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Evaluation of risk in supply chain management using stochastic simulation models

Master's Dissertation

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Abstract

Title

Evaluation of risk in supply chain management using stochastic simulation models

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Today, companies around the world are striving for a competitive advantage with their competitors, improving the performance of their supply chain. Global supply chain networks need guidance strategies for managing the material, information and financial flows in which these businesses operate. This is a challenge for supply chain management.

Supply chain management has become one of the most important issues for managers. Many different simulation tools have been developed for this management, with the main advantage being the analysis of complex systems and the offer of alternatives for their management.

Modeling and simulation have their own development process in which data is collected, a model is constructed that simulates a complex real system, and the process is defined. A very important factor of the process is the validity of the data, the model that simulates a real complex system and the process of the simulations. Feedback of outcomes using what-if scenarios leads to analysis process and modeling.

Modeling and simulation give supply chain management the opportunity to see what strategies and options they can have in a real system, and with testing they can simulate seeing the results of those choices before applied.

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Last but not least, very special thanks to my family who helped me in all the phases of my life.

Contents

Part I

Introduction

Chapter 1
Introduction

1.1 Problem Definition

In the two case studies that are examined, the problems of the uncertain demand and the uncertain orders and lead time for inventory control are addressed, as well as the risks that the management choices for dealing with them hide. These two risk categories are among the most important for companies in the supply chain.

The stochastic simulation models should try to figure out:

- Which is the best economic quantity of production to achieve the highest value of profit with the lowest risk.
- Which are the best quantity orders and re-order level to achieve the highest inventory service level.
- Which are the best quantity orders and re-order level to achieve the highest inventory service level in the scenario that the products have shelf life.

1.2 Purpose

The purpose of this dissertation is to analyse the functions of the supply chain from the point of view of risk management and how the risks in its operations are identified and assessed using stochastic simulation models.

1.3 Methodology

The report is mainly a both qualitative and quantitative case studies. The report is divided into two main parts. The theoretical analysis based on information from literature, books, articles on the Internet and from theses of colleagues of previous years. And the empirical study with the use of case studies of real companies.

1.4 Objectives

The objectives of this project are to analyzing:

- Why model the supply chain
- What is modelling
- What is simulation
- How the stochastic simulation models evaluate the risk in Supply Chain
- Why choose stochastic simulation to improve supply chain performance?

Part II
Theoretical Framework

Chapter 2
Supply Chain Management

2.1 Introduction

Supply chain is a changing and constantly evolving industry mainly over the last 100 years. Although the existence of the supply chain is observed many centuries ago, locally within the cities for the production and distribution of basic goods, its interpretation, analysis and development efforts have been made in the last two centuries.

At the beginning of the 20th century, the first trucks appeared, which helped in the faster transport of goods and raw materials, but also in the cooperation of cities and countries by roads. Twenty years later, changes began in the way goods were stored, with pallets still being objects of convenience and space saving for warehouses. Undoubtedly, the biggest development in the supply chain was the creation of shipping containers as well as all the know-how and applications that support and facilitate their operation. Containers made their appearance during the 5th decade of the 20th century. In 1975 it was the turn of the warehouse management to be modernized, helped by the use of barcode which makes it easier to manage the warehouse operations. On 4 June 1982 the term "Supply Chain" was used for the first time, by the logistician Keith Oliver in an interview. The terms "Supply Chain" and "Supply Chain Management" was coined in 1983. At the same time, with the advent of personal computers, monitoring and managing the supply chain became simpler and more understandable than in previous years. Another big emergence was the Enterprise Resource Planning (ERP) systems that improve data availability and accuracy and cause better management planning and scheduling. Reaching the present, the supply chain does not stop evolving steadily, facing all the difficulties and challenges it faces in its path.

2.2 Definition of Supply Chain

Supply chains do not have a specific structure as it is constantly evolving in the world market and are characterized by complexity due to the many and different members involved in its functions. Stakeholders interact with each other to create goods and services through complex processes that in turn rely on other stakeholders at different levels with limited knowledge of each other. The basic management of a supply chain presupposes the processes that start from the suppliers until they reach the consumers. The process to reach the product to the customer increases its complexity depending on the stakeholders involved in this process. Most parts of the process never come into contact with each other, know little or no information about each other and as supply chains are becoming longer and more complex companies become vulnerable to disruptions. These disruptions need to be properly managed or prevented by companies for the smooth running of the supply chain. This is the work of the supply chain management. The term Supply Chain Management (SCM) was originally introduced by consultants in the early 1980s and has subsequently gained tremendous attention. Since the early 1990's academics have attempted to give structure to Supply Chain Management. (Douglas M. Lambert, 1998). There are many definitions of the supply chain in the literature, the purpose of this work is not to indicate the best but to report the different aspects of the concept of supply chain as recorded over the years by various authors.

The following table lists various definitions that have been recorded by different authors over time.

Author(s)	Definition of Supply Chain
(Cox, 1997)	The functions within and outside a company that enable the value chain to make products and provide services to the customer
American Production and Inventory Control Society (APICS, 1990)	The processes from the initial raw materials to final consumption of the finished products linking across supplier user industries
(Inman, 1992)	The supply chain constitutes all functions within and outside an industry, which enable the value chain to make products and provide services to customers
(Scott, 1991)	The chain linking each element of the manufacturing and supply process from raw materials to the end user
(Douglas M. Lambert M. C., 1998)	Is an integrative philosophy to manage the total flow of a distribution channel from supplier to the ultimate user
(Jones, Thomas and Daniel W. Riley., 1985)	The planning and control of a total material flow from suppliers through

	manufacturing and distribution to the end–user.
(Lummus, R.R. and Alber, 1997)	The network of entities through which material flows. Those entities may include suppliers, carriers, manufacturing sites, distribution centers, retailers, and customers
(Christopher, 1994)	The network of connected and interdependent organizations mutually and co-operatively working together to control, manage and improve the flow of materials and information from suppliers to end users.

Table 2.1, Supply Chain Definitions

2.3 Value of Chain

The chain of cooperation of all members involved in the supply chain in order to meet the needs of the market for specific products or services, is called a value chain. The purpose of the value chain is to increase the value of a product or service. Value chains integrate a variety of supply chain activities throughout the product or service lifecycle such as: determination of customer needs, production, distribution, marketing, after sales service etc. The concept of value chain (Porter, 1985) is the context in which this process refers. Porter's value chain focuses on systems and how inputs are changed to output. Porter described a chain of activities that are common to all businesses and divided them into two types, primary and support activities as illustrated in the figure below.

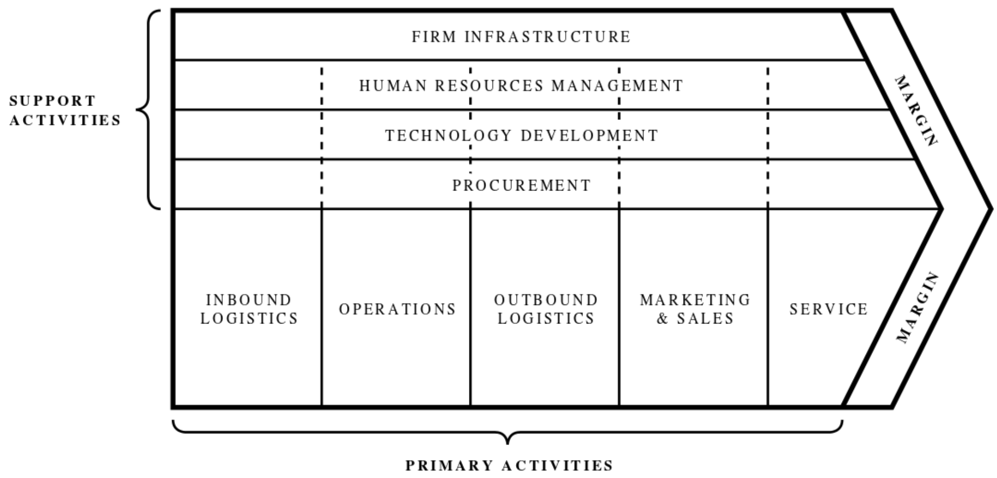

Figure 2.1 , Porter's Value Chain (1985)

Primary activities are related to the physical creation, sale, maintenance and support of a product or service. Primary activities are:

- Inbound Logistics: Receiving, Storing and distributing inputs.

- Operations: The process of changing inputs to outputs.
- Outbound Logistics: The delivering process of the final product
- Marketing and Sales: The process of persuade customers to buy products instead of competitors.
- Service: After sales support

Support activities are related to the support of the primary activities. Each support activity plays a role in each primary activity. Support activities are:

- Firm Infrastructure: Systems and functions that embody the proper day-to-day operation of a business
- Human Resources Management: Refers to the way that a company recruits, trains, motivates and rewards its employees.
- Technology Development: Managing information
- Procurement: Purchasing of various inputs for each primary activity.

2.4 Content of supply chain management

In this paragraph, there are briefly highlighted the principal features to understand the SC characteristics.

The main content of SCM is to distinguish the interdependence of stakeholders in the supply chain and, therefore, to monitor, control and configure the operations of the chain in order to properly complete business processes. Supply chain management involves the management of materials, information, and financial flows between the various stakeholders required to reach a product from where it was still a raw material until it reached the final consumer. Supply chain management, then, is the management and coordination of the activities of these supply chain flows in order to achieve the satisfaction of all members of the chain and achieve a competitive advantage. Monitoring these three main flows is of paramount importance for the supply chain management departments of each company.

Supply Chain Main Flows:

1) **Material Flow**: Defined as the material flow from the supplier when the product is still the raw material to the retailer as the final product and finally its purchase by the customer. For example, a typical material flow of goods in manufacturing is essentially the journey that starts at the supplier of the raw materials and as a terminal the customer, the intermediate stops of this journey are the manufacturer, the warehouse where the goods are transported and its distribution until it reaches the retail shelves. Material flow could be defined and the opposite direction of travel in rare cases where for various reasons the product can be returned.
2) **Information Flow**: All information derived from the movement of goods to the customer and vice versa is the object of information flow. Unlike most goods flows, the flow of information goes in both directions in the supply chain. Information flowing between customers

and suppliers includes prices, orders, order stages, invoices, receipts, customer complaints and so on.

3) **Financial Flow**: Financial flow involves the movement of money into the supply chain. After receiving the product and the necessary check, the customer pays the corresponding amount and so the cash flow starts back until it reaches the supplier. Over the years, the changes in the functions of the financial departments but also with the evolution of technology the flow of money sometimes changes direction starting from the supplier in the form of billing.

In all of the above flows it is necessary to have some members in order for the supply chain to exist. In its simplest form the chain includes the suppliers, the company and the customer of the company where the product is intended, but there are other more complex forms. John T. Mentzer (2001) illustrate three different types of supply chain, based on the number of members involved in its operations.

John T. Mentzer (2001) types of supply chain:

1) Direct supply chain

Figure 2.2 Direct Supply Chain

Is the simplest type, in this supply chain the only members are the supplier, the organization and the customer.

2) Extended supply chain

Figure 2.3 Extended Supply Chain

In this type added the suppliers of the immediate supplier and customers of the immediate customer, who also participate in all the flows of the supply chain.

3) Ultimate supply chain

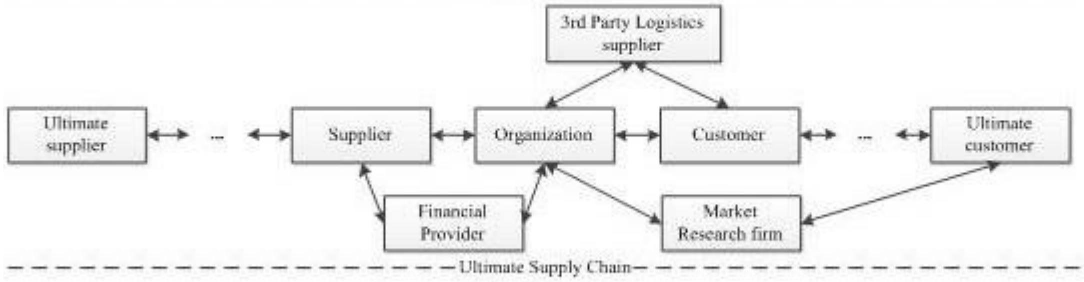

Figure 12.4 Ultimate Supply Chain

An ultimate supply chain includes the extended supply chain but getting more complex. In this chain added more members. Financial Provider may be a financial adviser of the supplier or the organization, 3rd Party Logistics supplier is in charge of the logistics activities and the Market Research firm may giving feedback from the ultimate customers to a company.

