led some large organizations to reduce the number of order fulfillment centers and optimize the ordering process through their web site. Although this can lead to an increase in transportation costs, the benefit of reducing all the costs mentioned above is greater and it is able to lead the organizations to lower the prices of products and services, in order to increase market share and enhance profitability. It seems like a necessity for several organizations to be able to gain customers interest via their web site and sell from there. But do not forget that the market is now customer oriented. That, in combination with the more and more use of e-commerce, has made customers more sophisticated in their online shopping and as a consequence, the percentage of online returns has been raised significantly. Many retailers, especially internet traders that have a lack of infrastructure, cannot handle returns volume. Logistics providers are coming in the forefront to solve this problem, by offering a solution package that includes returns handling, warehousing, defining where returned products must be sent and submitting them in the proper distribution channel. Especially in an international market, outsourcing logistics operation can be a savior for the most "brick and mortar" retailers. Logistics providers can handle those competencies by their knowledge and experience and let retailers handle the operations from where they can get a competitive advantage.

The development of technology also made sourcing better. Sourcing changed into e-sourcing and a new trend came to the forefront, the reverse auction. By using the appropriate software it became easier for the procurement personnel to handle the variables of the reverse auction process and achieve better conditions. In general, using an integrated to the organization strategy software can be beneficial. But first, let's discuss the disadvantages of not having the right software. Data has to be keyed for the first time in the organization's system in order to be usable and then rekeyed to be used in an individual document or copied and pasted, if possible. This gives us two problems. The first is that keying data is a time-consuming process and the second is that individual input of data can lead to errors while typing. Having information in an inappropriate system or form is a major problem, as well. This case can lead to an inability to use information in reviews and measurements or share information with other organizations, because of format inconsistency. Now let's get back to the right software to discuss some advantages. First, it can handle many variables and constraints, analyze quantitative and qualitative data in order to create the environment for the right decisions. International market also requires better visibility than the domestic. The appropriate software suite offers this improved visibility and has a positive effect on a cost-saving effort. Further benefits could be the optimization of income due to better price strategy, reduction in expenses related to the human factor and of course the making of loyal and satisfied customers.

Let’s have a look in some types of software solutions. **Enterprise Resource Planning (ERP)** is a kind of software that helps on planning production schedule, taking as input demand forecast. Some advantages of ERP are:

- Information entered is available for all processes of the company
- Can improve some processes and communication inside the company
- Creates a strong database
- Can lead to the establishment of competitive advantage

Some difficulties can occur from the use of an ERP system. First of all, it usually is expensive and not everyone can afford it. Secondly, it is very complex and it is hard to be customized for specific needs. Lastly, it is going to bring changes and there is always some employees that face change as a threat.

Advance Planning and Scheduling Systems (APS) are systems that use software in order to manage a network of facilities and with the help of mathematics to make a production schedule.

Radio Frequency Identification (RFID) is a technology that can identify and track tags by specific readers using radio waves. Using the right software and be part of an integrated RFID network can be very helpful. Anything in a supply chain can be tracked with a bar code. Inventory levels can be observed at any time, which can lead to a better level of responsiveness. Additionally, this technology can contribute to the reduction of counterfeit, waste and theft. Like ERP, it usually comes expensive.

The best way to use all of these systems is by being able to share all these information and data with all members in a supply network. **Electronic Data Interchange (EDI)** can help an organization to achieve that. EDI is about an extranet system that contributes to the spread of business documents and information in electronic format between the members of a supply chain. The main benefit for suppliers is the immediate access and accurate information about the market and plan their production, and for retailers to provide better customer services and always have products on-shelve.

A main concern of almost every company is to keep its costumers satisfied and loyal. This can be achieved with a **Customer Relationship Management (CRM)** software. This software uses data analysis about customer's interaction with the company, in order to improve business relationships between them. The main concern is the retention and the meeting of every customer's need in the best way possible.

In a global market and in global supply chains there is always the concept of risk. Perhaps extended supply chains can spread risks to many different markets by reducing centralization, but the more extended is the supply chain the more vulnerable it is to external threats. These threats may be environmental like weather conditions, geopolitical like terrorism or piracy, economic or even technological. In complex networks, there is less visibility, longer lead times and less agility. Further problems may occur from currency fluctuations, shipping costs, less quality control, and corruption. Many organizations in order to deal with those risks build up buffer stock. Others create a near-sourcing strategy but remote production. But one of the most important factors is the ability of the organization to adapt and react to threats and be highly agile. The adoption of new technologies will help with this latter.

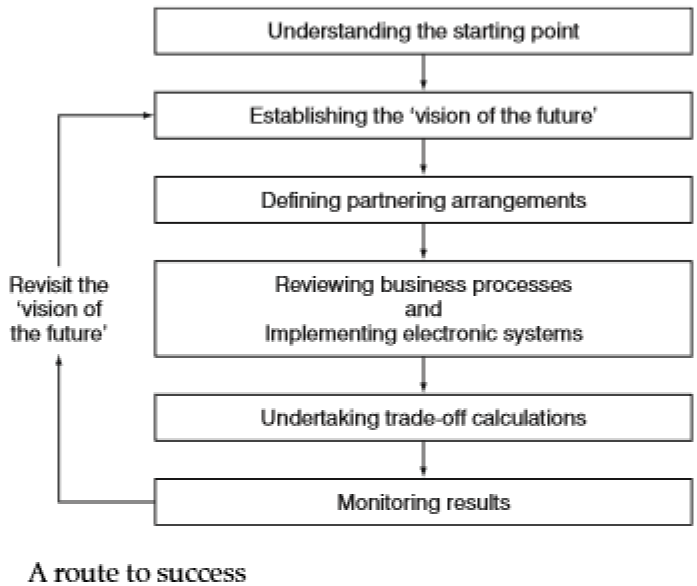


Figure 4: A route to success[4]

[4] Donald Waters, 2003, Global logistics and distribution planning 4rth Edition, Kogan Page Limited, pp. 146

Chapter 3

3.1 Decision Making

A successful global supply chain network is all about decisions. Decision is a selection of an activity to handle from several alternatives. Tough decisions have to be made in the right timing and with proper implementation. Objectives and criteria play the most important role in making decisions. They can be divided into three categories depending on the timeline to which they refer. *Strategic* decisions, are long term and include the location of plants, size of distribution centers, the design of the supply chain and so forth. *Tactical* decisions are short term and include production planning and inventory planning. The third category is *operative* decisions, which are even more short term and include production schedule, material handling and so forth. In order to make the right decisions for the supply network, firstly the organization needs to be coordinated from inside. After that, the appropriate team needs to be set up. This team is going to make the choices, so it needs to be composed of members from all the divisions of the company, in order for rounded information to exist. In problems with shipments, the team has to search and find quickly the source of the problem in order to solve it once and for all. Customers will be satisfied if they know they can trust the organization and there will always be a win-win relationship. Lastly, the organization needs to choose the appropriate processes. For example, although decentralization is flexible to needs, it leads to poor coordination between countries and has little authority. So procurement is better to be centralized because in this way the company can control the entire global procurement process.

A critical issue in taking decisions is uncertainty. Uncertainty shows the incompleteness of our knowledge due to lack of information. Either there is no information at all or there is vague or random information. Uncertainty leads to risk. Uncertainty also leads to larger quantities of inventory. Too much inventory equals to unavailable capital. It also leads to constructing bigger warehouses, plus there is always the risk of obsolescence. Another important issue when going global is customs requirements and procedures.

If an organization cannot handle customs, can come up with increased inventory costs and delays in deliveries. These can create unhappy customers which equates to bad reputation and loss of sales.

A further decision to be made is if the organization is about to cooperate with a Third-Party Logistics (3PL) operator and which are the main criteria to choose one. Cost reduction is the main concern when choosing a 3PL operator. An emphasis, also, is placed upon the implementation of new information technologies and value-added services. The establishment of international trade and the constantly increasing competition are driving companies to optimize their strategies. When the existence of a company is threatened, reengineering and strategic alliances may be saviors. All members of the alliance must align their business processes and information systems to support decision-making across the supply network. Moreover, communication must be enhanced throughout the supply chain in order for the service level to be increased and customers be more satisfied. Equal emphasis should be placed upon operational and manufacturing costs reduction, in order to enhance profitability.

3.1.1 Models

Models are being used to solve problems. As model, can be presented a system that needs to be investigated for obtaining information about another system which will probably help in solving the problem.

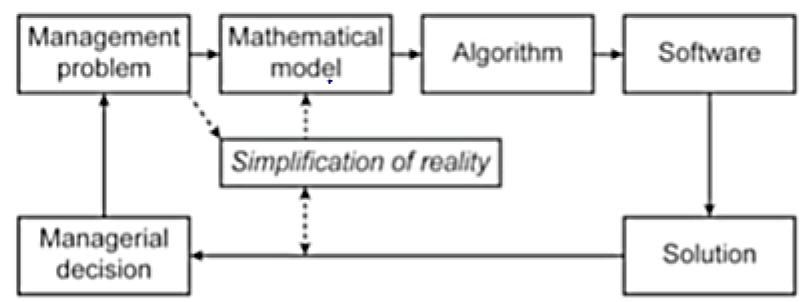


Figure 5: Model-based decision-making process

[5]

Models can be divided into *quantitative* and *qualitative.* Quantitative models are also divided into three approaches. The first one is *optimization,* which is a method that determines the best solution for a specific problem. These models usually are very complex and difficult to be solved. The second approach is *simulation*. A simulated system is created, in which potential solutions are tested in order to gain knowledge about the reaction of the real system. The third approach is *heuristics.* This is easier to implement, but usually, the quality of the solution is unknown. From the qualitative perspective, *case-studies* can be used. Real cases are being examined in order to find a correlation to the real problem and create a solution. Furthermore, for data collection, *surveys and interviews* of experts can be used.

Models can be used in order to deal with more specific issues.

- Production issues, like plant location, technology usage, and production in a single plant or in more than one.
- Distribution issues, like the number of distribution centers, their location, distribution methods.
- Issues about manufacturing a product or buy it ready.

3.1.2 The 3 Rs

[5] Dmitry Ivanov, Alexander Tsipoulanidis, Jörn Schönberger, 2017, Global Supply Chain and Operations Management A Decision-Oriented Introduction to the Creation of Value, Springer, pp. 60

As customers are always seeking added value in their shopping, companies are trying to gain their trust through competitive advantage. A good way to act is the optimization of the 4 Ps: product, promotion, price and place. From the logistics perspective, there is something to be added. This is the 3 Rs:

- Reliability
  For most organizations, too much inventory is a great cost. Inventory equals to committed resources, there is always the risk of obsolescence and it may require bigger warehouses than is necessary for fact. Those are some of the reasons organizations want to keep their inventory low. To achieve that they need suppliers who can guarantee that they can deliver whatever they need whenever they need it.

- Responsiveness
  One way to gain a competitive advantage is to be faster. Organizations need to create shorter lead times and become more flexible. A helpful tool to achieve that is time compression. Time compression is about strengthening the structure of the supply chain and make tactical time-based decisions, to optimize the speed of response to customers' needs and without affect quality negatively. A good way to achieve time compression is by making complex processes simpler. Moreover, good communication across the supply network is essential, in order to create integrated information flows. Continuous control of processes can reveal non-value activities. Elimination of those activities is necessary to reduce serious costs. If time compression is achieved, then lead times are going to be shorter which leads to a reduction of cycle stock and a shortage of the forecasting period. The shorter the period, the better the accuracy and therefore the smaller the risk.

- Relationships
  Companies are trying to reduce the number of their suppliers and create long-term relationships, with the trend to recommend single sourcing. This way, better quality can

be achieved along with better communication between partners. Commitment to common interests, innovation sharing, and integrated scheduling constitute factors able to create competitive advantages.

3.2 Facilities

3.2.1 Potential location characteristics

As organizations grow while taking part in international trade, they often expand their facilities to foreign countries, in order to serve better customers' needs. Building new facilities though is not an easy decision. A large amount of capital is about to be spent and success is not guaranteed. The expansion of facilities in a foreign country either by creating new or rent already existent, is a long-term decision to be made and there are some critical components to be thought. One of them is the market size and growth potential. As mentioned above, a large amount of capital and time are going to be spent, so there must be adequate success possibilities. A second critical factor is human recourses. Skilled labor is necessary when dealing with value-added activities, plus the organization has better chances to reduce cost in several operations. Proximity to the home country can play an important role and especially for logistics companies, transport infrastructures are crucial. Political stability, a fair legal system that solves every disagreement with integrity and government incentives can make a country trustworthy and attractive to foreign investments.

