

Monte Carlo Simulation Concept for Demand Risk Identification in a Supply Chain

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Abstract: *The supply chain industry is changing with a constant and rapid pace towards digitization, which is forcing the companies to work in collaborations. It is almost becoming impossible for organization to achieve all their targets all alone, they need to work with each other closely and this collaboration is increasing the risks associated with supply chain. In today's world of highly competitive environment, an effective demand management process is very important; this could lead to the success of any organization. Demand risks are one of the most prominent risks associated with any supply chain. Demands are the soul of collaboration and the companies have to achieve a great level of demand management to achieve their combined targets. A small error in the demand planning can lead to devastating results for businesses, that is why these the demand risks should be taken very seriously and have be identified and mitigated well in time. The aim of this research is to analyze the overall supply chain risks and to further focus on the risks associated with demands and to show possible methods and concepts to mitigate these risks. We have shown how Monte Carlo simulation models can be used to mitigate the risks associated with demands.*

Keywords: *supply chain risks, supply chain collaborations, demand risks, Monte Carlo simulation, automation*

1. INTRODUCTION

Risks are very common in day-to-day life; there is almost nothing where there is no risk involved. Risks are tied up with our lives and our lives are tied up with risks. With the fast growth in technology, the supply chains have become very complex, the more the supply chains are complex the more they are challenging. The managers of the supply chains have to take care of many things at the same time on the other hand engaging in collaborations and maintaining relationships has become a major concern for the managers in manufacturing and industrial companies, and collaboration has become a vital part of the supply chains across the globe. Although these collaborative networks are vital parts of the supply chains of today, still collaborations in the production industry experience a failure of 50% if not more (R. Dekkers, A. Sauer, M.Schönung, G. Schuh, 2005).

The firms have the common goals of saving cost, grabbing more customers and leading the Business market. In order to achieve these goals, it is need of the time that the Businesses and firms across the globe are bonded in collaborative networks. "A collaborative

network is the collection of businesses, individuals and other organizational entities that possess the capabilities and resources needed to achieve a specific outcome" (J. Shuman and J. Twombly, April 2008). As firms collaborate and combine forces to compete as extended enterprises against other integrated supply chains, risk is linked to the interdependence among supply chain partners (Robert E. Spekman, Edward W. Davis, (2004).

Many manufactures in today's world own different manufacturing sites where different types of products are manufactured, the manufactured products are sent to their warehouses, these manufactures have a known set of retailers, the orders of those retailers are known, while the frequency of the orders by those retailers are also known, so they send their products directly to the retailers from the warehouses, and then the retailers sell the products to the end customers, with this much simple supply chains the Businesses put their entire energy in the saving of costs.

The costs saving factors could of choosing the right transportation methods, the right forecasting methods, the right warehouse sizes and locations etc. besides this they focus on the quality of their products to get maximum customer satisfaction. Supply chains like the above from the manufactures to end customers are relatively easy to manage, because maximum of the parameters of the supply chains are known. But as the technology grows, the supply chains get more complex, in the recent days the online shopping has emerged, many manufactures offer their online shops where they sell their products directly to the customers.

For the Customers it is an easy way to get their orders without spending their times in search of products in different stores, it is an easy way to shop, a simple click and within few days their products are at their doorsteps, but in background it is really a complex job, and it becomes very challenging to fulfill the phenomenon to deliver "the right product, at the right time, to the right customer at the right cost" but still the supply chain managers and firms make sure that the products are delivered to the customers in time.

Many risky decisions in supply chain like, introducing a new product; outsourcing manufacturing; expanding into new markets; could result in a significant benefit to the company, but it is really important to identify those risks well on time and to use the correct mitigation strategies to overcome those risks.

Companies which take risks and plan for them (have mitigation strategies defined should the risk materialize) are likely to be more successful, they should try to be proactive not reactive. However, having a mitigation strategy is also not enough; a strategic competency in responding to the unexpected is also required. This ability is a combination of agile processes and tools that allow a company to recognize an event, assess the impact, and respond accordingly (Kinaxis, 2012). If organizations and firms want to Excel in their businesses, they have to identify their business risks and they should choose the right risk mitigation strategies to mitigate the risk well on time.

2. METHODOLOGY

The main objective of this research is to analyze the supply chain risks in general and to further focus on the demand risks mitigation concepts. For the success of any organization, an effective demand management is very important, different researchers have proposed different methods of risk management in demand fluctuation and forecasting problems, one of them is the "Linear weighted point method" but for further improvements and to achieve efficient results the "Linear weighted point method" will be embedded with Monte Carlo simulation in this research to analyze demand forecasting problem.