2.5 Supply Chain Management Processes

The main content of SCM is to distinguish the interdependence of stakeholders in the supply chain and, therefore, to monitor, control and configure the operations of the chain in order to properly complete business processes. (Douglas M. Lambert S. J.-D., 2005) identifies two approaches to motivation for the proper implementation of business processes. The first view of management processes is the transactional view of business process management which is based on developments in information and communication technology that allows the saving of time and the provision of the necessary information to the organization. The second view of business process management focuses on the inter-firm relationships in the supply chain with the contribution of the field of marketing.

Looking at the literature there are many organizations that have tried to determine what are the processes of supply chain management. Two of the most important are briefly analyzed below.

The **Global Supply Chain Forum** (GSCF) defines supply chain management as "the integration of key business processes from end user through original suppliers that provides products, services, and information that add value for customers and other stakeholders" (Douglas M. Lambert S. J.-D., 2005).

The following eight supply chain management processes are included in the GSCF framework:

- Customer Relationship Management
- Customer Service Management
- Demand Management

- Order Fulfillment
- Manufacturing Flow Management
- Supplier Relationship Management
- Product Development and Commercialization
- Returns Management

The **Supply-Chain Council** (SCC) developed the **Supply-Chain Operations References** (SCOR) framework. The five SCOR processes are (Supply Chain Counsil, 2012):

- **Plan** – balances aggregate demand and supply to develop a course of action which best meets sourcing, production, and delivery requirements.
- **Source** – includes activities related to procuring goods and services to meet planned and actual demand.
- **Make** – includes activities related to transforming products into a finished state to meet planned or actual demand.
- **Deliver** – provides finished goods and services to meet planned or actual demand, typically including order management, transportation management, and distribution management.
- **Return** – deals with returning or receiving returned products for any reason and extends into post-delivery customer support.

Interpreting these two frameworks we can conclude that the processes of the supply chain can be divided into 4 major categories:

1. **Demand Management**: planning, buying, selling.
2. **Supply Management**: production, distribution, warehouses, inventory.
3. **Operation Management**: sales, marketing, production, new products.
4. **Product Management**: product introduction, commerce, design.

2.6 Drivers of Supply Chain

Supply Chain Management and its processes are the way for an organization to ensure a sustainable future. The main purpose of management is to achieve a competitive advantage over its competitors. In order to achieve a competitive advantage, it is necessary to identify the drivers for the proper implementation of the respective strategy.

The factors that lead and determine the management and the way an organization or a company behaves in order to achieve its goals in all the activities of the chain are divided into internal and external.

(Basnet, 2013) defined as internal supply chain "the activities or functions within a company that results in providing a product to the customer. Integration of these functions involves the holistic performance of activities across departmental boundaries". The main drivers that determine the processes of an organization or a company in the management of the **internal supply** chain are:

- Low cost: Satisfying the needs of consumers and all stakeholders in the chain with the lowest possible cost and therefore higher profit is a major issue for all companies. This can be achieved by effectively managing the business activities such as production, warehousing, distribution and more.
- Quality improvement: Collaboration with suppliers to find environmentally friendly raw materials. The quality of raw materials but also the continuous improvement of production to achieve less possible contamination.
- Time reduction: Flexibility in time is an object of paramount importance for all companies. Reducing arrival time along with the quality of products on the market are the most important factors for customer satisfaction.

External drivers include factors outside the business that can influence its internal activities. The main **external drivers** are:

- Customers: Customer satisfaction is a key factor in the viability of a business.
- Competitors: Competition is a direct driver of supply chain management processes.
- Society: The environmental and social sensitivity of a company is an important factor for its reputation.

2.7 Resume

This chapter was the introduction to the supply chain, outlining its content and main features to assist in the introduction to the next chapters of risk management and the simulation models that used to evaluate supply chain risks. In this chapter, with the help of the literature, the supply chain was defined, its evolution was reported, but also the framework and the management process were analyzed.

Chapter 3
Risk Management

3.1 Introduction

All actions and projects of companies carry risks. Management must identify and evaluate them, implement strategies to avoid or address their effects, minimize risks and be in a state of constant monitoring. Risk management is the identification, understanding and prioritization of risks, combined with actions to minimize or mitigate risks. If risks occur, their effects must be controlled and monitored in order to reverse the negative consequences and to create opportunities through them.

3.2 Content of Risk

Recognition of a risk, an opportunity or an uncertainty is a major issue in the modern management of companies. The prediction, the identification, the assessment but also the strategy of the company to avoid it or to minimize its impact is an important factor for the viability of the business.
A simple general definition could be that:
Risk is the possibility or chance of loss and the uncertainly of an action. It has not necessarily bad meaning, the same risk can be an opportunity for some stakeholders and a threat for someone else.

Based on the definition above it turns out that a risk can be both objective and subjective. The implications of a business action can be both positive and negative depending on the role of each stakeholder. For example, the implications of opening a mall in an area can be both positive and negative depending on how one perceives it. Objective risk is defined as the risk where the effects and the probabilities of the scenario are equal, such as whether the roulette ball will stop in black or red. However, most risks are subjective and everyone analyzes them from their own point of view in order to proceed with the corresponding actions.

Another separation of risk concerns the approach to its evaluation. A risk analysis can be either qualitative or quantitative.

Qualitative Risk Analysis:

With the implementation of a project, various risks are created, the confrontation and the creation of a strategy of these risks is impossible to be at the same time for all the risks together, thus prioritizing the risks in the project is very important for a company.
Qualitative risk analysis enable prioritization the risks of a project by assigning a probability and impact and arriving the risk exposure of a risk, this exposure is the factor which prioritize the risks. Based on the above the main objectives of qualitative analysis are:

- Assess and evaluate risk characteristics
- Prioritize Risks
- Assess Risk (Probability-Impact)
- Risk categorization (Low-Medium-High)

Quantitative Risk Analysis:

In quantitative risk analysis there are two important risk calculations that will be analyzed in detail in the next chapter where the models will be analyzed. Deterministic and stochastic calculations. In both of these approaches the objectives of analysis are:

- Numerical estimation of risk exposure
- Evaluation of likelihood of a project's success
- Applicable for time and cost invest
- Not mandatory
- Estimation of overall project risk

3.3 Risk Management Frameworks

The two main risk management frameworks standards that many companies follow are COSO Framework and ISO 31000.

(COSO, 2004) define ERM (Enterprise Risk Management) as *"a process, effected by an entity's board of directors, management and other personnel, applied in strategy setting and across the enterprise, designed to identify potential events that may affect the entity, and manage risks to be within its risk appetite, to provide reasonable assurance regarding the achievement of entity objectives."*

COSO objectives are strategic, operations, reporting, compliance and considers activities at all levels of an enterprise. The components of COSO's ERM framework are:

- Interval Environment
- Objective Setting
- Event Identification
- Risk Assessment
- Risk Response

- Control Activities
- Information and Communication
- Monitoring

ISO 31000 states that *"the success of risk management will depend on the effectiveness of the management framework providing the foundations and arrangements what will embed it throughout the organization at all levels".*

ISO 31000 framework components are:

- Mandate and Commitment
- Design of framework for managing risk
- Implementing risk management
- Monitoring and review of the framework
- Continual improvement of the framework

Both standards argue that if companies take risks or handle what emerges properly, companies will make a profit and that if companies taking the risk factor into the company's decision-making process ensures that the company takes the right risks so that it has more efficient results.

3.4 Risk Management Process

The risk management process aims to analyze all aspects of risk and in order to minimize their impact, addressing the possibility and direct impact. As already mentioned, risk management is all the decisions about the processes made by a company to manage a risk. To manage risk could mean to avoid, reduce, transfer and share risks (Brindley, 2004). The simplest form of risk management process involves four main steps:

1. Risk Identification
2. Risk Assessment
3. Risk Treatment
4. Risk Monitoring

3.4.1 Risk identification

Risk identification is the first and very important step of risk management process and is the main pillar on which the next steps of the process will be based. If the risk is not properly identified, none of the next steps in the proceedings matter. If there are existing risks that have not been identified for a project of a company then the future actions of the management will be wrong, thus the correct identification of risks ensures risk management effectiveness.

The term risk identification does not only mean the recognition of a potential loss that will occur in a business but also the possibility of seizing an opportunity through the occurrence of a risk. Failure to identify potential gains is as ineffective as unrecognizable risks. The lack of a good profit opportunity that an organization seeks is a problem that equates to the losses that can occur (Dickson, 1989).

There are many techniques and ways to identify risks in risk analysis. The management collects data and information from the internal and external environment of the company, at all levels of the hierarchy, taking into account all those involved who are affected by its actions. The company must identify all stakeholders who either influence the company's work or are affected by it. This makes the identification of stakeholders very important for the identification of risks. Not only the heads, employees and associates of an organization are interested, they are also the members of the external environment of an organization such as society, the environment, government, competitors and so on. It is important to ensure that stakeholders are correctly identified as well as their correlation and impact on the organization at a level that makes strategic sense (F Ackermann, 1998).

Risk identification includes 4 very important elements. (Tchankova, 2002)

- Sources of risks (elements that can bring some positive or negatives outcomes)
- Hazards (a condition that increases the chance of losses or gains)
- Peril (Unpredictable negative results)
- Exposures to risk (if the risk event occurs the are objects facing possible losses or gains)

There are several ways and techniques of risk identification in the literature, some simple some more complex. When a company or organization is in the process of implementing a project SWOT analysis or PESTEL analysis are some of the techniques that usually used.

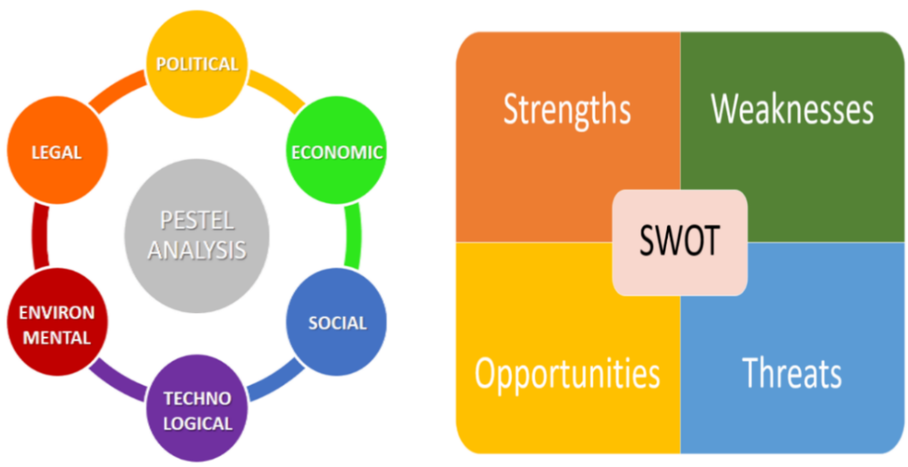

Figure 3.1 SWOT and PESTEL Analysis

Other techniques to identify risk and its sources are the "Event tree" and "fault tree" analysis. Event tree analysis shows all the contingencies that can occur after a critical event. He tries to evaluate the results after the beginning of the event by researching its consequences. The fault tree analysis, on the other hand, focuses on the potential events that led to the initial critical event. It focuses on the critical factor and presents the results in the diagram which shows where the system fails.

Other risk identification techniques are "WHAT IF", Delphi technique, Brainstorming, SWIFT etc.

3.4.2 Risk Assessment

Risk Assessment is the process used to assess the extent to a company may be harmed by a risk and the likelihood of the risk being manifested. It is essentially the means of identifying the magnitude of the impact and the risk prioritizing. This means that all identified risks must be considered individually in order to quantify the likelihood of their occurrence and the extent of their impacts.

Risk assessment main purpose is to conclude the importance of a risk in decision making. After assessing the risks in a project, the risk management has the data to decide if the project or a part should be avoided, if there are any other options to reduce its impact or to minimize the risk and the cost of those options.