Furthermore, the sector of investments is playing a critical role in location selection. Some firms prefer to locate in free trade areas, while others need to be near an airport or near coastal areas. Competitiveness level is crucial too. Larger firms tend to locate in coastal areas, while smaller tend to create their facilities in free trade areas and far from coastal areas where competition is not that intense. Land costs, financial services and agglomeration economies are some extra factors that play an important role in this long-term decision.

Another cost to be considered is the supply cost. Organizations need to calculate if it is more cost effective to create facilities in a new market or supply this market without opening new facilities, by using transportation links. This issue can be solved by using the

Warehouse Location Problem (WLP), with the help of the appropriate software, which proposes an optimal solution to be compared with the real world data and then proceeds to the implementation stage or try another solution.

3.2.2 Selecting a location

When organizations find some locations that meet their requirements, it is time to choose the one. There are several methodologies that help decide in which location to create new facilities. One of them is the *Factor-Ranking Analysis.* The way this methodology gives the optimal location is very simple. Firstly, potential locations and several criteria need to be identified. Secondly, the list of locations needs to become as short as possible. Lastly, the location with the best score in the selected criteria is considered as optimal.

A second methodology is *Utility Value Analysis.* This method gives the optimal location in four steps. In the first step, the selection of the economic region takes place. Some critical criteria for this selection are the attractiveness of the region, political and legal stability. In the second step, it is time to select one country inside the selected economic region. An important role plays the quality and quantity of the human recourses, the availability of suppliers, appropriate infrastructure and so forth. The third step consists of the selection of a region within the country. Finally, in the fourth step, it is time to select the facility location. Some of the criteria that help in the selection are the cost of land, opportunities for expansion, opportunities for suppliers to locate nearby, environmental issues and so forth.

3.2.3 Factory planning

When firms decide to expand their production in a foreign country, they may need to build a factory. A team needs to be set up, in order to create the ideal layout of the factory, according to leadership' will. What is following, is an adaptation to reality. Subsequently, a decision for the final factory layout has to be made, in order for the detailed planning to start. In this stage, block layouts have to be designed, the exact positions of machines and equipment. Office infrastructure has to be designed as well. Furthermore, environmental issues have to be considered, like waste emissions and everything else that is needed so that the factory can be created.

A further decision to be made when a new factory is about to be created in a foreign country is the type of factory. Some types of factories are presented below.

- An offshore factory is established for low-cost production of items about to be sold or used for additional production.
- A source factory is established for low-cost production as well, but it can achieve the best production quality for a specific product compared to the whole company's network.
- A server factory is established in order to serve a specific market and it has the potential to modify some of the characteristics of the product to fit the local market.
- An outpost factory looks like an offshore, but its primary role is to be close to competition and get the knowledge that the company needs.
- Finally, a lead factory is established with the purpose to create new products, new processes and in general to be innovative.

Factories frequently have more than one roles, according to the firm’s needs and strategies.

3.3 Sourcing

According to Chopra and Meindl (2012), sourcing is *the "set of business processes required to purchase goods and services"*. In this set, some of the processes that are included are the selection of the suppliers, product design, collaboration across the network and control of suppliers' performance. In general, the relationships with suppliers are included in order for the materials, capital, tools and all necessary means of production to be available. According to Cook (2007), "*sourcing is transferring the site of your manufacturing to a foreign location but maintaining some or all of the control over ownership of the manufacturing process.*" Sourcing is a very important activity in the Supply Chain. *The purchased parts and materials can account for over 60 % of the cost of finished goods; for retail companies within the SC, this can be as high as 90 %* (Ivanov, Tsipoulanidis and Schönberger, 2017).

Sourcing connects supply with demand. But how this process is going to be performed effectively? Firstly, companies have to decide about the materials required. The type, quality, volume. The second decision to be made concerns the ordering process. Specifically about delivery frequencies, timing, invoice control, goods reception and approval. Thirdly, supplier research has to be performed. Evaluation of the possible suppliers' bases, potential partnerships and negotiations have to be examined. After that, it is time for the supplier network to be managed. Here we talk about on-time deliveries, reliability, flexibility and the establishment of strong relationships. Another crucial decision to be made from the company is what to produce and what to buy ready. Managers have to decide about the most economically preferable solution. The economic aspect though is not the only one that needs to be considered. There are some other factors, as well, such as competitive factors and more specifically the risk of losing one's competitive advantage by letting others to get some of the knowledge needed. There are countries that there is no such thing as patent protection. In this case, even if the buy option is economically preferable, the own production option is the one that has to be chosen. Most governments have free trade zones. These zones offer tax and duty relief to companies, which import spare parts, raw materials, assemblies and so forth tax-free, with the requirement that the final product is manufactured there. Tax and duty are applied to the materials but not to the final product.

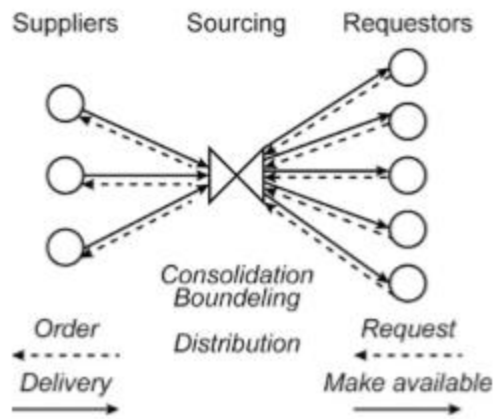


Figure 6: Sourcing process[6]

3.3.1 Sourcing strategies

In this phase, companies have to decide about the sourcing strategies that they are going to follow. Here we discuss two different options. The first one is *Single or Multiple Sourcing.* In this area, companies have to choose the appropriate number of their suppliers. By choosing the single sourcing strategy, companies can achieve volume bundling effects. They can also establish long-term agreements, price stability, and low transactional costs. However, depending on just one supplier can be too risky. Thus, it might be better to choose two or more suppliers, to achieve a better balance of flows and reduce the total risk. Some companies tend to have more than one suppliers, even only one of them provides about 80% of the volume and the others just the remaining 20%.

The second strategy which refers to the location of the suppliers is the *Local or Global Sourcing.* In the first corner, there is the local sourcing strategy which is good because the company and the

[6] Dmitry Ivanov, Alexander Tsipoulanidis, Jörn Schönberger, 2017, Global Supply Chain and Operations Management A Decision-Oriented Introduction to the Creation of Value, Springer, pp. 102

suppliers share the same norms, same language, and culture. They also use the same currency and they are developed under the same political climate. However, the number of suppliers is very limited and thus the power of the company which buys is limited in terms of better prices and services. In the opposite direction, the global sourcing strategy gives the opportunity to the interested company to compare and negotiate with suppliers because there are too many and thus the power of buyer is greater. In global sourcing, there is not just more, but different types of suppliers and a furthermore larger portfolio of products and services to choose. Additionally, a trend is direct deals, which means cutting out the middleman, the advantage of which is increased margins. This margin benefit is used by companies by lowering the prices and thus gain market share. The trick has been – and will be – to exploit the elasticity of demand by just enough to get more volume than the margin that has been conceded. Getting this right makes both sales and profits grow (Waters, 2007). This type of strategy has its disadvantages, as well. There is longer transportation time, longer response time and perhaps larger lot sizes. Moreover, chains become extended and thus lead times are getting longer, plus there is less agility in responding to changes in the market. These situations need excellent planning and forecast accuracy. Additionally, buyer and supplier share different culture, different norms, and language, which is able to incommode the relationship. For global sourcing, items of high volume, steady demand, and low transportation costs are most preferable (Ivanov, Tsipoulanidis and Schönberger, 2017). A lot of firms usually prefer a mixed sourcing strategy that includes both local and global sourcing.

As we talk about Global Supply Chain Management, let's present some additional reasons why global sourcing can be a good idea.

- Companies can obtain lower exchange rates for the purchased order when the exchange rate is down in the country of the supplier. This could be an opportunity to make a price agreement in the long-term.
- A critical factor that leads to foreign sourcing is the reduced labor cost and product prices of foreign countries. Especially, when the market of that country is

very extensive, the volumes that are produced should be large enough to produce economies of scale and thus lower prices.

- Firms can find out new products, new trends and fresh ideas by collaborating with foreign suppliers, which can help them become more competitive in the local market.
- Working with foreign suppliers can make a company more powerful in terms of negotiating with local suppliers, because of the more alternatives available.
- When considering products with ethnic background, importing them from the country of origin can influence the sale.
- Moving plants to foreign countries spread the risk. Diversification is a long-term risk mitigation factor.
- Local tax laws of some countries are created towards the direction of attracting foreign investment and thus it is financially beneficial to develop manufacturing there.

3.3.2 E-Procurement

Development of new technologies, global communication systems and the optimization of the traditional EDI systems, have contributed to the establishment and development of e-procurement. Systems with user-friendly interfaces, based on electronic catalogs and highly automated processes, allow the user to make faster and easier orders from anywhere, anytime. These systems are integrated so they can provide the visibility that is necessary for flow control. Orders are usually repetitive, as there is always a background of all the previous orders. By using e-procurement, companies can check anytime the availability of products, prices and they can track their order just by using a computer. So this process can be a savior in terms of time and other processing costs and through this, companies can use the gained resources to other processes that can make a difference. There are two critical issues concerning e-procurement. The first one is the management of the electronic catalog. The catalog should always be updated, comprehensive and accurate. The second is referred to the security of payments. The system used by the company should provide a highly secured interface in terms of data transfer.

3.3.3 Global Sourcing Network Design

When designing a firm's global sourcing strategy it is important to deal with issues referred to the physical location of manufacturing. It is about answers in questions like "witch actions will be performed, at which facilities and for what reason" (Wood, Barone, Murphy, Wardlow, 2002). This is the configuration aspect. Another aspect, coordination's aspect, answers the "why" and "how" questions of the design process. Its main purpose is to help the firm gain and maintain a global competitive advantage. After answering these questions it is time for the firm to look for suppliers. Firstly, it has to make an assessment of global sourcing opportunities. Secondly, the firm has to find some alternatives in sourcing, just in case, someone becomes temporarily unavailable. After that, a firm has to find a decent number of suppliers and choose with who it is going to cooperate. Subsequently, a good relationship has to be set up between partners and furthermore a win-win situation, in order to establish a strong and long-term bond. Finally, it is critical to measure performance regularly and try to get better. This can be met with the establishment of models that use quantitative and qualitative measurements such as on-time deliveries, completeness of orders, units accepted or rejected and so forth. "*Whatever the measures or techniques used, the important factor is the continuous nurturing of the sourcing relationship by both buyer and seller*" (Wood, Barone, Murphy, Wardlow, 2002).

3.4 Production

3.4.1 Planning

As customers gain more and more power on the market, the operation of production is also customer oriented. Firms should know the exact amount of products the market needs, otherwise, there will be too much inventory, thus extra cost or lack of products, which equals less profit. So firms need an excellent production planning. Aggregate planning tries to meet forecasted demand while minimizing costs. This type of planning needs to be as accurate as possible, otherwise, if the plan is poor there will be either lost profits because of the inability of inventory to meet demand or a large amount of excess inventory. Manufacturing resource planning (MRP) designs production and purchasing plans, using data from demand forecasts and matching them to the business plan and to all available constraints from finance, manufacturing and so forth.

Aggregate planning gives information about production quantities, inventory held, backlogs, customer service level, the condition of machines and much more. Firms use this information to match supply and demand by using inventory or varying human labors' size to deal with demand changes, using subcontractors and by making changes to the products or the prices to influence demand. A critical issue of aggregate planning is to make the right trade-offs in order to achieve a balance between costs related to capacity, inventory, and backlogs. There are three alternatives that help with the trade-offs. The first is related to production capacity and claims that it should be changed according to demand fluctuations. The way capacity can change is by changing the size of inventory held in order to deal with high or low demand periods or by deviating the human labor size. The second is related to demand and it is about finding a balance between supply and demand, by changing lead times or trying to influence demand with strategic tricks like promotion advertising. The third alternative is a mix of the two mentioned above.