In order to link this research to the field of Supply Chain Risk Management, it is important to identify and present the current progress in this field with the help of various definitions, terminologies, literature and to identify research opportunities and to further discover the gaps between ideas of different researchers.

2.1 Understanding risk

One cannot define risk in specific words; it is the probability of the unforeseen occurrence of something, which can have a negative impact on any Business. In previous days risk used to be simply linked to unexpected events but with the passage of time and continuous interest of researchers shown in the risk management, different researchers define risks in different ways some important definitions are given below: Risk is a direct measure of probability of its occurrence and its potential degree of damage that can take place by selecting the given risky situation (Lowrance, W.W., 1980).

Risk is the "level of exposure to uncertainties that the enterprise must understand and effectively manage as it executes its strategies to achieve its Business objectives and create value" (Deloach J.W., (2000). A more standard definition of risk is " risk is a chance, in quantitative terms, of a defined hazard occurring" (Brindley, 2004). The firms and Businesses can reduce or limit the impact of the Supply Chain disruptions by identifying the risks within their supply chains and developing the right ways and strategies to mitigate them. It is important to identify the disruptions within

the supply chains in order to Excel in the Business market. This process should be documented in the risk management plan, which is part of the overall business plan (Queensland Government, 2013).

2.2 Supply Chain Risk Management

Supply chain risk management is now more critical than ever in all sectors of the industry. The potential impact of the supply chain risks on the core business and reputation of an organization cannot be underestimated (Andrew Underwood, 2013). In earlier days the main focus of the supply chain management used to be on the material flow, financial flow and information flow, but in fact the risk events which have a direct or indirect influence on the supply chain should also be considered as one of the important focal points and should be taken very seriously but in recent times the risk management is considered as a new norm and it is a hot topic in the supply chain industry, different authors have shown interest in this sector and similar ideas have been presented by (Musa, S. Nurmaya,, (June 2012), (Sunil Chopra and ManMohan S. Sodhi,, (October 2004)), (Johnson, M. Eric,, (March 2001), (Robert E. Spekman, Edward W. Davis, (2004) all these authors have tried to identify the dimensions of risk in the supply chain operations.

A supply chain can be affected by different kind of risks, when the risks interrupt the supply chain, the performance of the supply chain is affected, and different risk's types can have different impact on the supply chain performance so a solid risk analysis process could identify the impact of disruption on supply chains. All these risks can be managed through a standard risk management process.

The supply chain risk management is the process, which shows how the risks associated to the supply chain can be properly managed. Supply chain risk management as "the ability of a firm to understand and manage its economic, environmental, and social risks in the supply chain", which could be materialized by the adoption of contingency planning and having resilient and agile supply chains (Musa, S. Nurmaya,, (June 2012). The supply chain risk management process consists of 2 elements; supply chain risk analysis and supply chain risk control. Figure 2.1. shows the supply chain risk management process.

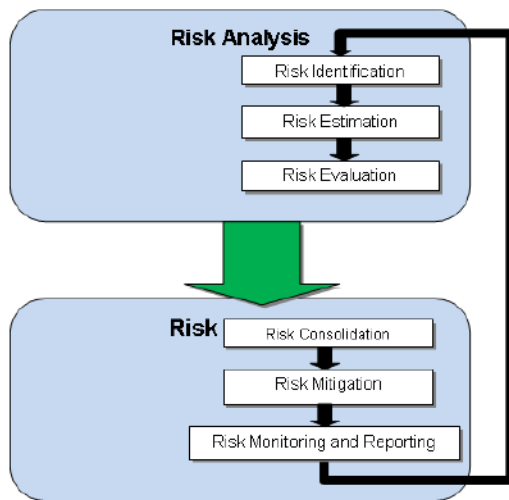


Figure: 2.1. supply chain risk management process¹.

2.3 Supply Chain Risks Types:

The risks associated with supply chain can be divided into 2 main types External risks and internal risks. Internal supply chain risks are referred to the risks, which are inside the supply chain.

2.3.1 Internal supply chain risks:

The Internal risks gives better opportunities to be mitigated because they are inside business's control, some of the most vital internal risks are "Manufacturing risks", "Technological risks", "Material flow risks", "Planning and control risks", "Performance Risk", " Organizational cultural risks".