Prioritization is also very important part of risk assessment. A common way to prioritize risks that have been identified by the first step of risk analysis is Matrix maps. In a Matrix map included impacts and possibilities of occurrence of some different events and the comparison of them. One form of Matrix map is Risk Assessment Chart. Risk management team list all the risks from a project. They identify the impact for every risk and the possibility of its occurrence. They develop a scale and distribute the impacts and probabilities of the risks, for example a three-level scale for probabilities can be (unlikely, moderate, probable) and for impact (low, moderate, high) as figured in the table below:

Level	Impact	Likelihood
1	Low	Rare
2	Moderate	Possible
3	High	Certain

Table 3.1

After placing the impacts and the probability of occurrence for each risk at the correct scale level and adding the results to a chart with a horizontal axis of the impact and vertical axis to the probability, the categorization and prioritization takes place as figured below:

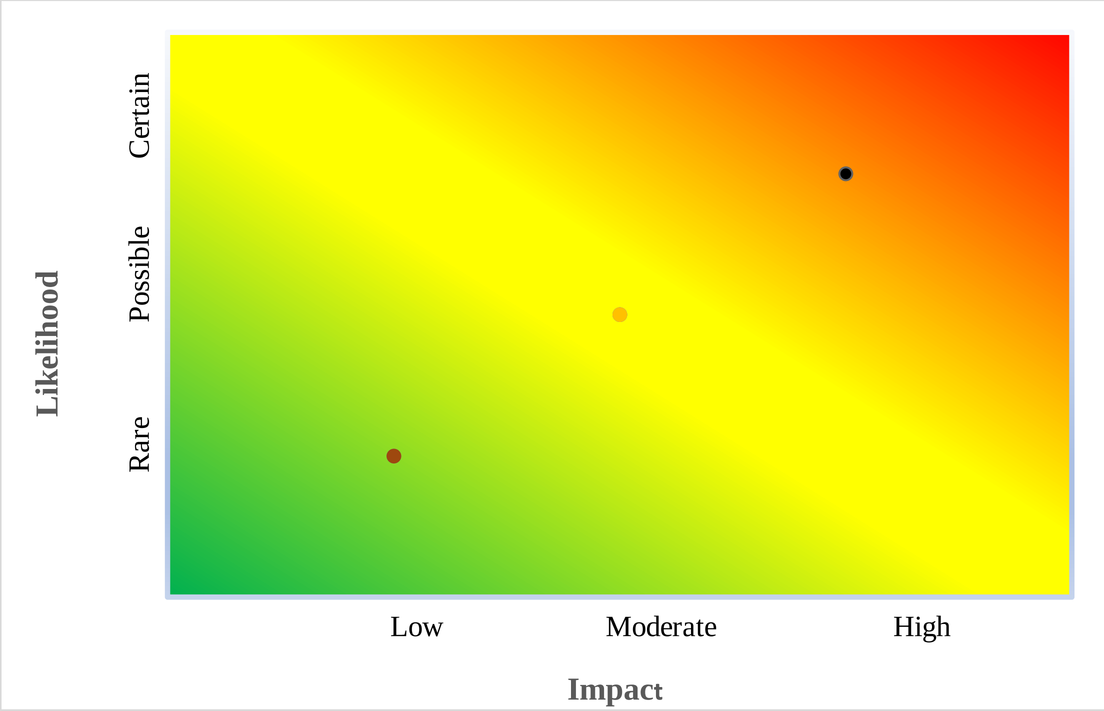

Figure 3.2

Assuming that the colored bullets in the chart are Risk events the prioritization and the categorization of the risks can be like below:

1. High Risk: ●
2. Medium Risk: ●
3. Low Risk: ●

As it mentioned in a previous paragraph risk can assessed through deterministic and stochastic models. Deterministic calculations have a set of known data and give a result of a unique data set, whereas stochastic calculations also include random variables that therefore lead to random results. Due to the constant evolution of technology in the business world, the software that appears helps more and more in the implementation of such calculations.

3.4.3 Risk Treatment

The third step of risk management process in risk analysis, is the response to risk. Risk treatment includes all the actions that a company will follow to manage the risks. After the risk assessment the management decides the way of treatment of every risk based on the level in the scale. At this stage the management decides on the alternative activities and their evaluation based on the risk profiles and choose the more efficient strategy. The objectives and strategy of any business with the combination of the business's risk aversion are the main factors that lead to the choice of management risk strategy (Adrian-Cosmin, 2020).

There are four main treatment strategies in Risk management:

1. **Avoid the Risk**: This strategy mainly concerns cases where the impacts of an action are catastrophic or will put a company in a very unfavorable position and the probability of this happening is very high. This strategy is the most effective as with the withdrawal of a project all the risks created by its implementation disappear but the objectives of the project disappear too. However, the objectives that a company had with the implementation of a project are not rejected, only the implementation of other projects is investigated, which will yield the corresponding results with a lower risk.
2. **Reduce the Risk**: In this case, the profits of a company from the achievement of a project are so significant for it that it cannot give up, thus risk management aims with this strategy to reduce either the impact that will occur or the likelihood of risk occurring. This is the most common strategy as the objectives that a company has set can be achieved and succeed in achieving its goal with the project it has chosen, however, there is a possibility that the risk reduction strategy will be ineffective and the results will be catastrophic.
3. **Transfer the Risk**: With this strategy the risk or part of it is transferred to a third party who assumes the responsibility of dealing with it. Is a good strategy that follow by companies to deal with risks that have a high potential impact or the realization of the risk is frequent and there is the option of transferring the risk to a third party.
4. **Accept the Risk**: In the world of risk management the saying high risk high returns is accepted by all, some risks have to be taken anyway without reducing their impact and probability of occurrence and without the choice of transferring the risk to someone else, also the risks whose impacts are minimal must also be taken. There are also risks that their treatment strategy is expensive. However, a contingency plan and recovery plan must be in place even if the risk has been accepted to address the consequences of the risk if it occurs.

3.4.4 Risk Monitoring

In the monitoring phase, the project management must monitor the progress as well as the discrepancies that may occur and introduce the corrective actions required to achieve the desired project objectives (V M Rao Tummala, 1999). The internal and external environment of a business is constantly changing, so the risks that may arise are constantly changing and must be monitored, in addition new risks may appear. To identify all these changes and the possible new factors that may increase the likelihood and impact of a risk, the risk management should monitor every aspect of a project even if the company has already earned its objectives or a risk has already faced.

3.5 Supply Chain Risk Management (SCRM)

Having mentioned the content and the main elements of risk management but also the broader meaning of the supply chain, it is important to refer to the risk management within it. The supply chain risk management (SCRM) literature is very extensive. The analysis and study of SCRM involves different approaches and different perspectives on all aspects of research.

The identification and management of risks within the supply network and externally through a coordinated approach amongst supply chain members to reduce supply chain vulnerability as a whole (Mark Goh, Joseph Y.S Lim, Fanwen Meng, 2004). Vulnerability in this context "reflects the susceptibility of a supply chain to disruption" (Waters, 2011). Supply chain risk management is of growing importance, as the vulnerability of supply chains increases. Supply chain management risk is the collaboration with partners in the supply chain to apply risk management process tools to deal with risks and uncertainties caused by, or impacting on, logistics related activities or resources (Andreas Norrman, Ulf Jansson, 2004).

3.5.1 Supply Chain Risk Categories

Risks can exist in all three flows in the supply chain and can have a huge influence at all levels and members of the supply chain. It is therefore necessary to know the exact location of risks in the supply chain and what causes them. In the risk management literature, there are many categorizations of risks by many authors over the years. What needs to be mentioned, however, is that the common denominator was the separation of risks into external and internal. The risk categorization of Christopher and Peck (2004) is the most used and accepted categorization in SCRM. Cristopher and Peck divide risks that are internal into Control and Process risks and external into Supply and Demand Risks.

Internal Risks

Internal risks are more likely to be reduced as they occur in the business environment where s firm has a greater influence on their appearance factors and their control. Internal risks are defined as all those risks that may exist within the company but also all those that appear outside the company but are in its supply network. The main types of internal risks with the factors that can caused them based on the literature are:

- Process risks: Caused by disruptions of operations or processes of the firm.
- Organizational risks: Caused by changes in management, structures or business processes.
- Control risks: Caused by inefficient management, monitoring and evaluation.

- Mitigation risks: Caused by no alternatives solution in case of something goes out of the plan.

External Risks

External risks caused by factors that affect all or part of the supply chain flow but are outside of the supply network and by the company itself. External risks are more dangerous because the factors and sources of the risks are outside the management of the company, are unpredictable and more difficult to assess before their appearance. The main types of external risks with the factors that can caused them based on the literature are:

- Demand risks: Caused by unpredictable customers behavior.
- Supply risks: Caused by disruptions in of products, raw materials within the supply chain.
- Environmental risks: Caused by factors such as economic, climate, social etc.
- Business Risks: Caused by stakeholder's stability.

There are many lists of more targeted risks in the supply chain literature. Chandra and Grabis (2006) more specifically defined the main issues that concern the supply chain and are listed below:

- Distribution network configuration
- Inventory control
- Supply contracts
- Distribution strategies
- Supply chain integration and strategic partnering
- Outsourcing and procurement strategies
- Information technology and decision support systems
- Customer value
- Challenges for information sharing in supply chain

3.5.2 Supply chain risk management framework

There are many different risk management frameworks in the supply chain. There is no specific risk management framework that is most appropriate and applicable to all situations. In the table below quoted some frameworks from the literature for the risk management supply chain processes.

Author(s)	Framework elements
(Ghadge, 2013)	1. risk taxonomy 2. risk trending 3. risk modeling 4. strategy planning 5. risk mitigation
(Uta Jüttner, Helen Peck, Martin Christopher, 2003)	1. assessing the risks sources for the supply chain

	2. defining the supply chain risk concept and adverse consequences 3. identifying the risk drivers in the supply chain strategy 4. mitigating risks for the supply chain
(Paul R. Kleindorfer Germaine H. Saad, 2009)	1. specification of the nature of the underlying hazard that gave rise to the risk 2. risk quantification through a disciplined risk assessment process 3. approach solution according to the given supply chain environment 4. integration of policies and actions with on-going risk assessment and coordination among supply chain partners
(Timothy J Pettit, Keely L. Croxton, Joseph Fiksel, 2013)	1. identify hazards 2. assess risks 3. analyze controls 4. determine controls 5. implement controls 6. supervise and review

Table 3.2, SCRM Frameworks

3.6 Resume

This chapter had the purpose to briefly present the concept of risk management. This chapter is based on the theoretical approach through the literature. Therefore, the main concepts of risk analysis, evaluation and management have been introduced. In addition, a description of the risk assessment process was provided. This theoretical approach will help in the further practical analysis that will follow.

Chapter 4
Modeling and Simulation

4.1 Introduction

As mentioned in previous paragraphs, in the quantification of risk analysis is done with use of simulation models. Simulation is the representation of the operation of a real process over time. Simulation is the creation of a virtual representation of a system, the observation of this representation draws conclusions about the characteristics of the real system. The simulation describes and analyzes the behaviors of real systems

Simulation models made their appearance in 1960 when Tocher and Owen develop GSP (General Simulation Program) and since then many researchers and professionals are concerned with the progress and application of such models. Now, simulation models are used to research all the aspects of real-world systems in a wide range of areas such as communication, health, manufacturing and transportation. The complexity of the world and the new challenges that appear in combination with the evolution of technology but also the competition in the computer industry has led to technological discoveries and the production of constantly better products.

4.2 Characteristics of Simulation Models

A model represents a system and the essential relationships involved. (Blanchard, Benjamin S., and Fabrycky, 1998). (Schmidt, J. W., and R. E. Taylor, 1970) define the system as all the entities that act and interact together toward the accomplishment of some logical end. There are two types of systems, discrete and continuous. In a discrete system all the state variables change instantaneously at separated points in time and in a continuous system all the state variables change continuously with respect to time.

If all entities and their interaction are simple and distinct then existing mathematical models can draw information and give answers in the context of interest under consideration. However, most systems are more complex and the analytical solution provided by mathematical methods is not sufficient. Simulation modelling is used to research the behavior of these real-world systems.

A simulation is the capture of the operation of a real process or system over time. The system includes all the entities that interact together in order to achieve a specific goal. A simulation model studies the behavior of a consistently evolving system over time. The model takes the form of a set of mathematical or logical assumptions concerning the operation of the system. A model represents all objects in some form other than that of the entity itself.