Customers demand responsiveness from companies. They want their order to be there as soon as possible. One useful tool firms can use is postponement. Postponement is about differentiating the generic product or service into a specific end-product or service according to customers' order. According to Van Hoek (2001), it is *"an organizational concept whereby some of the activities in the Supply Chain are not performed until customer orders are received".* This way there is safety stock only for one generic product, where it would be safety stock for many more end-products. By not having end-products in stock, there is no risk of obsolescence, as well. Another tool is modularization. According to Baldwin and Clark (1997) modularization is about "building a complex product or process from smaller subsystems that can be designed independently yet function together as a whole". This way firms can achieve economies of scale.

3.4.2 Push – Pull Processes

There are two production processes, which differ in terms of the production moment and demand knowledge. Production takes place either before or after the placement of an order. In the push process, production takes place before the placement of an order, in anticipation of orders, without knowing customer demand. In the opposite direction, in the pull process, production takes place in response to an order, with certain customer demand. In the first option firms can achieve economies of scale, they are highly flexible due to the inventory level and they can also achieve short supply times. In the second option, the advantages are good responsiveness and highly individualized production.

3.4.3 Types of Production Strategies

Below, some production strategies are mentioned, which are highly linked with the push-pull processes.

- *Make to stock strategy* is used for mass production of standard products. With this strategy, economies of scale can be achieved, as well as flexibility in production quantity according to demand. A critical issue can be the size of the inventory, which can lead to serious costs.

- *Assemble to order strategy* refers to high product individualization, which takes place within the manufacturing. The assembly is unique for each customer. With this type of strategy, high flexibility and low inventory levels can be achieved.
- *Make to order strategy* is a highly individualized production strategy, which starts to be unique in the early stages of the components manufacturing of the final product. "*Make To Order can be recommended for customer-specific products with fluctuating demand"* (Ivanov, Tsipoulanidis, Schönberger, 2017)
- *Engineer to order strategy* is referred to as the highest degree of individualization. It is used in the production of high value and complex products, like houses, where the customer is involved in the engineering process, in the selection of design and materials about to be used in the production phase.

3.5 Distribution Planning

One core element of global logistics is transportation. The transportation network is strongly related to the efficiency of the global supply chain. There are a lot of distribution ways and modes, with the most used to be the road, rail, sea, air, and multi-modal transport. Multi-modal transport is highly used, connected with just-in-time logistics capability, with an emphasis on partnership between carrier, shipper, and customer. As multi-modal transport, is considered the transportation of freight to a specific destination, by using several transport modes. Better security can be achieved by using multi-modal transport, because of the reduction of cargo handling. Another advantage is that the freight is transported faster and in most cases efficiently. The goal is to exploit the main advantages of different modes of transport and at the end of the day be more efficient. Shipping lines, for instance, fit well with intermodal transport, as they can provide hinterland routes in many cases.

Customer satisfaction should be the first priority for every company. It is strongly related to a company's ability to react immediately to customer demand and be highly agile and reliable. In order to achieve customer satisfaction and be closer to them, companies in some cases tend to establish new facilities. However, companies have to examine some costs related to that. Inventory cost, for instance, tends to grow when further facilities are established. Another cost driver is the cost associated with the usage of new facilities. A final important type of cost that has to be considered, is transportation costs, which typically comprise 6-8% of the company's costs according to Ivanov, Tsipoulanidis, Schönberger (2017).

3.5.1 Partnership

The international market is very complicated. There are risks and threats, as well as opportunities that can only be found by experienced personnel. Partnerships can help firms face those threats and take advantage of the opportunities. Above, is mentioned the importance of coordination between carrier, shipper, and customer. A top-performing logistics department is a valuable partner for a firm to have because this partner can negotiate the transportation freight rates that can reduce the overall transportation costs. A broker is another good partner to have. Brokerage companies can also negotiate transport freight rates, even more than the logistics department. Furthermore, they can handle bureaucratic issues and also the payment of some costs like customs and additional freight charges. By doing all these, they save time and additional costs to organizations. Experienced logistics partners can take efficiency to the next level, as they may find shorter routes, as well as the best combination of transportation means for the firms' transportation planning.

Finding an appropriate partner is a crucial issue. Before making a decision it is very important for a firm to consider some requirements. To start with, the size and flexibility of the service provider should be taken into account. Additionally, a company must know the other clients of the service provider, as well as the modes of transport that the provider is involved. Another issue is the ability of the systems used to meet the transport requirements of the countries that the firm work with. Furthermore, what insurance certificates provider has and does the provider offer electronic status information about the freights? As global trading is very complicated, there are much more issues to consider before sign a contract.

3.5.2 Transportation strategies

- Postponement

  According to Ivanov, Tsipoulanidis, Schönberger (2017), using postponement *"The incoming demand is merged with postponed quantities to the recently available demand. Full truck loads (FTL) are derived from the available demand quantities but residual quantities are postponed until a later day of the week".* Using only fully loaded trucks, economies of scale can be achieved. This strategy can be applied, making the assumption that there is no urgency related to the shipment of demand. In the opposite case that demand requests immediate transportation of the shipment, this strategy is fragile and can no longer be applied.

- Milk-Runs

When logistics department wants to use fully loaded trucks, but this cannot occur from every individual pickup location, the milk-runs strategy can be a savior. According to this type of strategy, one truck visits more than one pickup locations in order to reach the full load possible and then it brings the complete load to a common final destination. An issue related to this strategy is that it has to be adapted to daily demand, thus in some cases the use of an almost empty truck is about to be inevitable.

3.5.3 Distribution Networks

Distribution network structures are strongly related to the transportation network design. When production strategy is *make to order* or *assemble to* order, as mentioned in the Production chapter, storage is taking place on the manufacturing site and distribution is made directly to customers. Another option is multi-stage systems, which contain intermediate warehouses, distribution centers, cross-docking centers and so forth.

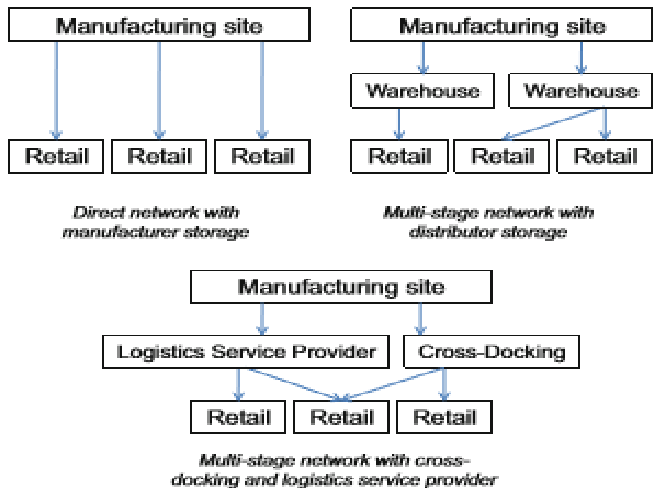


Figure 7: Types of distribution networks[7]

*"Cross-docking implements the idea of the consolidation of goods from inbound trucks to outbound trucks via an intermediate transit point (i.e. the cross-docking center). The special feature of cross-docking is that the goods do not remain in the warehouse longer than 24 h" (*Ivanov, Tsipoulanidis, Schönberger, 2017). Using cross-docking, economies of scale can be achieved, along with low inventory levels. Furthermore, cross-docking allows more frequent deliveries and faster product flow with increase in fleet capacity utilization. This type of network requires perfect information flow, as it is very complex, along with an impenetrable security system for data protection.

[7] Dmitry Ivanov, Alexander Tsipoulanidis, Jörn Schönberger, 2017, Global Supply Chain and Operations Management A Decision-Oriented Introduction to the Creation of Value, Springer, pp. 242

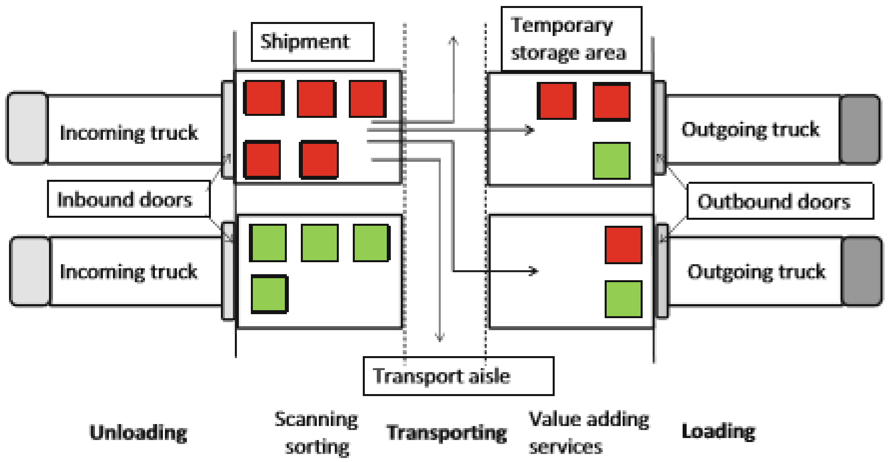


Figure 8: Cross-docking terminal[8]

3.5.4 Elements of Transport Modes

- Speed
  Speed is an important element in transportation when there are delivery deadlines. The speed of delivery is critical in long-distance supply chains and for products of high value and short life cycle. It is an element which helps manufacturers and retailers to avoid the risk of obsolescence. Air freight is considered to be the fastest way to deliver products.

- Frequency
  Frequency of service is a very important element when products can only be sold in small quantities at frequent timelines. Frequency helps to achieve low stock levels, with reduced lead times, as well as it reduces the risk of obsolescence and warehouse costs. When customers demand a variety of products, frequent replenishment, and low stock levels are firms' top priorities.

- Warehousing
  Although modern supply chains tend to eliminate warehouses and safety stocks, there are still some

[8] Dmitry Ivanov, Alexander Tsipoulanidis, Jörn Schönberger, 2017, Global Supply Chain and Operations Management A Decision-Oriented Introduction to the Creation of Value, Springer, pp. 243

advantages of warehousing. It allows the build of safety stock in anticipation of seasonal demand or just change of demand. It can improve customer service by faster order preparation and delivery, as well as it can achieve economies of scale by allowing longer production runs. However, large stock levels are equal to increased inventory costs and increased risk of obsolescence.

3.5.5 International Distribution

In international distribution, everything begins with an order. When buyers' inventories turn low, an order is placed through EDI. When the seller have available quantities, the products are about to be sent. After that, goods must be labeled in order to reach their destination through the distribution channel and become clear that they are about to be sold from retailers in the country of import. Furthermore, goods are packaged, in order to prevent damage during their journey either from mishandle or from natural causes. In some 'markets a recyclable package is considered to add extra value to the product. After the goods are shipped, the seller sends information to the buyer about the transport mode, the route and offers tracking and tracing support as products move along the transport network. A serious problem in international distribution is piracy. Global supply networks should be aware of this panacea and be strong and ready to face it.

3.6 Outsourcing

Outsourcing made its appearance in the mid-1970 and according to Waters (2007) it *"describes the deliberate movement of a series of connected business processes to a third party, which manages them on behalf of the company".*

3.6.1 Reasons for outsourcing

Outsourcing in global supply chains is a very common practice. From a firm's perspective, some reasons for that are:

- Lack of management resources
- Demand for higher service level
- Lack of expertise
- Increased supply chain complexity
- Pressures to do it fast
- Need for inventory reduction
- It is not core and there is the need to focus on core competencies
- The services of the provider are more tailored to clients' requirements than ever before

Some financial reasons, such as:

- Limited access to investment funds
- Costs are too high for the firm to do It alone
- One change may affect other operations, which may result in additional costs
- A provider can borrow at a better rate

In the technology sector, firms usually buy the needed software and outsource the implementation phase, or in collaboration with a provider, they make their own integrated software. In general, if a company focuses on some operations, using almost all its resources there in order to optimize them, then outsourcing the others should be considered. The reason is that using all the resources to other operations does not give space for the rest operations to get optimized and thus achieve the desired service level and lower costs.

3.6.2 Outsourcing drivers

When demand points get shifted, existing distribution centers and depots may stop serve as they should. It appears, then, the need for logistics to be relocated and for some distribution centers to be closed and new ones to be opened. This attempt is very costly and time-consuming, thus it gets attractive for outsourcing.

Logistics providers usually have expertise in the technology sector. They offer integrated systems and high-tech development concerning information technology, such as warehouse management systems (WMS), track services, radio frequency identification (RFID) and so forth.

As mentioned above there are several cost-related factors that lead firms to outsource some of their operations. Also, investments that firms have to make, in order to optimize their operations are costly and thus high risky. Service providers can spread the risk of investments over a number of clients.