2.3.2 External supply chain risks:

Those risks which have an impact on the supply chains from outside, they are outside of one's control or one can have very little control on them can be called as external supply chain risks, but when they are properly identified, they can be controlled and can be mitigated. Some of the important external risks are "Supply risks", "Market risks", "Environmental risks", "Natural Disasters", "Political risks", "Economic risks" "Demand risk" (this is our target risk for this research and is explained in details). Demand risks are can be the outcome of the other risks as well when they occur, a simple correlation is shown below.

A. Demand risk:

The most frequent risk to which the supply chains are always prone is the demand risk. When they say "customer is always right", it is very difficult to forecast the right demand because there are a lot of elements which revolves around the demand. Different authors define the demand risks in a different ways, according to (The Decision Makers, ,(2001)) (Cranfield School of Management, ,(2013)) "Demand risk relates to

potential or actual disturbances to flow of product, information, cash, emanating from within the network, between the focal company and the market. This demand risk can be a failure on either the high or low side to accurately accommodate the level of demand".

The demand risk can be caused by unpredictable or misunderstood customer or end-customer demand (Queensland Government, 2013). (Vinod Lall, 2011)in his report compares the demand risk with the demand risk, according to him the demand risk is the downstream equivalent of demand risk and the demand/outbound side of the supply chain is prone to this risk.

The demand risk may arise due to an unexpected increase or decrease in customer demand that results into a mismatch between the forecast and actual demand of the company. Further (Vinod Lall, 2011) and many other authors writes in their reports that, an increase in customer demand leads to depletion of safety stocks, resulting in stock-outs and back orders while on the other hand a fall in the customer demand leads to increased holding costs and price reductions. (Jim Lawton, 2007) Describes a Demand risk as demand and inventory fluctuations and challenges. While some suppliers jump at the chance to take on new opportunities but enthusiasm does not necessarily mean they are in the best position to Excel. Figure 2.2 shows the possible demand risks to any supply chain.

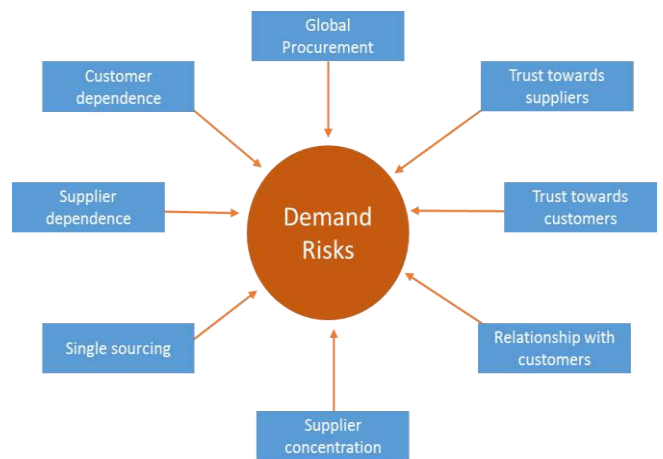


Figure 2.2. Demand Risk ²

In real world the demand risk is taken quite seriously by every firm, they are quite aware of the demand risk within their supply chain, many logistics specialist in different firms have the job to accurately estimate the forecasts in order to save costs and different types of forecasting techniques are being used by different specialist to properly identify the forecasts.

¹(Musa, S. Nurmaya, (June 2012) (Stefan Seuring and Martin Muller 2003).

²Conceptualizing a Model for Demand –Side Risk in Supply Chain, (Santanu Mandal 2012)

The demand risk is one of the most common risks to the supply chain industry for this reasons it is really important to identify the demand risks well on time and within less possible time, these risk should be mitigated. If it is not taken seriously, it can have a very costly impact on the business and on the entire supply chain because all the elements of the supply chain are very strongly inter-connected. Further to the demand risks below are some more risks which has a direct impact on the demand fluctuation when they occur.

B. Geopolitical Risks:

Politics plays a vital role in today's global supply chains with collaboration, this risk is also a vital risk to the supply chain industry, it can have a great impact on the supply chain operations and demand fluctuations. Every business, which is involved in the flow of goods and in dealing with the emerging markets, is exposed to geopolitical risks. Although there are many supplies of raw materials and other goods in the emerging markets but the geopolitical risks are also significant and can have an impact on the bottom line profit of most of the businesses (Corina Monaghan, April, 2011).

The geopolitical disruptions consists a range of potential disruptions, which includes conflicts and unrests, terrorism, corruption and organized crime. The effects of terrorism on global supply chains is illustrated by a cumulative increase in expenditure of over US\$ 1 trillion in the US domestic homeland security since 9/11, as well as a range of new industry regulations and requirements across supply chain and transport networks (Dr Frank Appel, 2012). In the recent times, Brexit is already having an impact on the demand fluctuations in many major industries.