In addition to the system and the model there are several components of the Simulation. The following are the most important.

- **Entities** are all the parts that make up a system and whose actions affect the state of that system.
- **Attribute** define the entity with specific value.
- **Activities** are all these processes that can cause changes in the system.
- **State of the System** is the collection of all the variables that describe the system to sufficient level at any time.
- **Event** is anything that occurs and affect that state of the system.

Simulation is not appropriate for using when the system is too complex to give us significant results or too simple that the common sense can give us the solution. In addition, if the data of the system is unavailable, the estimations are unavailable too, so simulation isn't the right choice to make. The simulation does not provide the solution but allows the observation of all the information within the system that investigates the model.

Campuzano and Mula captured their own different guidelines for proper simulation modeling which are listed below:

- Not constructing a complicated model but a simple one that works.
- Understanding problem modeling to use a suitable technique.
- Models must be validated before applying them.
- A model must never be put under pressure to do, or be criticized for not doing, that which it has never been devised for.
- A model cannot be better than the information entering it.
- A model must never be considered literally.
- Models cannot replace decision makers.

4.3 Types of Models

In choosing a model, the main purpose is to select the model that accurately reflects the system being monitored and analyzed for the purposes of the decisions to be made. The first classification of models is the physical or mathematical models. A physical model is a scale representation of the same physical entities that the model represent. Physical models most used for studying engineering and management systems, but the majority of the models that have been built are mathematical which help to estimate the uncertainties in the data and their calculations and extract numerical results from the system studied to understand the behavior of the model, however if the analytical solution that mathematical models give is unavailable then the simulation type of models are chosen to study the system.

Simulation models can be classified in a number of different ways. The following classification of (Averill M. Law, w. David Kelton , 1991) has three dimensions:

1. Static vs Dynamic simulation models

A static simulation model represents a system at a specific point in time, in this model time has no role. Dynamic simulation models refer to a system that evolving over time.

2. Deterministic vs Stochastic simulation models
   If a simulation model does not contain any probabilistic components, it is called deterministic. If there is at least one random variable the model is called stochastic. Focusing on supply chain in this classification there are two more types of model hybrid and IT-driven models.
3. Continuous vs. Discrete simulation models
   In a discrete simulation model change occur at separate points in time. In a continuous model, state variables change continuously over time.

4.3.1 Advantages

Simulations offer a great deal of opportunities for studying complex systems and their use is growing rapidly over time, offering many advantages in the study and analysis of real functions and systems, the most important of these are listed below.

- First of all, the simulation allows the study of possible changes and decisions without having to spend resources on options that may not lead to the desired result. With the use of simulations, the desired estimates are made for future plans without great cost, but also the corrections and changes that will be needed for the best result are identified, so that when the time for decisions comes, all aspects of the project are already known.
- Another important advantage of simulation is the time compression. The simulation can track behaviors in real functions and systems that last for years in just a few minutes.
- The simulation not only provides data on the behavior of a system but can also provide information on why a system behaves this way.
- Simulation allows the better understanding of the interactions among the variables that included in a complex-systems. The knowledge of problems and the understanding of their content support the understanding of their important effects on the performance of the overall system.
- By using simulation to perform bottleneck analysis, the causes of the delays in work-in-process, information, materials, or other processes can be discovered.
- The construction of different simulation models helps to analyze and provide answers to different possible scenarios in the behavior of a system. Simulation asks what-if questions about the real system.
- Answering all of the what-if questions is useful for both designing new systems and redesigning existing systems and helps the preparation for change.
- The simulation provides an objective view by eliminating any personal perceptions in the decision-making process.
- Simulations have a very low cost compared to the cost of implementing a design and its possible corrections.

4.3.2 Disadvantages

Simulations is not without drawbacks. The disadvantages of the simulation include the following.

- It is not simple to create a model. To building a model requires special training and experience. Simulation software packages provide more and more features while reducing the requirements for users, however understanding the process of simulation analysis and modeling is essential.
- The implementation of a simulation model involves the possibility that the model may not provide certain answers. Simulation is a process of repeating specific sequences based on, among other things, random variables. Based on this, the reliability of the model may not be guaranteed.
- Modeling and simulation analysis can be time consuming and expensive. Failure or mismanagement of resources can lead to an inadequate model.
- As already mentioned, the simulation used in case that analytical solution is not available, but in some cases, simulation is used although an analytical solution exists. Simulation cannot generate optimal solution on their own as analytic models can.

4.4 Simulation Project

A few authors have attempted to define the steps of simulation modeling. Pegden et al. (1995), Law and Kelton (1991), Rinkel (2011), Strandhagen (1994) and Persson and Olhager (2000) are some authors that create important frameworks for the simulation modeling. In this study the framework of (Banks, J., J. S. Carson , and B. L. Nelson, 1996) is used and presented. The figure below shows a set of steps for simulation project.

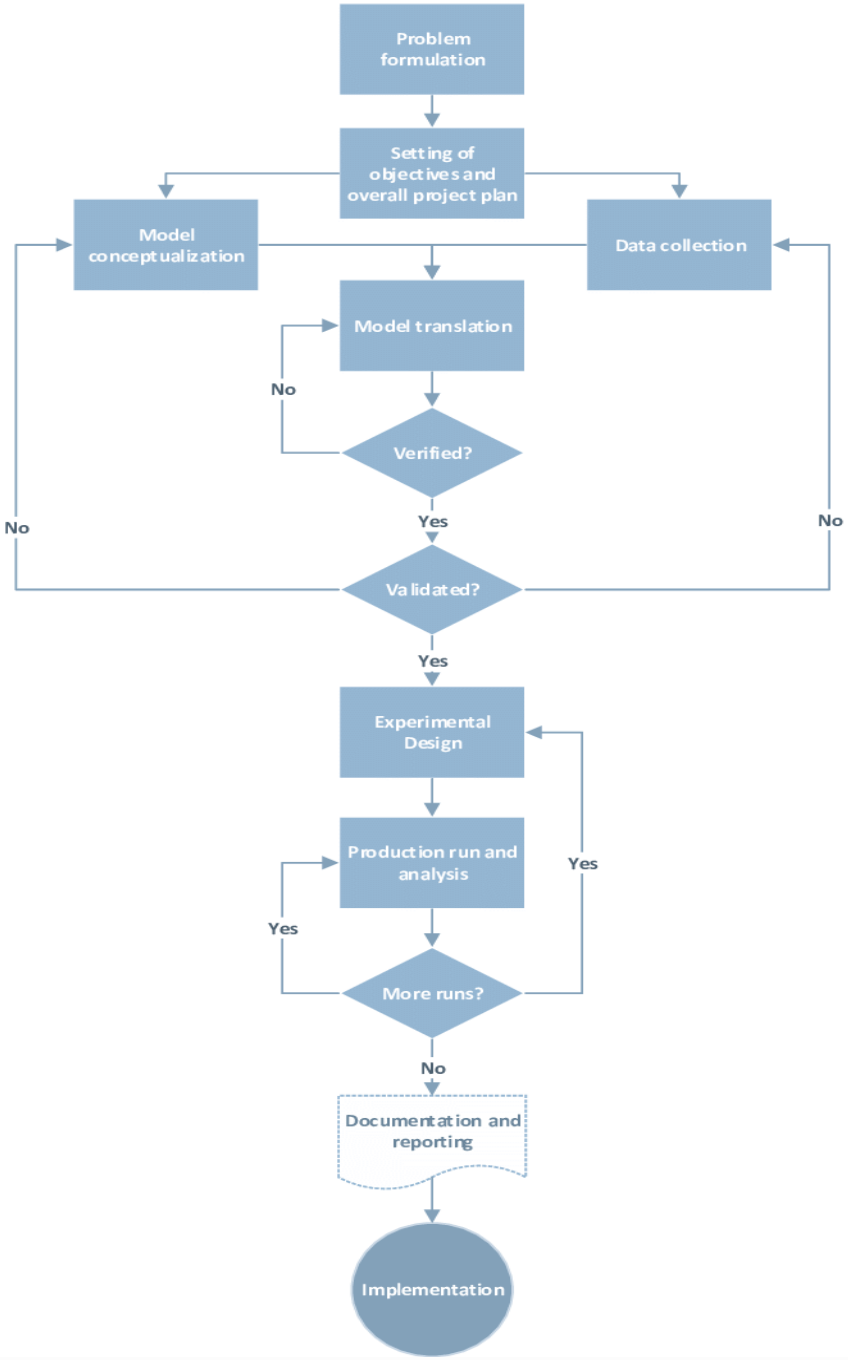

Figure 4.1 Simulation steps

Simulation Steps

1. **Problem formulation:** The definition of the problem is the first and most important step of each simulation model. It is fundamental that the model must have the necessary data to simulate the actual system being studied and include the predefined problem.
2. **Setting of objectives and overall project plan:** The objectives represent all the questions that has to be answered by the simulation study. The purpose of the study must be clear from the beginning of the project in order to make the model more accurate.
3. **Model conceptualization:** In this step the model taking its form. In this part the real-world system transferred into a mathematical and logical description. At first the model starts in a simple form and then improves to reflect the real system. The advantages but also the limitations and shields of the system as well as the limit states are taken into account so that the correct variables are used and the off-field variables are avoided.
4. **Data collection:** After reaching the purpose and goals of the model, the necessary data that lead to the answers that will be extracted from the model are drawn. Data sorting is a very important step, any mistakes or omissions can lead to wrong answers. The volume of data is usually very large and some data may also be more relevant than others, so you need to evaluate their relevance to the problem at hand.
5. **Model translation:** The conceptual model constructed in step three is coded into a computer-recognizable form, an operational model.
6. **Verified:** Verification is the operation that examines if the model performing properly. Verification should preferably take place throughout the modeling period and not at the end after completion.
7. **Validated:** Validation is the process that determine if the conceptual model is an accurate representation of the real system.
8. **Experimental design:** For each simulation the duration of the simulation, the number of replications and the method of preparation, as required, must be decided.
9. **Production runs and analysis:** The simulation is performed and the data is collected for analysis.
10. **More runs:** At the end of the simulations, the findings are evaluated to see if the data are reliable or if more tests are needed.
11. **Documentation and reporting:** The simulating program should be accompanied by essential documentation to explain how to manage it. In case the model is to be used again, it is necessary to have a document explaining how the model works. Also, if the model can be modified, having model documentation can be a great convenience.
12. **Implementation:** The data obtained is the main feed of decisions for implementation. If there is the necessary understanding and knowledge of how the model can be used and its results, it is more likely that the implementation will succeed.

4.5 Supply Chain Modelling

At the heart of the supply chain, the development of quality models is a necessity for making decisions about managing the risks that lurk in such a large and complex sector. Supply chain management problems such issues as inventory management, supply contracts, information flow, logistics control and design decisions managed with analytical models, simulation models and stochastic models. The first step in a supply chain design process is to decide which modelling approach to use (Harrison, 2004). According to (Pidd, 2003) modelling provides a method for developing better understanding of the behavior of complex systems, such as supply chain.

Supply chain modelling is a conscious effort to achieve its goals by making the right decisions in several sections inside the business. Supply chain modeling is used to take decision about the quantity of the production, identify markets, finding the ideally suppliers and with its implementation define the appropriate way to manage inventory, warehouses strategies, transportation, product distribution and several other issues that concern a business.

The process of modelling helps the individuals and managers to better understand how the complex system operates. A business uses its data in modeling to simulate a real system. By using what if scenarios it has the ability to prepare to reduce the effects of unpleasant events. Another privilege gained through the use of models in the supply chain is the understanding of the interactions of the members that make it up.

There are many more theories in literature, why modeling is so useful in the supply chain. (C. M. Macal, Michael John North, 2015) state some reasons about why a business have to use models in decision making process:

- No one can understand how all the various parts of the system interact and add up to the whole
- No one can imagine all the possibilities that the real system could exhibit
- No one can foresee the full effects of events with limited mental models
- No one can foresee novel events outside their mental models.

4.6 Supply Chain Simulation

Supply chain simulation suggests a procedural model that presents a supply chain or part of it. The are several reasons to choose simulation to improve supply chain performance and evaluating the risk. Simulation in supply chain can be used to:

- determine the stock values
- evaluate inventory policies
- identify bottlenecks
- evaluate the service level
- testing supply chain robustness
- estimate sales
- asking what if questions about all the facilities and processes of supply chain.