The size of a company is strongly related to the decision for outsourcing logistics. A large company may be able to handle global distribution in-house. On the opposite direction, a smaller company cannot handle global transport operation cost effectively on its own, so outsourcing seems to be the only way. In the case of multi-user operations, service may be better, due to more frequent deliveries of third-party providers to delivery points.

The development of reverse logistics is an important factor which leads especially smaller companies to outsource this operation. The main reason is the difficulty to organize returns and delivery times with customers.

3.6.3 Ways to do it

There are several ways to outsource logistical operations. The way chosen depends on the firm’s goals and strategies. One way to do it is takeover the system and have the full ownership. Another way is the creation of joint ventures with the provider. In this case, the firm retains part of the ownership and thus involvement in the operations. A further way is to spin-off logistical systems as subsidiaries, making them separate profit centers.

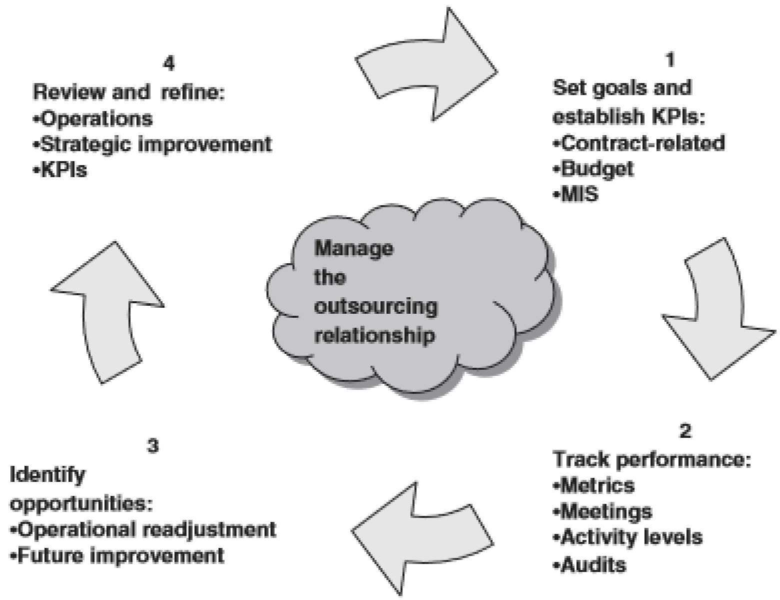


Figure 9: Outsourcing management[9]

3.6.4 Outsourcing risks

Outsourcing involves the collaboration of two different companies and especially in the global market with different strategies and goals. Cultural differences between the two parties can lead to several problems, as well. The alignment of the two strategies, trust, and respect for each other are critical components for this deal to succeed. A further issue that may occur is related to the confidentiality of information when the provider has more than one clients. The issue here is the possible mixture of a company's products with the products of the competition. An additional possible risk may be the vulnerability of the supply chain against unpredictable external events, such as natural disasters, terrorist attacks and so forth.

A Warehousing Education and Research Council (WERC) research showed that 55 percent of logistics outsourcing relationships are

[9] Alan Rushton and Steve Walker, 2007, International Logistics and Supply Chain Outsourcing From Local to Global, Kogan Page Limited, pp. 332

terminated after three to five years. Some reasons that lead there are:

- Inaccurate operational and volume information from a customer
- Inappropriate resources to manage 3PL
- Unrealistic expectations
- Poor implementation
- Focus only on cost reduction
- Over-promising
- Not focused on continuous improvement
- Poor service level
- Bad performance measurement system
- Poor communication between parties

3.6.5 An overall approach

As logistics gain more and more strategic importance, service quality is the main priority. As a result, the number of carriers used has been decreased and the selection of the appropriate carries has become more complex and very important. Very critical issue as well, is the selection of the provider of logistical services. There is the need to develop long-term partnerships, flexible with proactive reaction to change and of course win-win situations. In this effort, adequate information sharing is critical, as well as a performance measurement system. A system needs to be set, with key performance indicators like customer service level, productivity measurements, financial performance, and cost savings. The cost of logistics operation in relation to the expectations of the budget plan is a good way to monitor performance. A further way is the identification of changes in business volumes and of course the traditional benchmarking, where a firm is compared to the leaders. It is important, as well to include incentives for the achievement of certain goals, to gain the extra push. As stocks and buffers in retail stores tend to be reduced or even eliminated, the performance of logistics providers is measured by the establishment of their integrated delivery systems and information systems, which need to be more accurate and timely than before. Customers should stay involved, but not control the provider and let the provider make decisions on customer's behalf.

A development that has helped overcome some problems of third-party logistics (3PL) providers, related to the width of services, quality of the network, information technology and many more, was the development of fourth-party logistics (4PL) providers. According to Rushton and Walker (2007) *"a 4PL is an integrator that assembles the resources, capabilities, and technology of its own organization and other organizations to design, build and run comprehensive supply-chain solutions".* Some benefits of 4PL are:

- Single point of contact for all logistics aspects
- The management of multiple logistics providers being handled by a single organization
- Broader supply chain services
- Continuous monitoring of supply chain performance
- Benchmarking in global level

Outsourcing logistics operation in a global supply chain needs to be set up carefully and if be managed right, it can be very beneficial for the whole supply network.

3.7 Integration and performance measurement

Global competition is increasing the need for enterprises to internationalize and expand their operations in foreign countries that offer comparative advantages. Because of this, there has been an increase in the global flow of freight transportation, which has increased the competition between logistics providers and their efforts to increase their market share or defend it. Other enterprises follow more defensive strategies in order to prevent themselves from being taken over or prevent competition to become too strong.

3.7.1 Integration strategies

In this direction, multinational enterprises follow three different integration strategies: horizontal, vertical and conglomerate. The first one, horizontal, describes a situation that the investment is carried out in the same industry. The main goal of this strategy is to penetrate new markets or expand to existing markets of foreign countries, create efficient transport chains and get developed by exploiting economies of scale and scope as they get bigger. After a company achieves economies of scale, it can enhance the productivity of core activities by optimizing vehicle capacity utilization or by optimizing the use of its warehouse.

The second strategy, vertical integration, occurs when investment is carried out at the same industry, but at different stages. This allows logistics companies to diversify their services in three ways. The first option aims to offer door-to-door links to clients. The second option aims to extend the offered range of services and the final option is offering complementary activities to the core service. Vertical integration aims to penetrate new markets of services and develop new capabilities.

The third strategy, conglomerate integration, *"happens when the investment in a logistics activity is carried out by a non-logistics multinational enterprise"* (Mariotti, 2015). These inventors are usually larger than logistics firms and have available a large amount of capital for this purpose. The main goal of this strategy is to achieve economies of scale and reduce transactional costs.

3.7.2 Performance measurement

Supply chain is one of the most important elements in relation to the customer service level. The main goals of enterprises are the reduction of total cost and the optimization of service level and return on assets. As a consequence, the existence of a performance measurement system is crucial, in order to have a progress report. A part of the progress report is useful for the investors, who want to be able to judge their investments and make decisions and also the banks are also interested in this report in order to make their own decisions which related in making loans.

A model that measures performance and fits well with supply chain thinking is the balanced scorecard. According to Waters (2007), *"a balanced scorecard provides a picture of a business by combining financial measures with assessments for customer satisfaction, key internal processes, and organizational learning and growth"*. It contains several perspectives related to financial issues, customers, internal value, learning, and growth. A typical balanced scorecard is presented in the figure below.

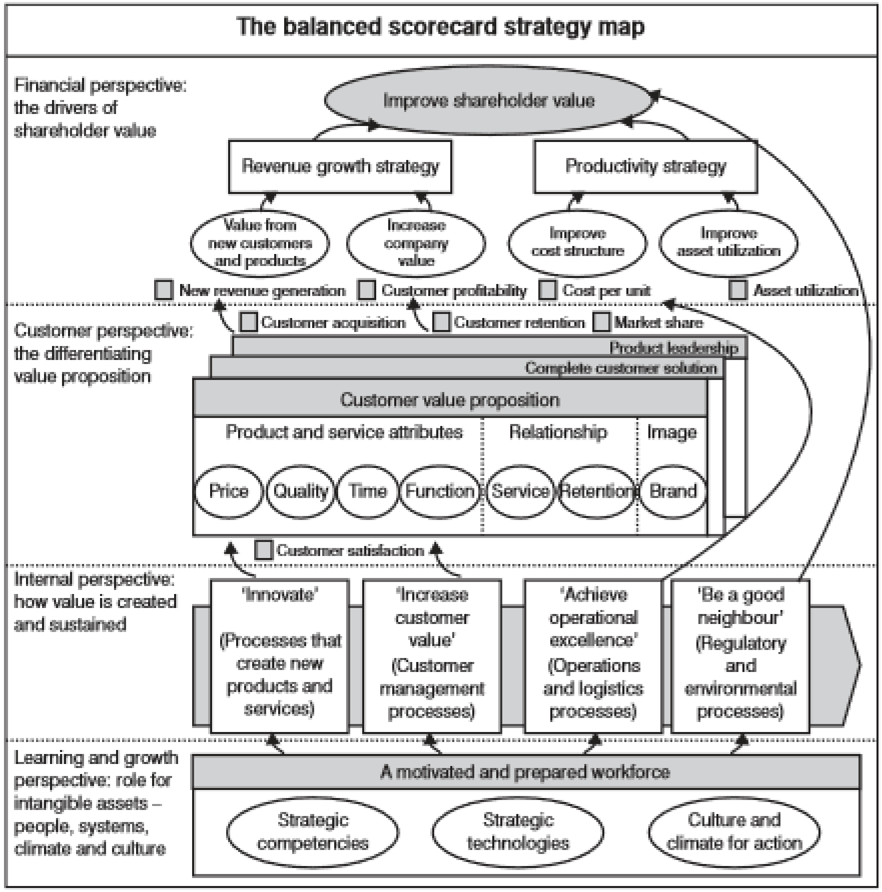


Figure 10: Balanced scorecard[10]

A further way to measure performance is by using the *service level agreements (SLA)* tool. It is about how various functions contribute and influence the performance of a whole supply network and about specific measurements by objectives, like quality and lead time in order to improve the overall performance.

As Waters (2007) says, although measurements are generic for most firms, competitive reasons, technology and characteristics of product and market create a measurements hierarchy across the chain. In the first level, measures are about the goal for change and specifically have to do with orders on time, stock cover and so forth. In the second level, measures are used to provide a better understanding of the results of the first level measures, like quality

[10] Waters, 2007, GLOBAL LOGISTICS New Directions in Supply Chain Management fifth edition, KOGAN PAGE, pp. 256

fill rate and finally in the third level, measures are used to solve specific problems and contribute to the overall improvement of the chain.

There are a lot of models and software in the market to be used for performance measurements. Companies should find the best combination that offers insight into the factors which are driven by the change and incorporate best practices in their portfolio, to better serve customers.

3.8 The future of global supply chains

Global trade has been established and more and more enterprises take place in the global market. In this chapter are presented some future trends that will be faced by global supply networks. Firms tend to give importance to integration, agility and performance measurement. Over the next years, companies will be characterized by a more synchronized supply chain, increased business process integration, stronger commitment and long-term relationships with suppliers and customers, higher quality products, lower inventory, and faster distribution systems. Furthermore, new multi-country alliances are about to be created and countries are about to be added to existing alliances. This will affect distribution systems and therefore the whole design of global supply chains.

A lot of shippers have an identification related to the specific mode of transportation they use. Some of them are more interested in the results of transportation and to meet service requirements rather than the means used. This is referred to as "amodalism". In the near future, it is expected that there will be no shippers with an identification of a specific mode of transportation and everyone will be "amodal".

An issue that concerns everyone is the protection of the environment. Developed countries are already working on green models and developing countries are in a promising way, as well. The future is about to find companies working on adjustments to their strategies and practices, in order to persuade customers and associates that they are protecting the environment.

Last, but certainly not least, that appears very promising, is space transport. At this time it is challenging to supply the International Space Station. It will be very challenging for logistics managers in the future to find the optimal way to supply multiple sites that will be located somewhere in space.