C. Economic Risks:

The Economic risks also have a great and direct impact on the demand fluctuations, the demand risks automatically increases as soon as the economic risks occur. The economic risks cover a wide range of disruptions which include currency fluctuations, sudden demand fluctuation, commodity price volatility, border delays and ownership/investment restrictions. Many of these have been highlighted by the global financial crisis in 2008 and the current Eurozone crisis (Dr Frank Appel, 2012). The report further states that following the 2008 financial crisis, annual filings for supplier bankruptcy within the automotive sector roughly doubled from 2007 to 2008

- Demand sudden fluctuation 44%
- Extreme instability in commodity prices 30%
- Border delays 26%
- Currency fluctuations 26%
- Global energy shortages 19%
- Ownership/investment restrictions 17%
- Labor shortage 17%

3. EXPLANATION AND RESULTS

In this phase of our research, we have explained Monte Carlo simulation concept with Microsoft Excel to perform the risks analysis associated with demands. Different authors have presented different types of risk analysis techniques in their projects and have worked well for them; in our research, we have used Monte Carlo Simulation to analyze the risks of the Supply Chain and the results have shown that a small demand fluctuation can have a big impact on the supply chain costs.

Monte Carlo simulation is a computerized mathematical technique that allows firms and users to account risk in quantitative analysis and decision-making. This technique is used by professionals in such widely disparate fields as finance, project management, energy, manufacturing, engineering, research and development, insurance, oil & gas, transportation, and the environment (Palisade Corporation, 2013).

Monte Carlo simulationis also called probability simulation and this technique is used to understand the impact of risk and uncertainty in financial, project management, cost and other forecasting models. The Monte Carlo method is distinguished from other techniques in numerical analysis by the use of random sampling to construct the solution of a physical or mathematical problem (L. L. Carter and E. D. Cashwell , 1975). "Monte Carlo simulation provides a range of possible outcomes and the probabilities of occurrence for any choice of action for a decision maker. It provides the extreme possibilities, the outcomes of going for broke and for the most conservative decision along with all possible consequences for middle of the road decisions" (Chris Rodger and Jason Petch, 1999). Monte Carlo simulation works in a very simple way, on every iteration and for each input, the Monte Carlo simulator selects a random value from the probability distribution, which is relevant and is used in the input, in a way over a large number of iterations; the distribution of the selected values shows the input probability distribution. For example, if we take the input of a modal as a normal distribution with a mean 5 and standard deviation 2, the distribution of the actual inputs selected during the simulation will be approximately mean 5 and approximately standard deviation 2. It is obvious, that the more iterations are run we will get the closer actual input distribution.

3.1. Simulation experiments:

In order to give a clear overview how monte carlosimulation can help to mitigate risks with demand forecasting we have presented a sample data to show the impact. The concept can be implemented to a large population data in the real world. In our experiment we have used Monte Carlo Simulation with Microsoft Excel to achieve our results. The experiment example is presented where the demand structure will be changed and the impact will be observed after the simulation is

run for around 10000 times. The idea to capture the reaction of the supply with this simple example, it can be further expanded to a bigger problem and the reaction of the supply chain can be observed.

In order to do Monte Carlo analysis in MS Excel, a Monte Carlo Simulation's ADD-IN for Excel has been used, which is called Risk Solver Pro (Risk Solver Platform, (2014)), this ADD-IN is available for commercial Purposes but one can get a 15 days to a month trial version, In this research a help from the trail version has been taken. With this simple example a simulation for 10000 times has been run to get the results.

This example shows that a company ABC is manufacturing one kind of shirts, these shirts are sold in the market. The company operates between 200-250 days in a calendar year depending on the situation, the actual operational days are not known but from the past experience we know the lower and higher operational days, whose range is from 200-250 days in a calendar year. As the actual operational days are uncertain, that is why a uniform distribution has been used for this. This distribution is been used in E7 in below figure 3.1. There is a built in function " $=PsiUniform(240,250, PsiName(B6))$ " in the Risk Solver Pro platform, where the upper and lower limits has to be given. Another uncertain variable has been used which is the demand of the shirts per day, we do not have a idea about the demand, but it has been assumed from the past experience that the demand of the shirts in off season was 80 shirts per day, the demand in normal seasons (most likely) was 100 shirts per day and the demand in the peak season was 110 shirts per day. As the demand value is uncertain, so a triangular distribution has been defined for the demand with low, most likely and upper limit. A built-in function " $=PsiTriangular(80,100,110, PsiName(B7))$ " is used for this distribution in the Risk Solver Pro platform, the values of upper, lower and most likely are given as the parameters. The selling price of a single shirt is 25 Euros. The unit price per shirt is 20 Euros, and the fixed costs per year is 100000Euros.