As mentioned above the simulation starts where the system is so complex to estimate from mathematical models. A supply chain is included in these complex systems. Supply chain simulation provides estimates and results for variables and parts but also how they interact with each other. Finally, it derives significant results from the analysis of data on new policies and initiatives and assesses the system's contribution to these changes and the risks that arise.

The conditions that showing the need to use simulation models instead of analytical described by (Shannon, 1975). If one or more of the following conditions appears then the simulation model have to use to express the system that studied:

- The problem has no mathematical function
- There is a mathematical model but without analytical resolution methods
- There is model and methods but simulation is simpler and less costly
- When the aim is to observe a simulated history of the supply chain
- When the aim is to experiment with a model before configuring the supply chain
- It is impossible to experiment the real supply chain
- The experimentation of a real system is possible but ethical reasons hinder this
- When the aim is to observe very slow supply chain evolution by reducing the time scale.

The objective of supply chain management is to meet customer demand. To achieves this has to transferring orders to the minimum delivery time of high-quality products and low cost. To achieve this objective the company needs to have knowledge for all the variables in the entire supply chain and the simulation is the way to make it. Simulation offers details for the improvement of the system using scenarios. Testing different decisions into the system and make conclusions about which is the preferable one and determines the priorities for every project. Simulation offers the necessary flexibility to customize and turn plans into real-time to deal with unforeseen events in the chain.

4.7 Stochastic Models

The only thing that a model needs to be stochastic is at least a random variable. Stochastic models are useful and, in some cases, necessary, as it is realistically difficult perfect mathematical models to interpret complex phenomena involving uncertainties and stochastic numerical methods allowing the solving of deterministic problems for critical situations where the deterministic models are irrelevant. Thus, stochastic models allow the evaluation of complex phenomena whose variables that affect them cannot be interpreted by accurate measurements. *“Stochastic modeling consists in choosing the probability distributions of the data and aims to compute the probability distributions of important characteristics of the phenomena under consideration”* (Carl Graham, Denis Talay, 2013). The results in a stochastic model are essentially an estimate of the probability of different outcomes.

The random variable used in the stochastic model each time, is the data that show differences over time and is also affected by immeasurable data. The final probability distributions result from many stochastic projections that reflects randomness in the inputs.

The basic steps to build a simple stochastic model are:

1. Sample space creation, is the list of all possible outcomes
2. Assign probabilities to sample space elements
3. Identify the events of interest
4. Calculate the probabilities for the events of interest

A very simple example of this process in action is a card game. Every time someone draws an ace from the deck wins.

1. The sample space includes all possibilities for drawing cards from the deck outcomes: P = {1, K, Q, J, 10, …}
2. The Probability for any card being pulled is 1/52
3. The event of interest is "draw an ace"
4. The probability of "draw an ace" is 4/52= 1/13

The model is ready for simulation.

4.7.1 Monte Carlo Method

Monte Carlo is an example of a stochastic simulation. Monte Carlo simulations are about modeling outcomes that cannot be easily predicted due to the effect of random variables on the process. The underlying concept is to use randomness to solve problems that might be deterministic in principle. A basic prerequisite for any Monte Carlo simulation is the production of a sequence of seemingly random numbers. Perhaps the best way to generate random numbers is to use a procedure such as rolling a dice, drawing numbers or create random numbers through computer applications. The logic of this method is to simulate a random variable using multiple independent iterations and then calculate the mean of these random numbers as an estimate of the mean of the original random variable. Repetition and estimation accuracy work accordingly, the more times the simulation is repeated the closer the estimate will be to reality.

The basic algorithm for Monte Carlo method is:

1. Producing n random variable J_i i=1, 2, 3, …, n that are independent with each other and are equal to a random variable J
2. Estimation for the real outcome of J is the mean of $\frac{1}{n}\Sigma_i{}^n{=}1^{X}{}_i$

The main steps for Monte Carlo simulation are:

1. Generate random input data
2. Run a deterministic harmonic load-flow
3. Store output variables
4. Evaluate statistics of output variables

The method has now undergone significant improvements such as the non-uniform sampling technique, that is, random numbers do not result from a uniform distribution but from a distribution that fits the model requirements. The method is used in many different fields such as chemistry, biology, economics, supply chain, insurance, manufacturing etc.

Monte Carlo simulation provides of advantages over deterministic simulation models:

- Probabilistic results: Results show the likelihood of each outcome.
- Graphical results.
- Sensitivity analysis: Monte Carlo shows the effect in the outcome for every input.
- Scenario analysis: Monte Carlo uses different combinations of values for different inputs to see the effects of truly different scenarios.

4.7.2 Excel and add-ins

Microsoft Excel is the most important spreadsheet software with 90% market share, which is used to calculate, analyze and present information. Excel input data are known and fixed and there is available a big range of mathematical functions which can manipulate inputs and calculate results. To introduce uncertainty and better simulate the behavior of real systems with stochastic models there are Excel add-ins available on the market, which use Monte Carlo Simulation. Some of these programs are @Risk, SimVoi, RiskAMP, RiskSolver, AnalyticSolver etc.

4.8 Resume

This chapter was the last for part of the theoretical framework and was the introduction to the concepts of modeling and simulation. This chapter answered and explained why modeling is used in the supply chain and how, what it is and how the simulation is done, their advantages and how they can improve the supply chain. It also suggested the concept of the stochastic model and the Monte Carlo method.

Part 3
Empirical Study

Chapter 5
Simulation Stochastic Models
Case studies

5.1 Introduction

In the previous 3 chapters, the three main bases that the empirical framework will deal with were explained theoretically with the help of the literature. In this chapter what has been analyzed will be practically applied. The chapter includes two case studies, one for estimating production risk with unknown demand and one for inventory and control risk, which is divided into two parts regarding the shelf life of products.

The purpose of the study in this chapter is the empirical study and analysis of risk evaluation of an organization's decisions using stochastic models in the supply chain and how these models improve its operations.

5.2 Case study for evaluation Demand Risk

Demand risk is a result of fluctuations in external customers as well as in the management of internal customer requirements. Forecasting the supply and demand chain is one of the most important issues for supply managers. Supply managers need to know and understand all the implications of decisions whether they ask for more than they really need or less. Demand risk is a risk that all companies in the supply chain must face. Businesses rely on forecasting tools, personal knowledge, information and experience to determine how many products they need to produce. Demand risk is essentially the wrong predictions about the quantity of product that customers will eventually buy. The risk for a business is that it may produce too much or too little of what it really needs, resulting in financial losses or loss. Various factors affect the final demand for products, some of which are not measurable. Deterministic models based on historical and other data are used to estimate the output that will be most profitable, although in complex situations they are not preferred. One such case is the case study that will be analyzed below.

5.2.1 Case description

Kallianiotis.C Team is a manufacturer of footwear materials and shoe accessories with many years of successful presence in the field of footwear in Greece but also with exports mainly in the Balkans. It deals with the wholesale trade, offering raw materials but also complete products to the largest factories and shoe companies in Greece but also retail outlets. Due to the condition of Covid-19, the organization of production for the supply of sandals is considered particularly difficult as it is unprecedented and uncertain. It is now time how many products to produce in this production run. Due to the specificity of the situation but also since the products are seasonal there will be no other production run. Predicting production is considered particularly difficult as the creation of such footwear takes place in the last 5 years where there has never been such a global crisis.

The production management team asked its ten sales managers concluding retail contracts to estimate demand based on their economic conditions, past sales and personal judgment.

Based on the estimates of these experienced sellers, a stochastic model will be built with use of Excel and Excel add-in SimVoi that will estimate the potential profits and the risk that the company will take if decide to produce the same quantity as last year or half quantity, because of the fear of the difficult situation or the mean of expected demand based on the managers expectations.

A model is a representation of a set of components of a real system. The model is developed for understanding, analysis, improvement or replacement of the system. A Monte Carlo simulation is a model used to predict the probability of different results using random variables. Monte Carlo simulations help assess risk and uncertainty in prediction. In this dissertation, the basic elements of the Monte Carlo simulation model have been adopted.

5.2.3 System

All the variables that describe the system are collected. In the case under consideration, after the production is decided and implemented, the products are transferred to the sales managers who resell them to the retail trade according to their demand, those products that are not sold are returned and exported at a low price.

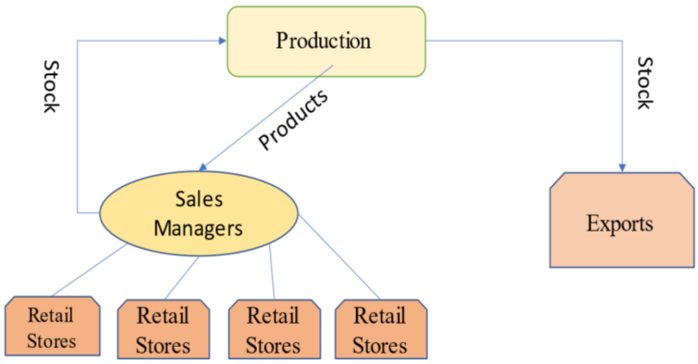

Figure 5.1 Order System

5.2.4 Modelling Objectives

The purpose of the simulation is to estimate the future profit of the business and the estimation of the risk of the choice they'll make.

Specific objectives for each production choice are:

1. Expected profits
2. Probability of loss

5.2.5 Model

<u>Model Variables</u>

Random Variable-Expected demand (Y_i)

Producing n random variable Y_i i=1, 2, 3, ..., n that are independent with each other, with n=1000(number of simulations runs)

Estimation for the real outcome of $\bar{Y}$ is the mean of $\frac{1}{n}\Sigma Y_i^n$

<u>Inputs:</u>

- Demand: Estimation from ten sales Managers (D):

Sales Managers	Demand (D)
1	20000
2	18000
3	12000
4	13000
5	7000
6	17000
7	21000
8	9000
9	10000
10	14000

Table 5.1 Demand Table

Mean (D^m)	14100
Std.Deviation (S.D)	4771,442829
Max D_{max}	7000
Min D_{min}	21000

Table 5.2 Demand Table

- Production cost per unit (c)
- Selling price per unit (s)
- Stock selling price per unit (e)
  (All stock that was not sold this season is being exported at a lower price)
- Fixed Production cost (F)
  (The cost of production regardless of the quantity of production)

c	14€
s	25€
e	10€
F	60000€

Table 5.3 Input Table

- Production Quantity (Q_1=7750, Q_2=15500, Q_3=14100)
  (Q_1 is the production that the management wants to produce this year and the Q_2 is the production that produced last year, Q_3 is the mean of manager's expected demand)

<u>Outputs</u>:

- Units sold (S)

S_i= min($Q_{1,2,3}$: Y_i), i=1,2,3,..,1000

(Is the minimum value between the quantity produced and the estimated demand in each repetition

- Units stocked (E)

$E_i=(Q_{1,2,3}-Y_i) > 0$, i=1,2,3, …,1000

(Is the value of the difference between the quantity of production and the estimated demand only if the result is positive otherwise it is zero)

- Production cost (P)

$P_{1,2,3}= c*Q_{1,2,3}$

(The cost of production based on the quantity produced is the number of units produced times their cost for producing them.

- Revenue from Sales (Rs)

$Rs_i=s*S_i$, i=1,2, 3, …,1000

(Is the value of Units sold times their price)

- Revenue from Stocked (Re)

$Re_i=e*E_i$, i=1,2, 3, …,1000

(Is the value of units stocked and sold at the end of the season in lower price times their price)

- **Profit (Π)**

$\Pi_i= Rs_i+Re_i-F-P_{1,2,3}$, i=1,2,3,…,1000

Estimation of real profit outcome is the mean of Π = $\frac{1}{n}\sum \Pi_i^n$

Distribution

For this case that there is uncertainly in demand and the only information about the demand are the manager's expectations the **truncated normal distribution** has chosen, the truncated normal distribution is the probability distribution derived from that of a **normally distributed** random variable by bounding the random variable from either below or above (or both).

In the truncated normal distribution, the random variable Y_i derived from the mean, standard deviation and the max and min values of the data. The truncated normal distribution helps to avoid negative or too large numbers that doesn't make any sense in this case. Thus, the random variable Yi takes values between the most pessimistic and optimistic manager.