Chapter 4

4.1 Linear single-commodity minimum-cost flow problem

In this section linear single-commodity minimum-cost flow problem is presented and subsequently, it is analyzed how to solve this type of problems. To start with, linear single-commodity minimum-cost flow problem is part of freight traffic assignment problems. *"Freight traffic assignment problems amount to determining a least-cost routing of goods over an existing network of transport services from their origins to their destinations"* (Ghiani, Laporte, Musmanno, 2013). They can be classified as static or dynamic. Static problems are those that are not affected by time. They are formulated on a directed graph G = (V, A), where each vertex V corresponds to a facility and each arc A represents transport services linking the facilities. Some vertices represent origins of transport demand for one or several products, while others are destinations. Each arc is associated with a cost and a capacity. In dynamic problems, transport services are affected by time and they are formulated over a specific planning horizon. Like the static version, each arc is associated with a cost and a capacity. Below is presented a static graph of a transport system with three terminals (A, B, C), that includes four possible transport services from A to B, from B to A, from B to C and from C to A and the same transport system in a dynamic version with a four day planning horizon. In the dynamic version, there may be supersinks, which describe economic sanctions and penalties in case of transport service failure.

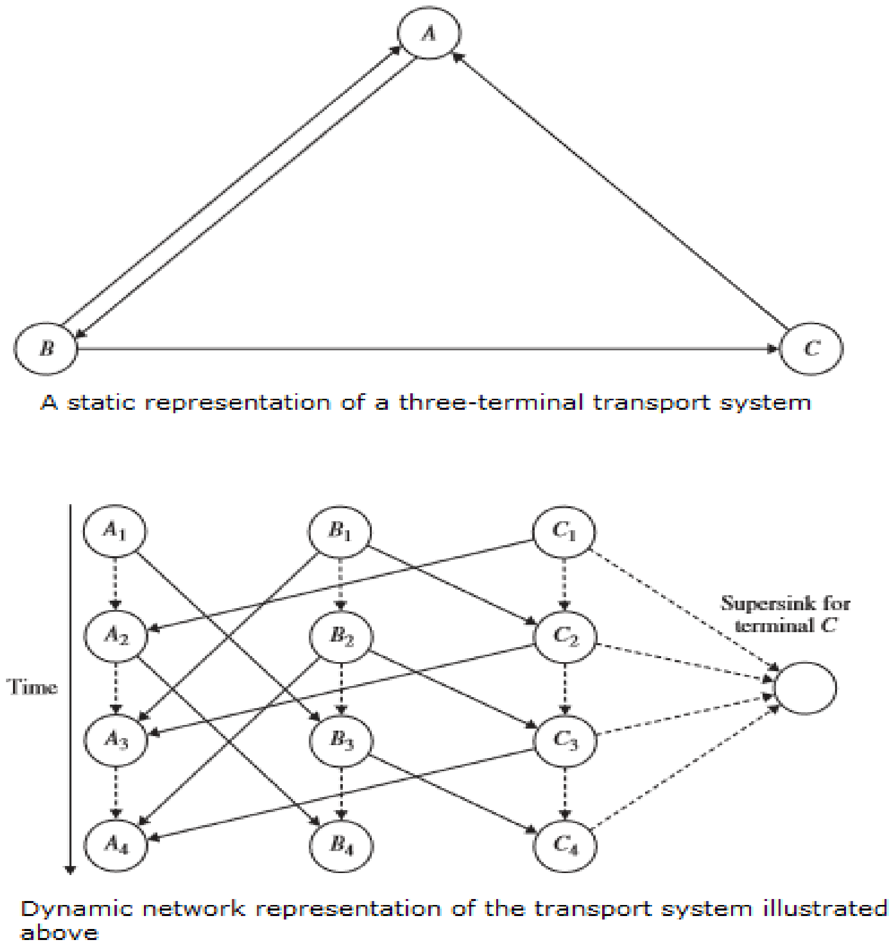


Figure 11: Static and dynamic freight traffic assignment problem[11]

4.1.1 Model formulation

The linear single-commodity minimum-cost flow problem (LMCFP) is a static problem, which tries to find out the least-cost routing of goods over an existing network of transport services from their origins to their destinations. Let O be the set of origins of commodity; D the set of destinations of commodity; T the set of transshipment points of commodity; o_i, i ∈ O, the supply of commodity of vertex i; d_i, i ∈ D, the demand of commodity of vertex i; u_{ij}, (i, j) ∈ A, the capacity of arc (i, j). Finally, let $C_{ij}x_{ij}$, (i, j) ∈ A be

[11] Ghiani, Laporte, Musmanno, 2013, Introduction to Logistics Systems Management second edition, A John Wiley & Sons, Ltd., Publication, pp. 327

the cost for transporting x_{ij} flow units of the commodity on the arc (i, j).

4.1.2 Objective function

$$Minimize \sum_{(i,j) \in A} CijXij$$

4.1.3 Constraints

1.

$$\sum_{[j \in V:(i,j) \in A]} Xij - \sum_{[j \in V:(i,j) \in A]} Xji = \begin{cases} oi, \ \ if\ i \in O \\ -di, if\ i \in D, \ \ i \in V \\ 0, \ \ if\ i \in T \end{cases}$$

2.

$$Xij \leq \mathrm{Uij}, (\mathrm{i}, \mathrm{j}) \in A$$

3.

$$Xij \geq 0, (i, j) \in A$$

The objective function is the total cost. The first set of constraints correspond to the flow conservation constraints holding at each vertex i ∈ V for the commodity. The second set of constraints impose that the flow of the commodity does not exceed capacity u_{ij} on each arc (i, j) ∈ A and finally, there is the constraint of non-negativity.

The LMCFP is a structured linear programming problem and so it can be solved through the simplex algorithm, the network simplex algorithm or through a linear programming procedure. For the purpose of this research, we assume that there are no capacity constraints. Given that, our linear single-commodity minimum-cost flow problem is formulated as follows.

$$Minimize \sum_{(i,j)\in \mathrm{A}} CijXij$$

Subject to

$$\sum_{[j\in \mathrm{V}:(\mathrm{i,j})\in \mathrm{A}]} Xij - \sum_{[j\in \mathrm{V}:(\mathrm{i,j})\in \mathrm{A}]} Xji = \begin{cases} oi, \ \ if\ i\ \in\ \mathrm{O} \\ -di, if\ i \in\ \mathrm{D}, \quad \mathrm{i}\ \in\ \mathrm{V} \\ 0, \ \ if\ i\ \in\ \mathrm{T} \end{cases}$$

$$Xij \geq 0, (i,j) \in\ \mathrm{A}$$

Using the network simplex algorithm there are some steps to be followed in order to solve this problem.

Step 1. Find an initial basic feasible solution $x^{(0)}$. Set h =0.

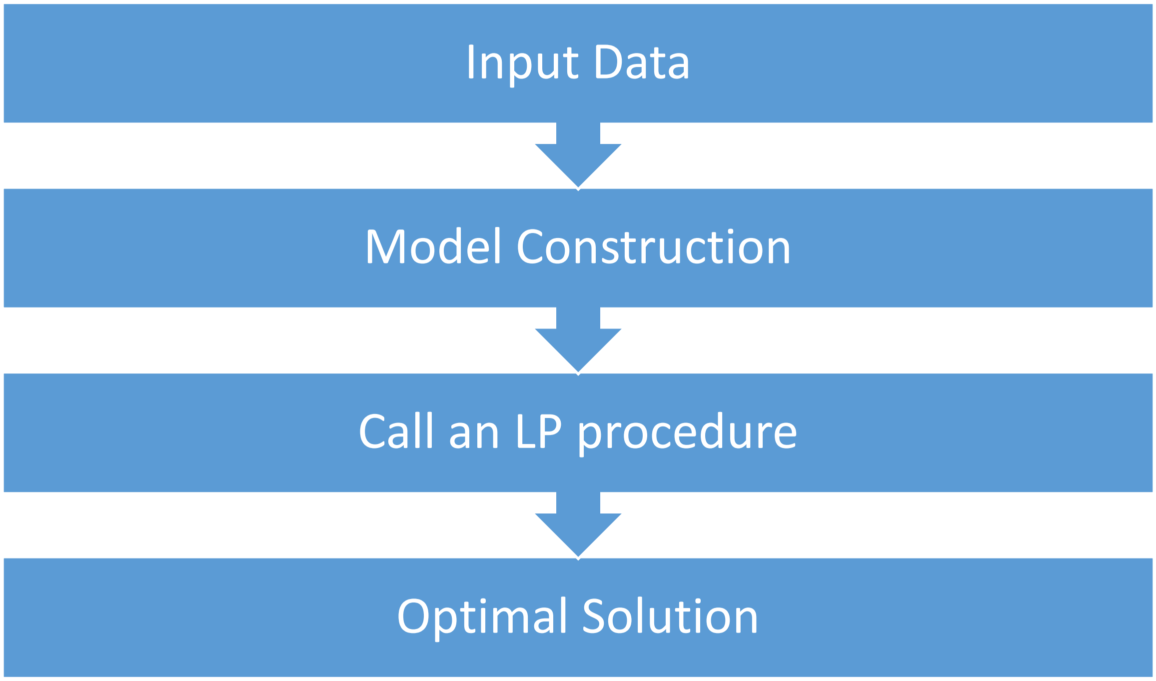
Step 2. Determine the reduced costs $c'^{(h)}$ associated to $x^{(h)}$.

Step 3. If $c_{ij}'^{(h)} \geq 0$, (i,j) ∈ A, $x^{(h)}$ is an optimal solution; otherwise choose a variable x_{vw} such that $c_{vw}'^{(h)} < 0$.

Step 4. Select a variable x_{pq} coming out of the basis and substitute x_{pq} for x_{vw} in the basis. Set h = h+1 and go back to Step 2.

In order to find a feasible solution (if any exists), *the big M method* can be used.

To solve this type of problems, some steps will be followed as presented below.



1. **Input Data**
    1.1. Number of vertices
    1.2. Connection between vertices
    1.3. Transportation cost of each arc
    1.4. Capacities and demands of each vertex

2. **Model Construction**
    2.1. Objective function

$$Minimize \sum_{(i,j)\in A} CijXij$$

    2.2. Constraints

$$\sum_{[j\in V:(i,j)\in A]} Xij - \sum_{[j\in V:(i,j)\in A]} Xji = \begin{cases} oi, & if\ i \in O \\ -di, if & \in D, \quad i \in V \\ 0, & if\ i \in T \end{cases}$$

$$Xij \geq 0, (i,j) \in A$$

3. **Call an LP procedure**

4. **Optimal Solution**
    4.1. Minimized total cost $C_{ij}x_{ij}$

4.2. Optimal flow of commodity

4.1.4 General solution

In this section, a general solution for the linear single-commodity minimum-cost flow problem is created, using the Matlab software.

First of all the number of vertices needs to be stated.

LinearSingleCommodityMinimumCostFlow.m

```
Number_of_vertices= ;
```

After that, a matrix needs to be created, in which the connections between vertices will be stated. The size of this matrix is number of vertices * number of vertices.

LinearSingleCommodityMinimumCostFlow.m

```
Number_of_vertices= ;
connections= zeros(Number_of_vertices,Number_of_vertices);
```

This matrix is now filled with zeros. It is time to insert the connections between vertices.

LinearSingleCommodityMinimumCostFlow.m

```
Number_of_vertices= ;
connections= zeros(Number_of_vertices,Number_of_vertices);
linearIndices = sub2ind(size(connections),[ rows ], [ collumns ]);
```

With the help of the following notation, “connections” matrix will be filled with 1 wherever there is a connection indicator between vertices.

LinearSingleCommodityMinimumCostFlow.m

```
Number_of_vertices= ;
connections= zeros(Number_of_vertices,Number_of_vertices);
linearIndices = sub2ind(size(connections),[ rows ], [ collumns ]);
connections(linearIndices) = 1;
```

Afterwards, a matrix filled with symbols is created. The size of this matrix is also number of vertices * number of vertices.

LinearSingleCommodityMinimumCostFlow.m

```
Number_of_vertices= ;
connections= zeros(Number_of_vertices,Number_of_vertices);
linearIndices = sub2ind(size(connections),[ rows ], [ collumns ]);
connections(linearIndices) = 1;
X = sym('X%d%d', [Number_of_vertices Number_of_vertices]);
```

Now it is time to start getting ready to create the equations related to the constraints. Firstly, a matrix is created and filled with zeros, which is about the left side of the equations and has as many rows as the number of vertices and one column.