Variable	Description	Assumed values	Distribution	Solution
1	Number of days serving in a year	200-250	Uniform	244 9651822
2	Demand of shirts per day	80-110	Triangular	102 0896896
3	Selling price per shirt	25.00 €		
4	shirt unit price	20.00 €		
5	Fixed Costs	100 000.00 €		
	Net Profit			15 247.81 €
	Average Profit			18 415.67 €

Figure.3.1. Demand Risk Experiment

At the end the net profit is obtained using formula 3.2.1, and the average profit is taken as the mean, for

taking the average profit a built in formula of the Risk Solver Pro is taken.

Formula 3.2.1: Net Profit = ((Number of days serving in a year x Demand of Shirts Per day x Selling Price per Shirt)-(Number of days serving in a year x Demand of Shirts per day x Shirt Unit Price))-Fixed Costs.

Note: The number of days serving in a year and Demand of shirts per day are uncertain so the values used in the simulation are the values from the distribution stated above.

Forumula 3.2.2: Average Profit = PsiMean(Net Profit)

With all the above values, the simulation is been made in the RiKS Solver Pro Excel platform, and the simulation is run 10000 times, figure 3.2 shows the simulation when it is run.

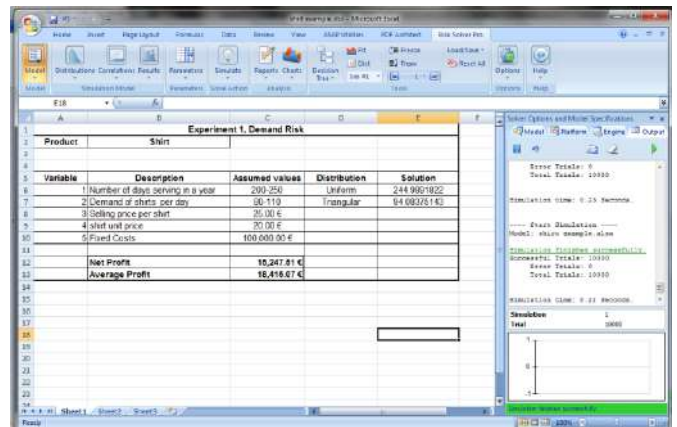


Figure.3.2. Demand Risk Experiment

We can see from figure 3.2 that the simulation is run with total trials of 10000 in a very short span of time of 0.22 seconds. The Net profit as per the above values with the above demand is around 15247 Euros, while the Average Profit is calculated as 18415 Euros.

3.2. Results of the simulation model (1st phase):

As stated above the simulation has been run for 10000 trails, the results of the simulation is presented here. Risk Solver pro is a good platform which provide details of results of the simulation. Figure 3.3 shows very interesting figures, it shows that with the above demand and values the company ABC has a 99.37% chance to earn profit. Further it shows that the company can get a maximum profit of around 36388 Euros, while there is a possibility of 0.63% to lose money and the loss can be of around 2441 Euros. These information are highlighted square lines in red in the figure 3.3.

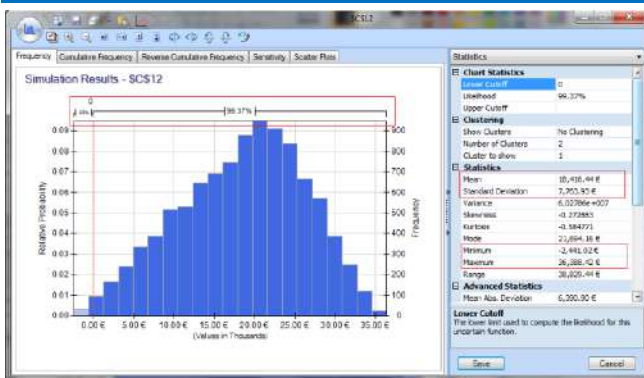


Figure.3.3. Demand Risk Experiment

The Monte Carlo Simulation with the Risk Solver Pro platform is helpful for the Businesses of today, the results gives a lot of information, which are important for supply chain managers. Figure 3.4 shows some more interesting information; it shows the importance of the Demand in the above situation. While the company ABC is already in profit with the above values, the Analysis shows that if the Demand side is increased the company profit can go to another level. In the next phase of the experiment with the same values, the Demand will be fluctuated and the reaction of the simulation on the total costs will be observed.