5.2.6 Simulation

Once defined the distribution for the inputs, declared which are the objectives that the analysis investigates, the SimVoi simulation might begin. SimVoi simulation in based upon Monte Carlo simulation. Monte Carlo sampling refers to the traditional technique for using random numbers to sample from a probabilistic distribution. Monte Carlo sampling technique is entirely random. Samples, of course, are drawn in areas of the truncated normal distribution. To assure reliable analysis a huge of iterations has to be run: for this purpose, SimVoi performed 1000 iterations. With the use of excel sheets and excel add-in SimVoi the model simulated for 1000 runs and give 1000 random values of demand Y for the tree different quantities Q_1, Q_2, Q_3. For the accuracy of the results and for the correct comparison of the three hypotheses, the random demand values remained the same for all three production quantities.

- Hypothesis #1 Q=7750

After the run of simulation with Production Quantity Q=7750 the following results were obtained.

The following histogram shows the distribution of the expected Demand that is truncated at the lowest and highest point.

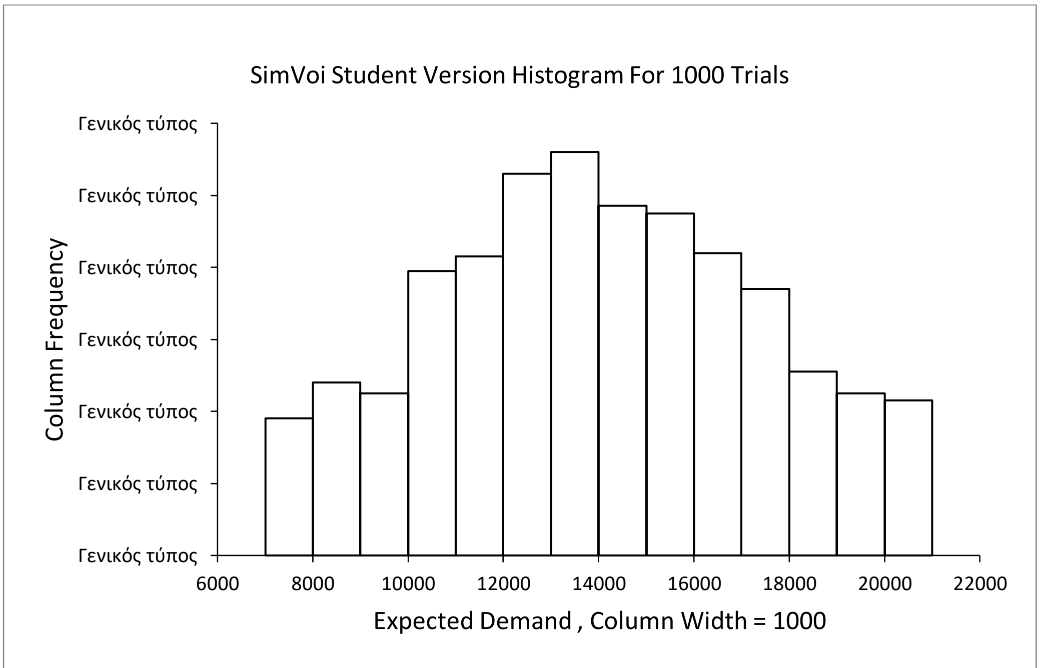

Figure 5.2 Expected Demand Distribution

The SimVoi simulation based on the model that described before give the following outcomes about the Profit with quantity production Q1=7750

	Profit Q1	Expected Demand
Mean	17369	14007
St. Dev.	983	3386
Mean St. Error	31	107
Skewness	-8,395	+0,016

Table 5.4 Outcomes Hypothesis #1

With the same way like the first simulation obtained the outcomes for the two other hypothesis.

- Hypothesis #2 Q=15500

	Profit Q2	Expected Demand
Mean	60913	14007
St. Dev.	36600	3386
Mean St. Error	1157	107
Skewness	-0,811	+0,016

Table 5.5 Outcomes Hypothesis #2

- Hypothesis #3 Q=14100

	Profit Q3	Expected Demand
Mean	59256	14007
St. Dev.	29434	3386
Mean St. Error	931	107
Skewness	-1,226	+0,016

Table 5.6 Outcomes Hypothesis #3

5.2.7 Outcome Analysis

In the following table are consumed the simulation outcomes of profit for the three different hypotheses for comparison:

Outcomes	Profit Q1	Profit Q2	Profit Q3	E.Demand Y
Mean	17369	60913	59256	14007
St. Dev.	983	36600	29434	3386
Mean St. Error	31	1157	931	107
Skewness	-8,395	-0,811	-1,226	+0,016

Table 5.7 Summary Table

Based on the data observed in the table, the production quantity 2 brings the most profits for the company, followed by Q3 and lastly Q1, however, these results are not sufficient to provide the necessary answers to the question of what quantity is appropriate for the production management team to choose for this season.

A very useful help is the Confidence Interval, this will show at what values the profits will fluctuate for each different quantity of production. To compute the confidence interval the standard deviation of the expected profits is needed that is the mean standard error from the table above.

For the calculation of 95% Confidence Interval the z-score was used. With the use of excel function:

NORM.S.INV(0,975), 95% Z-Score=1.96

, the calculation of the confidence interval for the profits of each case leads to the results of the table below:

	Mean	Mean Std Er	Low 95% CI	High 95% CI
Π_{Q1}=7750	17369	31	17307,81649	17429,6945
Π_{Q2}=15500	60913	1157	58644,66879	63181,54318
Π_{Q3}=14100	59256	931	57432,1268	61080,78353

Table 5.8 Profit Confident Intervals

But even after calculating the confidence intervals, the results cannot be considered sufficient to make the right decision. The Q_2 it seems the most popular decision but in the situation that the company defends these days, with the uncertainly that faced, what the company wants to ensure is to prevent any financial damage. Thus, the main objective of the model is to investigate the risk that the company faced with any of these three production demand decisions.

The add-in SimVoi automatically calculates how many profit scores from 1000 runs are negative, and by calculating the confidence intervals for the probability of loss, the outcome table are as follows:

Στήλη1	Mean	Mean Std Er	Low 95% ci	High 95% ci	p(<0)	Low 95& CI	High 95% CI
Π_{Q1}=7750	17369	31	17307,81649	17429,6945	0,00%	0,00%	0,00%
Π_{Q2}=15500	60913	1157	58644,66879	63181,54318	9,35%	7,55%	11,15%
Π_{Q3}=14100	59256	931	57432,1268	61080,78353	6,95%	5,37%	8,53%

Table 5.9 Probability of Profit<0

The model applied represents a real system of supply and demand, based on the results the model providing 95% confidence in the range of profits and production risk.

- As shown in the table, the quantity Q1 is estimated to bring the lowest profits but with minimal risk of loss,
- the quantity Q2 the most profits with the largest value range in potential profits but also with the greatest risk
- and Q3 slightly less profit than Q2 with less risk.

The decision that will take by the management based on the way that they perceive the risk. If the management is risk averse, they should take the decision to product the Q1 production otherwise they should choose between the two other options.

5.3 Case study for evaluation Inventory Risk

Inventory risk is the probability that an organization may not be able to sell its goods, may not be able to meet market needs, that the warehouse may not function smoothly, or that the value of the inventory may decrease. Potential loss may cause due to inventory planning and control failures. Organizations should understand and evaluate inventory risks to be able to design strategies for their management and implement best practices control inventories. In Inventory management there are several risks and timely and better management reduces costs for the organization.

Some of inventory risk types are:

- Theft: Is one of the biggest risks, theft risk prevention is something that firms spend millions of dollars to achieve.
- Shelf Life: Some products have a certain shelf life.
- Inaccurate Forecasting: The operation of the inventory does not meet the needs of the demand.
- Unreliable suppliers: Suppliers may not be reliable for delivery at the agreed delivery time and adherence to the quality and quantity of stocks.

Inventory monitoring using various online inventory control tools ensures real-time operation, optimizes forecasting and provides accurate inventory data.

5.3.1 Case description

The company Trofodotiki Aigaiou SA, since 1989, distributes consistently and responsibly, products of the largest companies. Trofodotiki Aigaiou provides services for the development and improvement of the distribution network, unique geographical coverage in the Aegean, continuous support - fast service - unsurpassed reliability and EX Van sales. The company with its staff, experience and equipment has the ability to represent or agency companies at home and abroad and sell their products in the wider market, in the Aegean islands. The company owns reliable infrastructure integrating the latest technology. Specifically owns 2000 sq.m. covered storage facilities, built to European Union standards, meet all safety and hygienic food storage standards, 200 sq.m. storage and freezing cold rooms, with electronic monitoring system for temperature fluctuations that meet the most modern safety standards, 200 sq.m. product handling and parking areas, 5 privately equipped trucks for transporting refrigerated and dry cargo and highly evolved computer system.

In this case it will be considered how a simulation of the inventory system, using a stochastic model can estimate any deviations from the company's goal which is the high level of services as well as the risk evaluation of the decisions taken in the ordering system by the suppliers.

Below developed simulations with stochastic inventory control models for two different products, one with an expiration date and one without with the use of Excel sheets.

5.3.2 Model for Product #1, No limited shelf life.

Trofodotiki Aigaiou cooperates with one of the largest oil companies Minerva. The oil bottles that it stores in the warehouses and distributes in the Aegean may not have a limited lifespan, however it cannot store a large volume in the warehouses of the company as the price of oil changes frequently.

With the study of the demand data and delivery time in the warehouses of the previous months, the necessary statistical analysis was made for accurate forecasts, the decisions were made on the way and the conditions that the orders will be made from the Minerva for each day of a month. The management decides to place an order when the boxes of oil quantity are less than 20 at the end of a day and the reorder quantity must be 20 boxes too.

These decisions will be considered for risks that may result in the level of service to the company's customers.

In this stochastic model there are two random variables the demand and lead time.

Based on the previous year orders and lead time defined the sample space and the probabilities of sample space elements. The statistical analysis led to the following results about the demand and the lead time.

Demand Table			
Limits	Upper	Demand(D)	Pi
0	0,02	0	0,02
0,02	0,07	1	0,05
0,07	0,16	2	0,09
0,16	0,31	3	0,15
0,31	0,51	4	0,2
0,51	0,69	5	0,18
0,69	0,8	6	0,11
0,8	0,89	7	0,09
0,89	0,95	8	0,06
0,95	0,98	9	0,03
0,98	1	10	0,02

Table 5.10 Demand

The table above shows what the demand probabilities are for a day. Demand values do not refer to units but to boxes containing bottles of oil.

Lead Time Table			
Lower	Upper	Days	Pi
0	0,2	1	0,2
0,2	0,6	2	0,6
0,8	0,95	3	0,15
0,95	1	4	0,05

Table 5.11 Lead Time

The table above shows the lead time probabilities of an order.

5.3.2.1 System

All the variables that describe the system are collected. Trofodotiki Aigaiou order the products from the supplier (Minerva Oil), stored in the inventory until the retail stores make their orders as it showed in the table below.

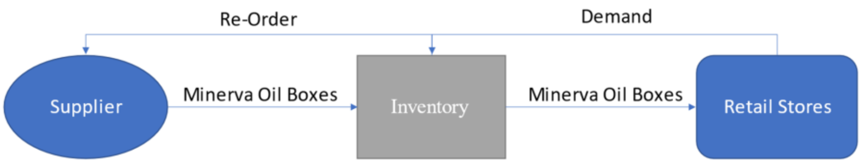

Figure 5.3 Order System

5.3.2.2 Modelling Objectives

The purpose of the simulation is to estimate the service level of the inventory for a month (30 days)

5.3.2.3 Model

<u>Inputs</u>

Reorder level is the minimum stock limit that the inventory management allows. Values below the limit lead to re-orders.

Re-order quantity is the number of boxes that the inventory order from supplier.

Beginning Inventory of the month is equal to 20 Boxes.

Reorder Level(RL)	20
Order Qnty(OQ)	20

Table 5.12 Inputs

Using the excel function RAND() created 30 random numbers between 0 to 1, one for each day of a month. These numbers used to create random variables based on the tables of probabilities for demand and lead time above.