LinearSingleCommodityMinimumCostFlow.m

```
Number_of_vertices= ;
connections= zeros(Number_of_vertices,Number_of_vertices);
linearIndices = sub2ind(size(connections),[ rows ], [ collumns ]);
connections(linearIndices) = 1;
X = sym('X%d%d', [Number_of_vertices Number_of_vertices]);
Left_equations= zeros(Number_of_vertices,1);
```

Subsequently, this matrix is declared symbolic.

LinearSingleCommodityMinimumCostFlow.m

```
Number_of_vertices= ;
connections= zeros(Number_of_vertices,Number_of_vertices);
linearIndices = sub2ind(size(connections),[ rows ], [ collumns ]);
connections(linearIndices) = 1;
X = sym('X%d%d', [Number_of_vertices Number_of_vertices]);
Left_equations= zeros(Number_of_vertices,1);
Left_equations= sym(Left_equations);
```

The same is done for another matrix, which is about to be filled with both of the two sides of the equations related to the constraints. The matrix is called “equations” and in the first place is filled with zeros and has so many rows as the number of vertices and one column.

LinearSingleCommodityMinimumCostFlow.m

```
Number_of_vertices= ;
connections= zeros(Number_of_vertices,Number_of_vertices);
linearIndices = sub2ind(size(connections),[ rows ], [ collumns ]);
connections(linearIndices) = 1;
X = sym('X%d%d', [Number_of_vertices Number_of_vertices]);
Left_equations= zeros(Number_of_vertices,1);
Left_equations= sym(Left_equations);
equations=zeros(Number_of_vertices,1);
```

Like the previous matrix, this is declared symbolic, as well.

LinearSingleCommodityMinimumCostFlow.m

```
Number_of_vertices= ;
connections= zeros(Number_of_vertices,Number_of_vertices);
linearIndices = sub2ind(size(connections),[ rows ], [ collumns ]);
connections(linearIndices) = 1;
X = sym('X%d%d', [Number_of_vertices Number_of_vertices]);
Left_equations= zeros(Number_of_vertices,1);
Left_equations= sym(Left_equations);
equations=zeros(Number_of_vertices,1);
equations=sym(equations);
```

Another data is ready to be filled in the software and it is about the amount of commodity each vertex can supply or the amount that is demanded. So an array is created that has to be filled by the user with the appropriate values.

LinearSingleCommodityMinimumCostFlow.m

```
Number_of_vertices= ;
connections= zeros(Number_of_vertices,Number_of_vertices);
linearIndices = sub2ind(size(connections),[ rows ], [ collumns ]);
connections(linearIndices) = 1;
X = sym('X%d%d', [Number_of_vertices Number_of_vertices]);
Left_equations= zeros(Number_of_vertices,1);
Left_equations= sym(Left_equations);
equations=zeros(Number_of_vertices,1);
equations=sym(equations);
demand supply=[must be filled by the user];
```

Furthermore, we declare the number of connections between vertices as zero, which is about to be updated in a while.

LinearSingleCommodityMinimumCostFlow.m

```
Number_of_vertices= ;
connections= zeros(Number_of_vertices,Number_of_vertices);
linearIndices = sub2ind(size(connections),[ rows ], [ collumns ]);
connections(linearIndices) = 1;
X = sym('X%d%d', [Number_of_vertices Number_of_vertices]);
Left_equations= zeros(Number_of_vertices,1);
Left_equations= sym(Left_equations);
equations=zeros(Number_of_vertices,1);
equations=sym(equations);
demand_supply=[must be filled by the user];
number_of_connections =0;
```

In addition, an array is created, which is empty in the first place, but it is about to be filled with the arcs that connect the vertices.

LinearSingleCommodityMinimumCostFlow.m

```
Number_of_vertices= ;
connections= zeros(Number_of_vertices,Number_of_vertices);
linearIndices = sub2ind(size(connections),[ rows ], [ collumns ]);
connections(linearIndices) = 1;
X = sym('X%d%d', [Number_of_vertices Number_of_vertices]);
Left_equations= zeros(Number_of_vertices,1);
Left_equations= sym(Left_equations);
equations=zeros(Number_of_vertices,1);
equations=sym(equations);
demand_supply=[must be filled by the user];
number_of_connections =0;
x_arcs=[];
```

What is next is a loop, which for every i and every j examines if "connections (i, j)" is zero or not. If it is not zero, it creates the left sides of the equations related to the constraints and puts them in the matrix "Left_equations". Afterwards, it creates the whole equations related to the constraints, by equalizing each row of the "Left_equations" matrix to each element of the array "demand_supply" the user has filled earlier. Furthermore, it counts every connection and updates the "number_of_connections". Finally, if j>i, it fills the array of the arcs that connect vertices with each $X_{(i,j)}$ and $X_{(j,i)}$ respectively. This happens in order to put the values in the right place and avoid re-entering them.

LinearSingleCommodityMinimumCostFlow.m

```
Number_of_vertices= ;
connections= zeros(Number_of_vertices,Number_of_vertices);
linearIndices = sub2ind(size(connections),[ rows ], [ collumns ]);
connections(linearIndices) = 1;
X = sym('X%d%d', [Number_of_vertices Number_of_vertices]);
Left_equations= zeros(Number_of_vertices,1);
Left_equations= sym(Left_equations);
equations=zeros(Number_of_vertices,1);
equations=sym(equations);
demand_supply=[must be filled by the user];
number_of_connections =0;
x_arcs=[];
for i=1:Number_of_vertices
    for j=1:Number_of_vertices
        if(connections(i,j)~=0)

            Left_equations(i)=  Left_equations(i)+ X(i,j)*connections(i,j)-X(j,i)*connections(j,i);
            equations(i)=Left_equations(i)== demand_supply(i);
            number_of_connections =  number_of_connections+1;
            if (j>i)
            x_arcs=[x_arcs,X(i,j)];
            x_arcs=[x_arcs,X(j,i)];
            end
        end
    end
end
```

The problem is solved with the help of “linprog” function. The general form is [X,Z]=linprog(C,A,b,Aeq,Beq,lb,ub). Z is total optimized cost and X is the optimal flow of commodity. Let C be the costs of each arc that the user must fill; A a matrix with the coefficients of X in inequalities and b a vector with the right sides of inequalities; Aeq a matrix with the coefficients of X in equalities and Beq a vector with the right sides of equalities; lb the lower bound of the variables and ub their upper bound. The next step in our effort to solve the problem is to make a matrix with the equations, using the Aeq and Beq, since there are only equalities and fill it with the equations and the arcs.

LinearSingleCommodityMinimumCostFlow.m

```
Number_of_vertices= ;
connections= zeros(Number_of_vertices,Number_of_vertices);
linearIndices = sub2ind(size(connections),[ rows ], [ collumns ]);
connections(linearIndices) = 1;
X = sym('X%d%d', [Number_of_vertices Number_of_vertices]);
Left_equations= zeros(Number_of_vertices,1);
Left_equations= sym(Left_equations);
equations=zeros(Number_of_vertices,1);
equations=sym(equations);
demand_supply=[must be filled by the user];
number_of_connections =0;
x_arcs=[];
for i=1:Number_of_vertices
    for j=1:Number_of_vertices
        if(connections(i,j)~=0)

           Left_equations(i)=  Left_equations(i)+ X(i,j)*connections(i,j)-X(j,i)*connections(j,i);
           equations(i)=Left_equations(i)== demand_supply(i);
           number_of_connections =  number_of_connections+1;
           if (j>i)
           x_arcs=[x_arcs,X(i,j)];
           x_arcs=[x_arcs,X(j,i)];
           end
        end
    end
end

[aeq,beq]=equationsToMatrix(equations, x_arcs);
```

After that, it is necessary to convert the Aeq and Beq matrices from matrices with symbols to matrices with doubles.

LinearSingleCommodityMinimumCostFlow.m

```
Number_of_vertices= ;
connections= zeros(Number_of_vertices,Number_of_vertices);
linearIndices = sub2ind(size(connections),[ rows ], [ collumns ]);
connections(linearIndices) = 1;
X = sym('X%d%d', [Number_of_vertices Number_of_vertices]);
Left_equations= zeros(Number_of_vertices,1);
Left_equations= sym(Left_equations);
equations=zeros(Number_of_vertices,1);
equations=sym(equations);
demand_supply=[must be filled by the user];
number_of_connections =0;
x_arcs=[];
for i=1:Number_of_vertices
    for j=1:Number_of_vertices
        if(connections(i,j)~=0)

           Left_equations(i)=  Left_equations(i)+ X(i,j)*connections(i,j)-X(j,i)*connections(j,i);
           equations(i)=Left_equations(i)== demand_supply(i);
           number_of_connections =  number_of_connections+1;
           if (j>i)
           x_arcs=[x_arcs,X(i,j)];
           x_arcs=[x_arcs,X(j,i)];
           end
        end
    end
end

[aeq,beq]=equationsToMatrix(equations, x_arcs);
Aeq=double(aeq);
Beq=double(beq);
```

It is time for the user to insert the costs of transport between vertices or the cost of each arc. Afterwards, a vector with the lower bounds must be created. It is known from the constraints that the lower bound of the variables is zero, so this vector is about to be filled with zeros and its size is equal to the number of connections. Furthermore, a vector with the upper bounds of variables must be created. This vector is about to be empty to declare that the upper bounds may tend to infinity. Matrix A and vector b are about to be empty as well since there are no inequalities.

LinearSingleCommodityMinimumCostFlow.m

```
Number_of_vertices= ;
connections= zeros(Number_of_vertices,Number_of_vertices);
linearIndices = sub2ind(size(connections),[ rows ], [ collumns ]);
connections(linearIndices) = 1;
X = sym('X%d%d', [Number_of_vertices Number_of_vertices]);
Left_equations= zeros(Number_of_vertices,1);
Left_equations= sym(Left_equations);
equations=zeros(Number_of_vertices,1);
equations=sym(equations);
demand_supply=[must be filled by the user];
number_of_connections =0;
x_arcs=[];
for i=1:Number_of_vertices
    for j=1:Number_of_vertices
        if(connections(i,j)~=0)

           Left_equations(i)=  Left_equations(i)+ X(i,j)*connections(i,j)-X(j,i)*connections(j,i);
           equations(i)=Left_equations(i)== demand_supply(i);
           number_of_connections =  number_of_connections+1;
           if (j>i)
           x_arcs=[x_arcs,X(i,j)];
           x_arcs=[x_arcs,X(j,i)];
           end
        end
    end
end

[aeq,beq]=equationsToMatrix(equations, x_arcs);
Aeq=double(aeq);
Beq=double(beq);
C=[costs - must be filled by the user];
lb= zeros(number_of_connections);
ub=[];
A=[];
b=[];
```

Finally, we are ready to call the function “linprog” to solve the problem and find the minimum cost and the optimal flow of commodity.

LinearSingleCommodityMinimumCostFlow.m

```
Number_of_vertices= ;
connections= zeros(Number_of_vertices,Number_of_vertices);
linearIndices = sub2ind(size(connections),[ rows ], [ collumns ]);
connections(linearIndices) = 1;
X = sym('X%d%d', [Number_of_vertices Number_of_vertices]);
Left_equations= zeros(Number_of_vertices,1);
Left_equations= sym(Left_equations);
equations=zeros(Number_of_vertices,1);
equations=sym(equations);
demand_supply=[must be filled by the user];
number_of_connections =0;
x_arcs=[];
for i=1:Number_of_vertices
    for j=1:Number_of_vertices
        if(connections(i,j)~=0)

           Left_equations(i)=  Left_equations(i)+ X(i,j)*connections(i,j)-X(j,i)*connections(j,i);
           equations(i)=Left_equations(i)== demand_supply(i);
           number_of_connections =  number_of_connections+1;
           if (j>i)
           x_arcs=[x_arcs,X(i,j)];
           x_arcs=[x_arcs,X(j,i)];
           end
        end
    end
end

[aeq,beq]=equationsToMatrix(equations, x_arcs);
Aeq=double(aeq);
Beq=double(beq);
C=[costs - must be filled by the user];
lb= zeros(number_of_connections);
ub=[];
A=[];
b=[];
[X,Z]=linprog(C,A,b,Aeq,Beq,lb,ub);
```

4.2 Real Case

In order to find out how our Matlab code works on real cases, we chose to solve the NTN's problem, as formulated on *"Ghiani, Laporte, Musmanno, 2013, Introduction to Logistics Systems Management second edition, A John Wiley & Sons, Ltd., Publication, pp. 333"*. Subsequently, it is shown that our Matlab code produces the exact same results as the original solution to the problem. This can be visually seen, as well, by comparing the original graphs (Figure 12, Figure 14) to the graphs reproduced by our own Matlab model (Figure 13, Figure 15).