Model Variables

Expected demand (Y_i)

Using the excel function VLOOKUP in the demand table and the 30 random numbers (0-1), created the random variable Y_i, i=1, 2, 3, . . . ,30

Demand refers to the numbers of boxes of oil sold every day.

Expected lead time (L_i)

With the same process as the random variable Y_i created the random variable L_i, i= the times that placed an order. Lead time refers to number of the days that the suppliers may needed to deliver the order.

- Receipt day (Rd_i): Is the day that the order receipt

  Rd= Day (1,..,30) + L_i + 1,

  e.g. If placed an order at the 3rd day of the month with lead time equal to two days the Receipt day is the equation, Rd= 3 + 2 + 1=6, which is the 6th day of the month.
- Units received (Ur_i) is equal to order Quantity , only the receipt days, the other days Ur=0
- Beginning Inventory (BI_i): The inventory at the beginning of each day.
- Ending Inventory (EI): The inventory at the end of the day.

BI_1= 20, the first day of the month.

For the rest of the days the beginning inventory is:

$$BI_i = EI_{i-1} + Ur_i ,$$

and $EI_i = BI_i - Y_i \geq 0$, otherwise $EI_i = 0$

- New inventory level (NL_i): At the end of the day the level of inventory changed if the demand $Y_i>0$,

If $NL_i<RL$, the inventory management place an order

and $NL_i = NL_{i-1} - D_i + OQ$,

otherwise $NL_i = NL_{i-1} - D_i$

- Lost Sales (S_i): Every day that the demand is higher than the beginning inventory meaning lost sales for the company

and $S_i = Y_i - BI_i$, Otherwise $S_i=0$

Outputs

Demand of the month (d)

$$d = \Sigma Y_i, \ i=1,2,3,\dots,30$$

(Is the Sum of each day Demand)

Lost sales of the month (s)

$$s = \Sigma S_i, \ i=1,2,3,\dots,30$$

(Is the sum of each day lost sales)

Service Level:

Is the objective of the model.

How accurate the forecasting of the management is?

Service Level= 1-s/d

Distribution

The distribution of demand and lead time is normal distribution. The values of demand are symmetric about the mean.

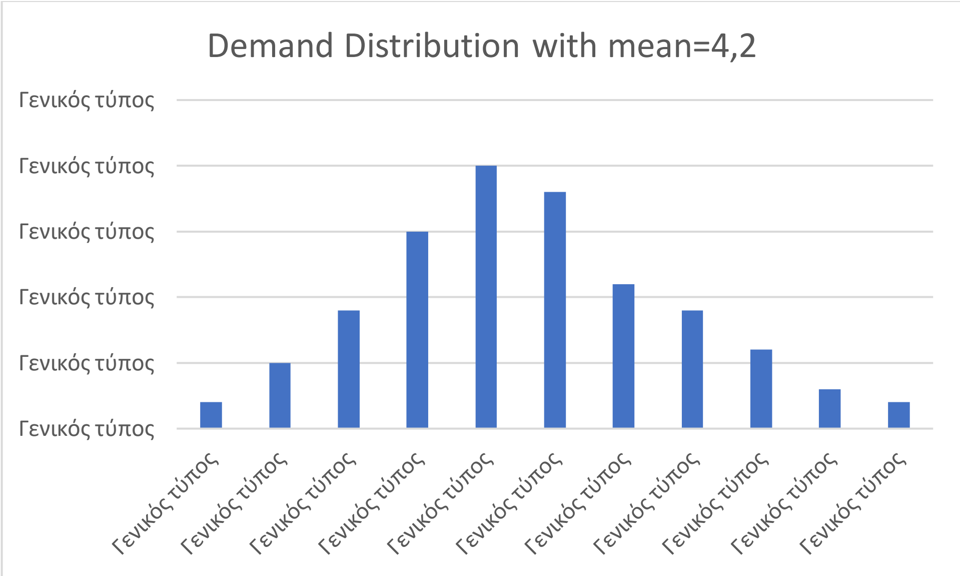

Figure 5.4 Demand Distribution

5.3.2.4 Simulation and Outcomes

After the 1000 run of simulation for 30 days, management can monitor and interpret the results. The model represents a real control inventory system. The management monitoring if the decision for order quantity and re order level was right or it can be dangerous for the inventory.

Day	Units Rc	Begin Inv	Rand No	Demand	End Inv	New Level	Lost Sales	Order?	Lead Time	Recpt Day
1		20	0,386437	4	16	16	0	YES	2	4
2	0	16	0,154579	2	14	34	0	NO		
3	0	14	0,998616	10	4	24	0	NO		
4	20	24	0,331466	4	20	20	0	NO		
5	0	20	0,59703	5	15	15	0	YES	2	8
6	0	15	0,420666	4	11	31	0	NO		
7	0	11	0,267201	3	8	28	0	NO		
8	20	28	0,067861	1	27	27	0	NO		
9	0	27	0,035375	1	26	26	0	NO		
10	0	26	0,546547	5	21	21	0	NO		
11	0	21	0,967631	9	12	12	0	YES	4	16
12	0	12	0,662801	5	7	27	0	NO		
13	0	7	0,248367	3	4	24	0	NO		
14	0	4	0,400952	4	0	20	0	NO		
15	0	0	0,198552	3	0	17	3	YES	1	17
16	20	17	0,492257	4	13	33	0	NO		
17	20	33	0,738616	6	27	27	0	NO		
18	0	27	0,378131	4	23	23	0	NO		
19	0	23	0,22742	3	20	20	0	NO		
20	0	20	0,905483	8	12	12	0	YES	3	24
21	0	12	0,518366	5	7	27	0	NO		
22	0	7	0,283995	3	4	24	0	NO		
23	0	4	0,649564	5	0	19	1	YES	2	26
24	20	19	0,136216	2	17	37	0	NO		
25	0	17	0,737153	6	11	31	0	NO		
26	20	31	0,341922	4	27	27	0	NO		
27	0	27	0,289309	3	24	24	0	NO		
28	0	24	0,987835	10	14	14	0	YES	4	33
29	0	14	0,552013	5	9	29	0	NO		
30	0	9	0,809002	7	2	22	0	NO		

Table 5.13 One-month Inventory System

In the table above showed one month Inventory system, after the model simulation of 1000 runs, the following results were obtained.

	Sum Demand	Sum Lost Sales
Mean	138,5642	5,8525
St. Dev.	11,96176353	8,515033431
Mean St. Error	0,119617635	0,085150334
Skewness	+0,050	+2,284

Table 5.14 Simulation Outcomes

Thus, the service level of the inventory with the specific re-order level and order quantity is Service Level=1-s/d=1-5.85/138.56= 0,957763= 95.78%

As it showed from the output table the service level is really high, which means that the decision on order quantities and re-order level was correct. Even if it were not, the management can apply what if scenarios in the model until it finds the right quantities that maximize its level of service.

If the management decides to order 25 boxes of oil and change the reorder point to 15 then the results will be different.

Sum Demand	145
Sum Lost Sales	26
SERVICE LEVEL	82,07%

Table 5.15 What if, Order=25, re-order point=15

As it showed from the second output table the service level is much lower than before.

Organizations use and review models before making their decisions to assess risks but also to consider alternatives.

5.3.3 Model for Product #2, Limited shelf life.

Trofodotiki Aigaiou S.A cooperates with another huge company in Greece, Dodoni, has its exclusive distribution throughout the Aegean and stores a huge volume of its products in its warehouses. The difference between these products and the rest is that they have a limited lifespan, so there is a specific time that they can be stored in the company's warehouses, can remain in warehouses for three weeks, after which they cannot be distributed as there is not enough time left to remain on the retail shelves. This is a key decision-making factor for inventory management in decisions about order size and warehousing. From the beginning of spring until the first days of autumn, there has been a great increase in demand for 1kg yogurt of packaging, the management wants to implement the most correct ordering and storage system so that it has a high level of service to its customers but also security that there will be no damage with products that will remain stored longer than the limits.

The products come and are distributed in boxes of 24 unit with a wholesale cost of 2 euros per unit and a resale price of 3.5 euros per unit. Unfortunately, there is an unstable demand, with a maximum number of boxes distributed in a week of 20.

The management decided for the 31 weeks that the biggest traffic is observed in this product to set as a minimum stock limit in its warehouse 10 boxes and a re-order quantity of 20 boxes. Delivery time is fixed, the order is placed every Friday and the products arrive at the warehouse next Monday.

What management wants to consider with the following stochastic model is the level of inventory in relation to revenue. The ratio of the expected revenues with the system that decided in relation to the maximum revenues that it would have if it covered all the market demand without any expired products on its shelves is therefore examined. The management considers as a successful performance the percentage of this ratio over 90%.

Based on the previous year orders defined the sample space and the probabilities of sample space elements. The statistical analysis led to the following results about the probabilities of demand for a week.

Demand Table			
Limits	Upper	Demand	Pi
0	0,01	0	0,01
0,01	0,02	1	0,01
0,02	0,03	2	0,01
0,03	0,05	3	0,02
0,05	0,09	4	0,04
0,09	0,13	5	0,04
0,13	0,18	6	0,05
0,18	0,23	7	0,05
0,23	0,3	8	0,07
0,3	0,39	9	0,09
0,39	0,51	10	0,12
0,51	0,61	11	0,1
0,61	0,69	12	0,08
0,69	0,76	13	0,07
0,76	0,83	14	0,07
0,83	0,88	15	0,05
0,88	0,93	16	0,05
0,93	0,97	17	0,04
0,97	0,98	18	0,01
0,98	0,99	19	0,01
0,99	1	20	0,01

Table 5.16 Demand Probabilities

The table above shows the demand and the probabilities of occurrence, with mean= 10.42 boxes

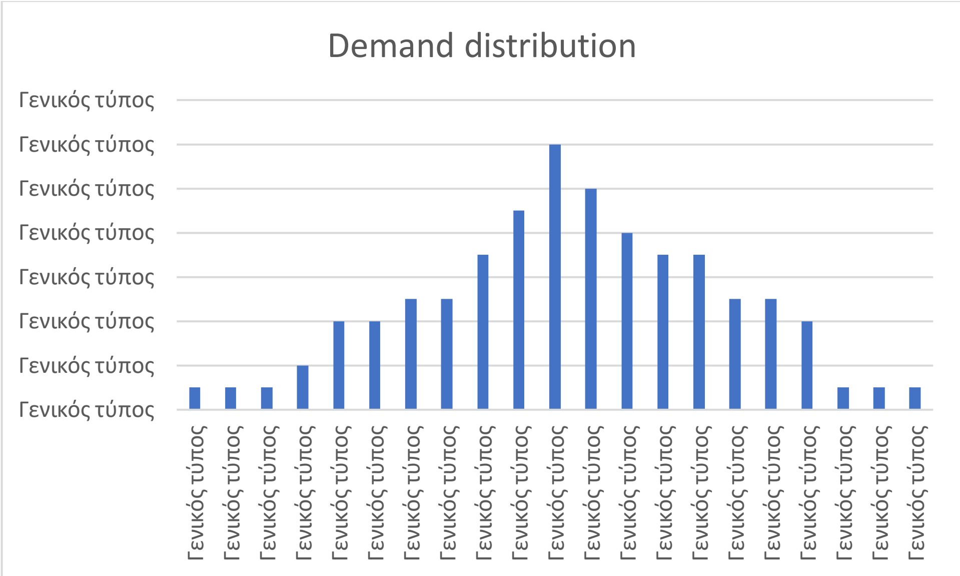

Figure 5.5 Demand Distribution

As it showed in the histogram above the distribution is close to normal.

5.3.3.1 System

All the variables that describe the system are collected. Trofodotiki Aigaiou order the products from the supplier (Dodoni), stored in the inventory until the retail stores make their orders, if the products stored more than the shelf-life limits are removed from the shelves and cannot be sold as it showed in the graph below.

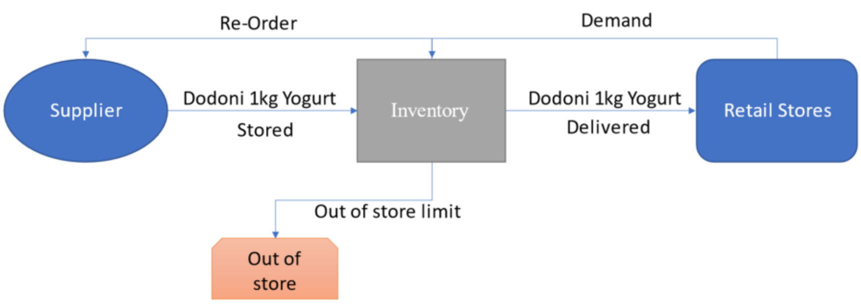

Figure 5.6 Inventory System

5.3.3.2 Modelling Objectives

The objective of this model is to investigate the risk that the order system decision gives a revenue score above the 90% for the duration of 31 weeks of high demand.

5.3.3.3 Model

Inputs

Re-order level is the minimum stock limit that the inventory management allows. Values below the limit lead to re-orders.

Re-order quantity is the number of boxes that the inventory order from supplier.

Beginning Inventory of the month is equal to 20 Boxes.

Wholesale price is the price that the company buys the product of the supplier.

Selling price is the price that the company sells the products to retailers.

Re-order Level (RL)	10
Re-order quantity (RQ)	20
Wholesale price (WP)	2€
Selling price (SP)	3.5€
Unit shelf-life (j)	3

Table 5.17 Inputs

Using the excel function RAND() created 31 random numbers between 0 to 1, one for each week of interval of evaluation. These numbers used to create random variables based on the tables of probabilities for demand above.

Model Variables

Expected demand (Y_i)

Using the excel function VLOOKUP in the demand table and the 31 random numbers (0-1), created the random variable Y_i, i=1, 2, 3, . . . ,31

Demand refers to the numbers of boxes of Yogurt sold every week.

The inventory applies first in first out system for its orders, thus the oldest products sell first.

- Units received (Ur_i) is equal to order Quantity, only the receipt weeks, the other weeks Ur=0
- Units in shelves, ($U_{i,j}$), j=1,2,3 shelf-life weeks remaining

  $\mathbf{U_{i,3} = Ur_i}$,

  $\mathbf{U_{i,2} = U_{i-1,3} - (Y_{i-1} - U_{i-1,2} - U_{i-1,1})}$,

  If $Y_{i-1} > U_{i-1,2} + U_{i-1,1}$

$\mathbf{U_{i,2} = U_{i-1,3}}$,
if $Y_{i-1} <= U_{i-1,2} + U_{i-1,1}$

otherwise $\mathbf{U_{i,2}=0}$

$\mathbf{U_{i,1} = U_{i-1,2} - (Y_{i-1} - U_{i-1,1})}$,
If $Y_{i-1} > U_{i-1,1}$

$\mathbf{U_{i,1} = U_{i-1,2}}$
if $Y_{i-1} <= U_{i-1,1}$

otherwise $U_{i,1} = 0$

- Expired Units (e_i) is the units that cross the time limit in shelves.
  $\mathbf{e_i = U_{i-1,1} - Y_{i-1}}$,
  if $Y_{i-1} < U_{i-1,1}$

  otherwise $\mathbf{e_i=0}$

- Beginning Inventory (BI_i): The inventory at the beginning of each week.
- Ending Inventory (EI): The inventory at the end of the week.

$BI_1 = 20$, the first week of the month.
For the rest of the weeks the beginning inventory is:
$BI_i = EI_{i-1} + Ur_i$,
and $EI_i = BI_i - Y_i - e_i \geq 0$, otherwise $EI_i = 0$

- Lost Sales (S_i): Every week that the demand is higher than the beginning inventory meaning lost sales for the company
  and $S_i= Y_i-BI_i > 0$, Otherwise $S_i=0$

<u>Outputs</u>

Demand of the period (d)
$d= \Sigma Y_i$, i=1,2,3, … ,31
(Is the Sum of each week Demand)

Lost sales of the period (s)
$s=\Sigma S_i$, i=1,2,3, … ,31
(Is the sum of each week lost sales)

Lost products of the period (e_p)
$e_p = \Sigma e_i$, i=1,2,3, … ,31
(Is the sum of each week expired units)

Max Revenue (mR)
mR = 24(number of units in each box) d* SP (unit selling price)
(Is the revenue that the company will earn if be cable of to satisfy the market needs)

Total Revenue (tR)
tR = 24(d-s) * SP – $24e_p$*WP (wholesale price)
(Is the expected revenue that the company earns)

Revenue Score is the objective of the model and is equal to tR/mR

5.3.3.4 Simulation and Outcomes

After the 1000 run of simulation for 31 weeks of interest, management can monitor and interpret the results. The model represents a real control inventory system. The management monitoring if the decision for order quantity and re order level was right or it can be dangerous for the inventory and company's revenue.

Week	Units Rc	Begin Inv	3 week	2 week	1 week	expired	Rand No	Demand	End Inv	Lost Sales	Order?
1	20	20	20	0	0	0	0,747855	13	7	0	YES
2	20	27	20	7	0	0	0,063311	4	23	0	NO
3	0	23	0	20	3	0	0,368438	9	14	0	NO
4	0	11	0	0	11	0	0,628305	12	0	1	YES
5	20	20	20	0	0	0	0,300284	9	11	0	NO
6	0	11	0	11	0	0	0,370157	9	2	0	YES
7	20	22	20	0	2	0	0,039854	3	19	0	NO
8	0	19	0	19	0	0	0,067969	4	15	0	NO
9	0	15	0	0	15	0	0,91789	16	0	1	YES
10	20	20	20	0	0	0	0,380183	9	11	0	NO
11	0	11	0	11	0	0	0,869496	15	0	4	YES
12	20	20	20	0	0	0	0,275336	8	12	0	NO
13	0	12	0	12	0	0	0,423604	10	2	0	YES
14	20	22	20	0	2	0	0,075224	4	18	0	NO
15	0	18	0	18	0	0	0,040196	3	15	0	NO
16	0	15	0	0	15	0	0,288512	8	7	0	YES
17	20	20	20	0	0	7	0,367949	9	4	0	YES
18	20	31	20	11	0	0	0,585024	11	20	0	NO
19	0	20	0	20	0	0	0,832515	15	5	0	YES
20	20	25	20	0	5	0	0,382057	9	16	0	NO
21	0	16	0	16	0	0	0,577911	11	5	0	YES
22	20	25	20	0	5	0	0,346874	9	16	0	NO
23	0	16	0	16	0	0	0,951697	17	0	1	YES
24	20	20	20	0	0	0	0,310679	9	11	0	NO
25	0	11	0	11	0	0	0,801064	14	0	3	YES
26	20	20	20	0	0	0	0,458606	10	10	0	NO
27	0	10	0	10	0	0	0,952699	17	0	7	YES
28	20	20	20	0	0	0	0,031318	3	17	0	NO
29	0	17	0	17	0	0	0,230217	8	9	0	YES
30	20	29	20	0	9	0	0,769482	14	15	0	NO
31	0	15	0	15	0	0	0,742812	13	2	0	YES

Table 5.18 Inventory System for 31-week period

In the table above showed a 31-week period inventory system. After the 1000 simulation runs of the model obtained the following outcomes.

	Sum Expired	Sum Lost Sales
Mean	7,8767	11,2804
St. Dev.	6,73393137	7,840479778
Mean St. Error	0,067339314	0,078404798
Skewness	+1,049	+0,941

Table 5.19 Simulation Outcomes

Based on the table above means:

e_p = 7.87767 expired units and s=11.2804 lost sales of the interest period.

	Sum Demand	Max Revenue
Mean	323,1068	27140,9712
St. Dev.	22,70549158	1907,261292
Mean St. Error	0,227054916	19,07261292
Skewness	+0,019	+0,019

Table 5.20 Simulation Outcomes

Based on the simulation runs means the total demand for the 1kg Yogurt boxes in the period of investigation will be d=323,1068 and the earnings that the company god earn if it covers all demand needs will be mR = 27140,9712€.

	Total Revenue	R.Score
Mean	25774,7544	95,00%
St. Dev.	2191,492337	2,87%
Mean St. Error	21,91492337	0,03%
Skewness	-0,264	-1,117

Table 5.21 Simulation Outcomes

Finally, the last table presents the expected revenue that company earns based on the model and the Revenue Score that company tries to keep it high. The revenue score is high but the question of the management is probability of being under 90%.

The add-in SimVoi automatically calculates how many revenue scores from 1000 runs are below 90%, and by calculating the confidence intervals for the probability of this with the use of excel function for 95% Z-score, the outcome table are as follows:

	Mean	Mean St. Error	Low 95% CI	High 95% CI	p<90%	Low 95% CI	High 95% CI
R.Score	95,00%	0,03%	94,94%	95,05%	5,0%	3,65%	6,35%

Table 5.22 Revenue Score CI

The model applied represents a real system of inventory with shelf-life products, based on the results the model providing 95% confidence that the probability Revenue Score will be below 90% is between 3.65%-6.35% that could be characterized as low risk.

5.4 Resume

In this chapter applied three stochastic models for the evaluation of risk in management decisions. The aim was to put into practice the theoretical framework that has been analyzed and to show how stochastic models improve supply chain processes and how it assesses the risks of its decisions. Finally, based on the results obtained, it is possible to adjust the procedures so as to achieve the desired result or to ensure that the occurrence of risk has been reduced.

Chapter 6
Conclusions

6.1 Conclusions

In order to comprehensively study the actions and transmissions of the supply chain network, it is necessary to understand the impact of business decisions and collaborations. Simulation of stochastic models has been found to be one of the most popular and suitable methods for understanding supply chain dynamics.

In this dissertation, tools for simulating important parts on the supply chain were developed to analyze and study different structures of its issues. The modules captured the general process and supply chain concepts.

Stochastic simulation models provide the ability to evaluate resource usage, evaluate supply chain structure, identify congestion in the system, evaluate alternative connection changes, and analyze business strategies, its risk and the its alternatives decisions.

According to all the models that were applied, the most important factor for decision making is the demand. This variable affects all outputs taken into account by the model and is therefore a key point for improving supply chain processes but also for decision making. The smooth and regular management and distribution of orders from the supplier and to the customer is more important than the number of orders placed, Because the uncertainty of demand does not allow the application of perfectly correct planning to cover it, the planning must take into account other variables such as ensuring low cost and avoiding loss.

From the model of the first study, the conclusion is drawn that when there is demand uncertainty with the use of what if scenarios, a decision can be made that covers more the personal characteristics of the respective management such us risk averse. If the management tends to keep the business at a level of protection with the risk of not making potential profits, using the model so that decisions can be made with the least loss rate, instead the risk tolerance management is looking to find the best production combination that will give it the most profits up to the risk limit it is willing to take.

In the second case study it was observed that demand uncertainty is not the only important variable in the supply chain, lead time can play a decisive role and its deflection increases the risk of unwanted risks.

Another important factor in the second case study was the differentiation of the products, products should not all be treated in the same way, For example if in the second part of the second case study the re-order quantity was the same as the product of the first part of the case study then the inventory may have had a very high level of service but would have a much higher risk of exceeding the product life limits and causing great financial loss that the largest number of order coverage did not cover it.

Both case studies confirm the literature which states that stochastic models take the place of deterministic when the system is particularly complex and uncertainty is the main problem.

As for the use of such models in the supply chain which is a system of complexity, it is evident from the application of the models that these assumptions and dilemmas for management decisions could not have been taken without their use.

6.2 Pros and Cons of the work

There are several advantages of the implementation of the stochastic models in case studies of supply chain that analyzed in the previous chapter. Some of that are:

- The model describes quite well a complex system, it is cheap and user-friendly.
- It is obviously less time consuming compared to performing a real experiment on the system.
- The model allows, to make different efforts and combinations until the desired result is achieved.
- It allows to test new policies without interfering with reality: this is the main purpose of a simulation model
- The models were based on specific inputs and sector but can be applied to other inputs that create uncertainty in other areas as well.

The advantages of the models that were applied are many, however, there are also disadvantages. Some of that are that the interval and other activities that affect the processes are not taken into consideration, only one supplier in each case was taken into account and only orders from one product each time, and others factors that affect the demand wasn't used.

Finally, stochastic models seem to be the best solution for risk evaluation in the supply chain that uncertainty in its operations and the factors that affect it is a given. The simulation of such a complex system is a huge source of time and money savings, the alternatives that are introduced each time show the behavior of the system to get the right strategy decisions or to improve the existing one in noticeably short time.

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