NTN is a Swiss freight intermodal carrier located in Lausanne. When a customer needs to transport goods between an origin and a destination, NTN supplies it with one or more empty containers in which the goods can be loaded. Once arrived at the destination, the goods are unloaded and the empty containers have to be transported to the pickup points of new customers. As a result, NTN management needs to reallocate the empty containers periodically (in practice, on a weekly basis). Empty container transport is very expensive (its cost is nearly 35% of the total operating cost). Last May 13, several empty ISO 20 containers had to be reallocated among the terminals in Amsterdam, Berlin, Munich, Paris, Milan, Barcelona, and Madrid. The number of empty containers available or demanded at the various terminals is reported, along with transport costs (in €/container). The problem can be formulated as follows:

Minimize $30X_{12} + 30X_{21} + 40X_{13} + 40X_{31} + 20X_{14} + 20X_{41} + 30X_{23} + 30X_{32} + 55X_{34} + 55X_{43} + 30X_{35} + 30X_{53} + 30X_{45} + 30X_{54} + 50X_{46} + 50X_{64} + 70X_{47} + 70X_{74} + 30X_{56} + 30X_{65} + 25X_{67} + 25X_{76}$

Subject to

$X_{12} + X_{13} + X_{14} - X_{21} - X_{31} - X_{41} = -10$

$X_{21} + X_{23} - X_{12} - X_{32} = 20$

$X_{31} + X_{32} + X_{34} + X_{35} - X_{13} - X_{23} - X_{43} - X_{53} = 50$

$X_{41} + X_{43} + X_{45} + X_{46} + X_{47} - X_{14} - X_{34} - X_{54} - X_{64} - X_{74} = 20$

$X_{53} + X_{54} + X_{56} - X_{35} - X_{45} - X_{65} = -50$

$X_{64} + X_{65} + X_{67} - X_{46} - X_{56} - X_{76} = -20$

$X_{74} + X_{76} - X_{47} - X_{67} = -10$

$X_{12}, X_{21}, X_{13}, X_{31}, X_{14}, X_{41}, X_{23}, X_{32}, X_{34}, X_{43}, X_{35}, X_{53}, X_{45}, X_{54}, X_{46}, X_{64}, X_{47}, X_{74}, X_{56}, X_{65}, X_{67}, X_{76} \geq 0.$

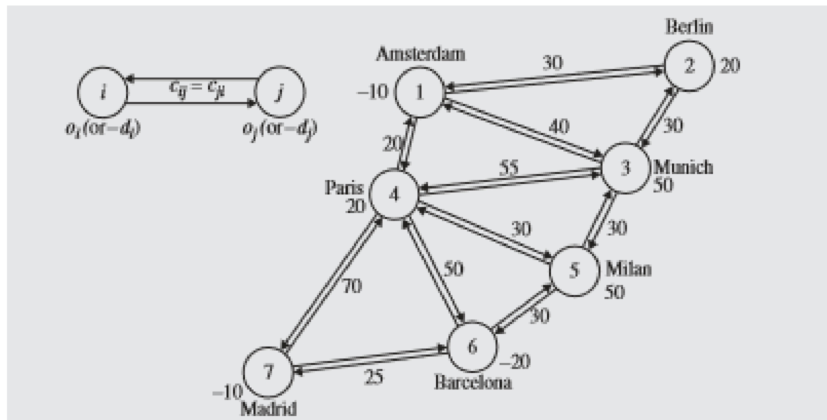


Figure 12: NTN's problem[12]

[12] Ghiani, Laporte, Musmanno, 2013, Introduction to Logistics Systems Management second edition, A John Wiley & Sons, Ltd., Publication, pp. 333

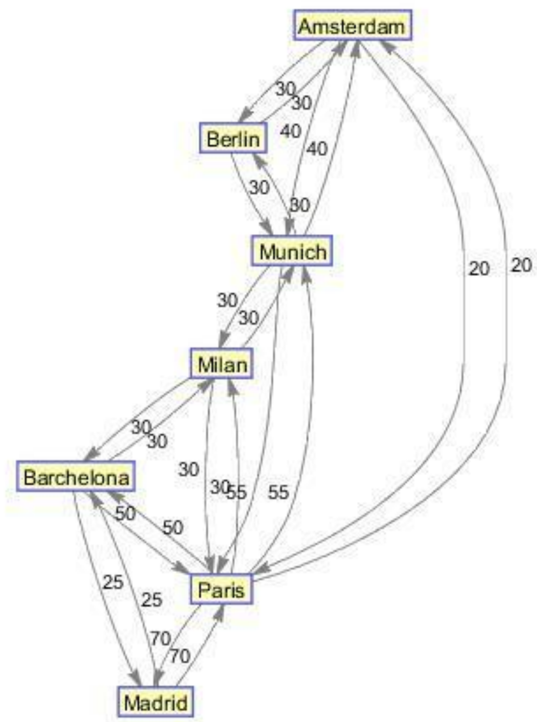


Figure 13: NTN's problem reproduced by our own Matlab model

4.2.1 Solution

Let's start with the number of vertices. In our case, there are seven vertices.

LinearSingleCommodityMinimumCostFlow.m

```
Number_of_vertices= 7;
```

Next step is the creation of "connections" matrix that is filled with zeros and its size is 7*7.

LinearSingleCommodityMinimumCostFlow.m

```
Number_of_vertices= 7;
connections= zeros(Number_of_vertices,Number_of_vertices);
```

```
connections =

     0     0     0     0     0     0     0
     0     0     0     0     0     0     0
     0     0     0     0     0     0     0
     0     0     0     0     0     0     0
     0     0     0     0     0     0     0
     0     0     0     0     0     0     0
     0     0     0     0     0     0     0
```

Now let's insert the connections between vertices and reveal them in the matrix "connections".

```
LinearSingleCommodityMinimumCostFlow.m

Number_of_vertices= 7;
connections= zeros(Number_of_vertices,Number_of_vertices);
linearIndices = sub2ind(size(connections),[1 1 1 2 2 3 3 3 3 4 4 4 4 4 5 5 5 6 6 6 7 7], [2 3 4 1 3 1 2 4 5 1 3 5 6 7 3 4 6 4 5 7 4 6]);
connections(linearIndices) = 1;
```

```
connections =

     0     1     1     1     0     0     0
     1     0     1     0     0     0     0
     1     1     0     1     1     0     0
     1     0     1     0     1     1     1
     0     0     1     1     0     1     0
     0     0     0     1     1     0     1
     0     0     0     1     0     1     0
```

Afterwards, the "X" matrix is created, which is filled with symbols.

```
LinearSingleCommodityMinimumCostFlow.m

Number_of_vertices= 7;
connections= zeros(Number_of_vertices,Number_of_vertices);
linearIndices = sub2ind(size(connections),[1 1 1 2 2 3 3 3 3 4 4 4 4 4 5 5 5 6 6 6 7 7
connections(linearIndices) = 1;
X = sym('X%d%d', [Number_of_vertices Number_of_vertices]);
```

```
X =

[ X11, X12, X13, X14, X15, X16, X17]
[ X21, X22, X23, X24, X25, X26, X27]
[ X31, X32, X33, X34, X35, X36, X37]
[ X41, X42, X43, X44, X45, X46, X47]
[ X51, X52, X53, X54, X55, X56, X57]
[ X61, X62, X63, X64, X65, X66, X67]
[ X71, X72, X73, X74, X75, X76, X77]
```

Subsequently, the “Left_equations” matrix is created, which is about the left side of the equations related to the constraints. Its size is 7*1. It is firstly filled with zeros and then is declared symbolic.

LinearSingleCommodityMinimumCostFlow.m

```
Number_of_vertices= 7;
connections= zeros(Number_of_vertices,Number_of_vertices);
linearIndices = sub2ind(size(connections),[1 1 1 2 2 3 3 3 3 4 4 4 4 4 5 5 5 6 6 6 7
connections(linearIndices) = 1;
X = sym('X%d%d', [Number_of_vertices Number_of_vertices]);
Left_equations= zeros(Number_of_vertices,1);
Left_equations= sym(Left_equations);
```

```
Left_equations =

     0
     0
     0
     0
     0
     0
     0
```

The same is done for the matrix “equations” as well, which is about the whole equations related to the constraints.

LinearSingleCommodityMinimumCostFlow.m

```
Number_of_vertices= 7;
connections= zeros(Number_of_vertices,Number_of_vertices);
linearIndices = sub2ind(size(connections),[1 1 1 2 2 3 3 3 3 4 4 4 4
connections(linearIndices) = 1;
X = sym('X%d%d', [Number_of_vertices Number_of_vertices]);
Left_equations= zeros(Number_of_vertices,1);
Left_equations= sym(Left_equations);
equations=zeros(Number_of_vertices,1);
equations=sym(equations);
```

```
equations =

     0
     0
     0
     0
     0
     0
     0
```

It is time for more data input from the user. It is about the amount of commodity each vertex can supply or the amount that is demanded.

LinearSingleCommodityMinimumCostFlow.m

```
Number_of_vertices= 7;
connections= zeros(Number_of_vertices,Number_of_vertices);
linearIndices = sub2ind(size(connections),[1 1 1 2 2 3 3 3 3 4 4
connections(linearIndices) = 1;
X = sym('X%d%d', [Number_of_vertices Number_of_vertices]);
Left_equations= zeros(Number_of_vertices,1);
Left_equations= sym(Left_equations);
equations=zeros(Number_of_vertices,1);
equations=sym(equations);
demand_supply=[-10 20 50 20 -50 -20 -10];
```

```
demand_supply =

   -10    20    50    20   -50   -20   -10
```

Furthermore, we declare the number of connections between vertices as zero for now and then we create an empty array, which is about to be filled with the arcs that connect the vertices.

LinearSingleCommodityMinimumCostFlow.m

```
Number_of_vertices= 7;
connections= zeros(Number_of_vertices,Number_of_vertices);
linearIndices = sub2ind(size(connections),[1 1 1 2 2 3 3 3 3 4 4 4
connections(linearIndices) = 1;
X = sym('X%d%d', [Number_of_vertices Number_of_vertices]);
Left_equations= zeros(Number_of_vertices,1);
Left_equations= sym(Left_equations);
equations=zeros(Number_of_vertices,1);
equations=sym(equations);
demand_supply=[-10 20 50 20 -50 -20 -10];
number_of_connections =0;
x_arcs=[];
```

This step follows the creation of the loop, that for every i and every j examines if "connections (i, j)" is zero or not. If it is not zero, it creates the left sides of the equations related to the constraints and puts them in the matrix "Left_equations". In addition, it creates the whole equations related to the constraints, by equalizing each row of the "Left_equations" matrix to each element of the array "demand_supply" the user has filled earlier. Furthermore, it counts every connection and updates the “number_of_connections”. Finally, if j>i, it fills the array of the arcs that connect vertices with each $X_{(i,j)}$ and $X_{(j,i)}$ respectively.

LinearSingleCommodityMinimumCostFlow.m

```
Number_of_vertices= 7;
connections= zeros(Number_of_vertices,Number_of_vertices);
linearIndices = sub2ind(size(connections),[1 1 1 2 2 3 3 3 3 4 4 4 4 4 5 5 5 6 6 6 7 7], [2
connections(linearIndices) = 1;
X = sym('X%d%d', [Number_of_vertices Number_of_vertices]);
Left_equations= zeros(Number_of_vertices,1);
Left_equations= sym(Left_equations);
equations=zeros(Number_of_vertices,1);
equations=sym(equations);
demand_supply=[-10 20 50 20 -50 -20 -10];
number_of_connections =0;
x_arcs=[];
for i=1:Number_of_vertices
    for j=1:Number_of_vertices
        if(connections(i,j)~=0)

           Left_equations(i)=  Left_equations(i)+ X(i,j)*connections(i,j)-X(j,i)*connection
           equations(i)=Left_equations(i)== demand_supply(i);
           number_of_connections =  number_of_connections+1;
           if (j>i)
           x_arcs=[x_arcs,X(i,j)];
           x_arcs=[x_arcs,X(j,i)];
           end
        end
    end
end
```

```
Left_equations =

                             X12 + X13 + X14 - X21 - X31 - X41
                                         X21 - X12 + X23 - X32
                 X31 - X23 - X13 + X32 + X34 + X35 - X43 - X53
 X41 - X34 - X14 + X43 + X45 + X46 + X47 - X54 - X64 - X74
                             X53 - X45 - X35 + X54 + X56 - X65
                             X64 - X56 - X46 + X65 + X67 - X76
                                         X74 - X67 - X47 + X76
```

```
equations =

                             X12 + X13 + X14 - X21 - X31 - X41 == -10
                                         X21 - X12 + X23 - X32 == 20
                 X31 - X23 - X13 + X32 + X34 + X35 - X43 - X53 == 50
 X41 - X34 - X14 + X43 + X45 + X46 + X47 - X54 - X64 - X74 == 20
                             X53 - X45 - X35 + X54 + X56 - X65 == -50
                             X64 - X56 - X46 + X65 + X67 - X76 == -20
                                         X74 - X67 - X47 + X76 == -10
```

```
number_of_connections =

    22


x_arcs =

[ X12, X21, X13, X31, X14, X41, X23, X32, X34, X43, X35, X53, X45, X54, X46, X64, X47, X74, X56, X65, X67, X76]
```

As mentioned earlier, the problem is about to be solved with the help of the function "linprog", [X,Z]=linprog(C,A,b,Aeq,Beq,lb,ub). What is needed now, is to prepare the elements of this function to work. C is going to be filled with the costs of transport by the user, matrix Aeq and vector Beq are going to be filled with equations and arcs, vector lb is about to have as many zeros as the number of connections between vertices, vector ub is going to be empty to show that upper bound of variables may tend to infinity and matrix A and vector b are going to be empty, since there are no inequalities.

LinearSingleCommodityMinimumCostFlow.m

```
Number_of_vertices= 7;
connections= zeros(Number_of_vertices,Number_of_vertices);
linearIndices = sub2ind(size(connections),[1 1 1 2 2 3 3 3 3 4 4 4 4 4 5 5 5 6 6 6 7 7], [2 3
connections(linearIndices) = 1;
X = sym('X%d%d', [Number_of_vertices Number_of_vertices]);
Left_equations= zeros(Number_of_vertices,1);
Left_equations= sym(Left_equations);
equations=zeros(Number_of_vertices,1);
equations=sym(equations);
demand_supply=[-10 20 50 20 -50 -20 -10];
number_of_connections =0;
x_arcs=[];
for i=1:Number_of_vertices
    for j=1:Number_of_vertices
        if(connections(i,j)~=0)

           Left_equations(i)=  Left_equations(i)+ X(i,j)*connections(i,j)-X(j,i)*connections(j
           equations(i)=Left_equations(i)== demand_supply(i);
           number_of_connections =  number_of_connections+1;
           if (j>i)
           x_arcs=[x_arcs,X(i,j)];
           x_arcs=[x_arcs,X(j,i)];
           end
        end
    end
end

[aeq,beq]=equationsToMatrix(equations, x_arcs);
Aeq=double(aeq);
Beq=double(beq);
C=[30 30 40 40 20 20 30 30 55 55 30 30 30 30 50 50 70 70 30 30 25 25];
lb= zeros(number_of_connections);
ub=[];
A=[];
b=[];
```

Aeq =

1	-1	1	-1	1	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-1	1	0	0	0	0	1	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	-1	1	0	0	-1	1	1	-1	1	-1	0	0	0	0	0	0	0	0	0	0
0	0	0	0	-1	1	0	0	-1	1	0	0	1	-1	1	-1	1	-1	0	0	0	0
0	0	0	0	0	0	0	0	0	0	-1	1	-1	1	0	0	0	0	1	-1	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	1	0	0	-1	1	1	-1
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	1	0	0	-1	1

Beq =

```
   -10
    20
    50
    20
   -50
   -20
   -10
```

C =

30	30	40	40	20	20	30	30	55	55	30	30	30	30	50	50	70	70	30	30	25	25

Finally, let's call the function "linprog". Total cost Z = 3900€ and the optimal flow of commodity is shown below.

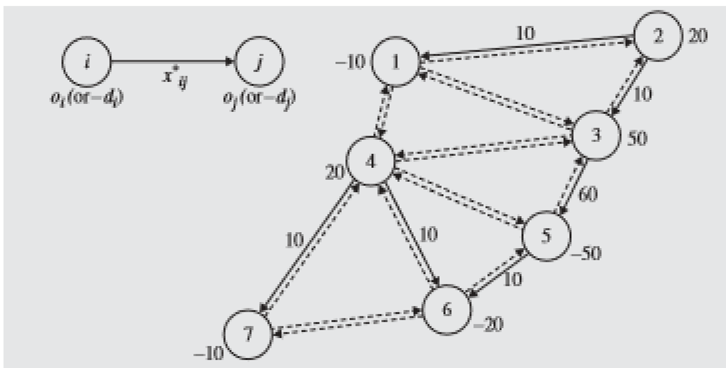


Figure 14: Solution of NTN problem[13]

[13] Ghiani, Laporte, Musmanno, 2013, Introduction to Logistics Systems Management second edition, A John Wiley & Sons, Ltd., Publication, pp. 333

LinearSingleCommodityMinimumCostFlow.m

```matlab
Number_of_vertices= 7;
connections= zeros(Number_of_vertices,Number_of_vertices);
linearIndices = sub2ind(size(connections),[1 1 1 2 2 3 3 3 3 4 4 4 4 4 5 5 5 6 6 6 7 7], [2 3 4 1 3 1 2
connections(linearIndices) = 1;
X = sym('X%d%d', [Number_of_vertices Number_of_vertices]);
Left_equations= zeros(Number_of_vertices,1);
Left_equations= sym(Left_equations);
equations=zeros(Number_of_vertices,1);
equations=sym(equations);
demand_supply=[-10 20 50 20 -50 -20 -10];
number_of_connections =0;
x_arcs=[];
for i=1:Number_of_vertices
    for j=1:Number_of_vertices
        if(connections(i,j)~=0)

           Left_equations(i)=  Left_equations(i)+ X(i,j)*connections(i,j)-X(j,i)*connections(j,i);
           equations(i)=Left_equations(i)== demand_supply(i);
           number_of_connections =  number_of_connections+1;
           if (j>i)
           x_arcs=[x_arcs,X(i,j)];
           x_arcs=[x_arcs,X(j,i)];
           end
        end
    end
end

[aeq,beq]=equationsToMatrix(equations, x_arcs);
Aeq=double(aeq);
Beq=double(beq);
C=[30 30 40 40 20 20 30 30 55 55 30 30 30 30 50 50 70 70 30 30 25 25];
lb= zeros(number_of_connections);
ub=[];
A=[];
b=[];
[X,Z]=linprog(C,A,b,Aeq,Beq,lb,ub);
```

```
X =

         0.0000
        10.0000
         0.0000
         0.0000
         0.0000
         0.0000
        10.0000
         0.0000
         0.0000
         0.0000
        60.0000
         0.0000
         0.0000
         0.0000
        10.0000
         0.0000
        10.0000
         0.0000
        10.0000
         0.0000
         0.0000
         0.0000
```

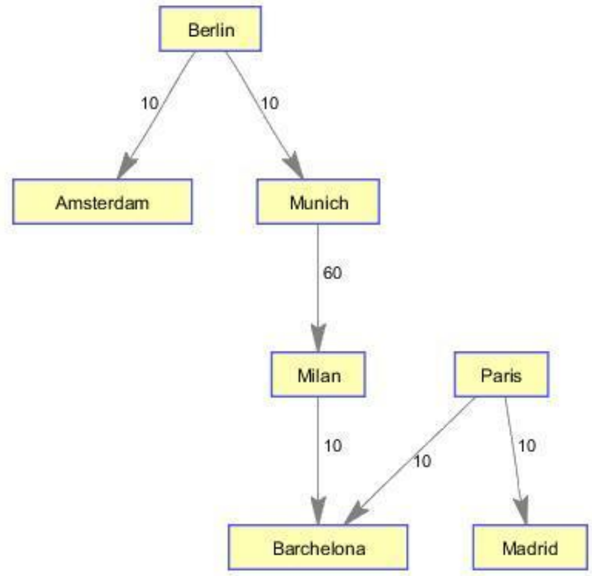
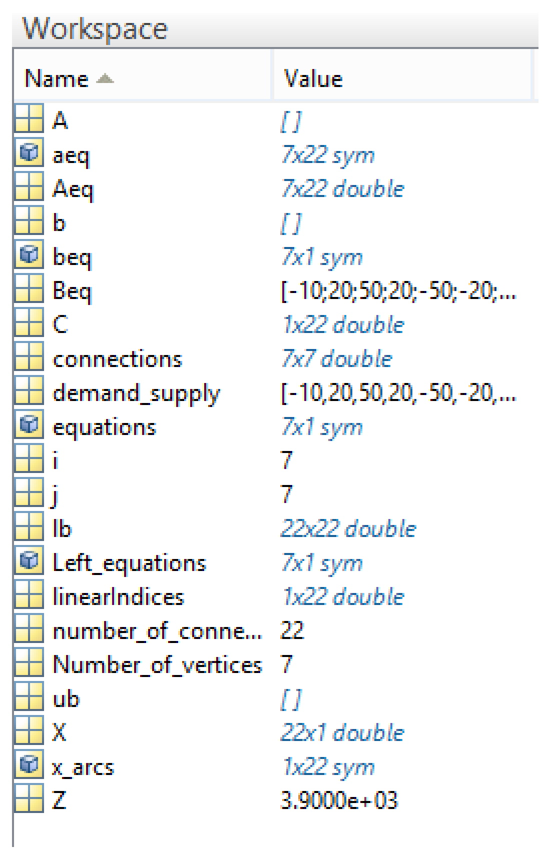


Figure 15: Solution of NTN's problem reproduced by our own Matlab model

```
Z =

   3.9000e+03
```



Workspace

Name	Value
A	[ ]
aeq	7x22 sym
Aeq	7x22 double
b	[ ]
beq	7x1 sym
Beq	[-10;20;50;20;-50;-20;...
C	1x22 double
connections	7x7 double
demand_supply	[-10,20,50,20,-50,-20,...
equations	7x1 sym
i	7
j	7
lb	22x22 double
Left_equations	7x1 sym
linearIndices	1x22 double
number_of_conne...	22
Number_of_vertices	7
ub	[ ]
X	22x1 double
x_arcs	1x22 sym
Z	3.9000e+03

4.3 Appendix

LMCFP generated in Matlab:

```
Number_of_vertices= user must fill the number of vertices ;
connections= zeros(Number_of_vertices,Number_of_vertices);
linearIndices = sub2ind(size(connections),[ rows ], [ collumns ]);
connections(linearIndices) = 1;
X = sym('X%d%d', [Number_of_vertices Number_of_vertices]);
Left_equations= zeros(Number_of_vertices,1);
Left_equations= sym(Left_equations);
equations=zeros(Number_of_vertices,1);
equations=sym(equations);
demand_supply=[must be filled by the user];
number_of_connections =0;
x_arcs=[];
for i=1:Number_of_vertices
  for j=1:Number_of_vertices
    if(connections(i,j)~=0)

      Left_equations(i)=      Left_equations(i)+    X(i,j)*connections(i,j)-
X(j,i)*connections(j,i);
      equations(i)=Left_equations(i)== demand_supply(i);
      number_of_connections =  number_of_connections+1;
      if (j>i)
      x_arcs=[x_arcs,X(i,j)];
      x_arcs=[x_arcs,X(j,i)];
      end
    end
```

```
  end
end

[aeq,beq]=equationsToMatrix(equations, x_arcs);
Aeq=double(aeq);
Beq=double(beq);
C=[costs - must be filled by the user];
lb= zeros(number_of_connections);
ub=[];
A=[];
b=[];
[X,Z]=linprog(C,A,b,Aeq,Beq,lb,ub);
```

Conclusion

The goal of this master project was to deeply examine the Global Supply Chain Management. More specifically, by studying whole global supply networks, we faced challenges in decision making related to warehouse facilities, sourcing strategies, production planning and models, outsourcing, distribution planning, integration strategies, and performance measurement. Subsequently, we examined the linear single-commodity minimum-cost flow problem and specifically the case without capacity constraints. It is a part of freight traffic assignment problems, a static version which can be solved by simplex algorithm, network simplex algorithm or by linear programming. Within this context, we created a linear programming procedure in Matlab software, with which every problem of this type can be solved. Finally, we chose to solve the real case of NTN, to test our model and help the reader deeply understand our procedure.

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