1000 trails with the Monte Carlo Simulation. Demand parameters have been set, lower limit demand of 70 shirts per day, most likely demand of 90 shirts per day and the high possible demand of 100 shirts per day. The same built in function " $=PsiTriangular(70,90,100, PsiName(B7))$ " is used here as well.

Figure 3.5 shows these initial values, after this the Monte Carlo simulation will be run to collect the values of 10000 different trails, the results of the simulation will be explained in the next figures.

Variable	Description	Assumed values	Distribution	Solution
1	Number of days serving in a year	200-250	Uniform	244.688652
2	Demand of shirts per day	70-100	Triangular	91.13082958
3	Selling price per shirt	25.00 €		
4	shirt unit price	20.00 €		
5	Fixed Costs	100.000.00 €		
Net Profit				
Average Profit				

Figure.3.5. Demand Risk Experiment (with demand fluctuation)

3.4. Results of the simulation after demand fluctuations:

After running the simulation for 10000 trails it is observed that the little fluctuation in the demand has a great impact on the overall cost, the chance that the ABC Company will make profit has been reduced from 99.37% to 77.11% and the chance that the company ABC will lose money has been increased to 22.89%. Figure 3.6. Shows the simulation results in a graphical representation with the percentage of loss and profit.

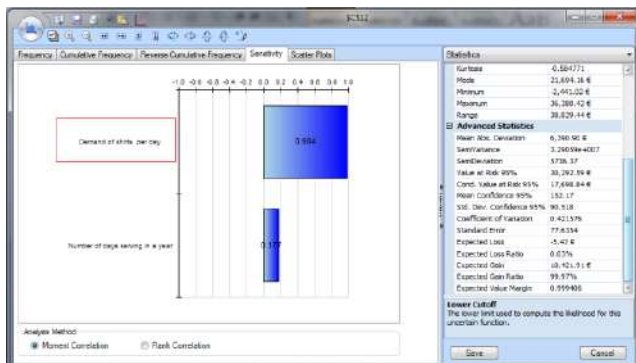


Figure.3.4. Demand Risk Experiment

3.3. Demand Risk Experiment with Demand Fluctuation:

The main aim of these experiment is to show with the help of the Monte Carlo Simulation that how the demand fluctuation can affect the costs of the supply chain, the demand uncertainty is really important to be addressed in any supply chain because it is the demand which can really influence the revenue of the supply chains and by doing this part of the experiment it is shown in a very practical way that how the demand fluctuation influence the net profit.

In the previous phase of the example above, after a 10000 trails it is shown that with the demand scenario above, the company ABC has a 99.37 % chance to be in profit. Now a fluctuation is been made in the demand of shirts for the company ABC, beside the demand fluctuation all the other parameters have been kept the same. It will be noticed that how the supply chain profit is affected by the demand fluctuation after running

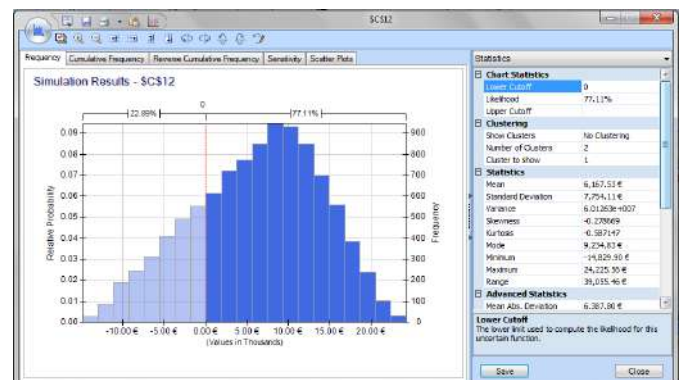


Figure.3.6. Demand Risk Experiment (with demand fluctuation)

The simulation results further shows the mean value and standard deviation of the experiment with demand fluctuation.

Further from the results of the simulation with the demand fluctuation, it is found out that the company

ABC can go a maximum profit value of around 23,754 Euros and it can go into a loss of around 15,199 Euros.

If we do some more changes in the demand, simulation gives us different values each time but the fact remains the same that with the demand fluctuation there is a certain influence on the overall costs of the supply chain, as the demand increases the revenue of the company increases, as the demand decreases the revenue of the company decreases. Here a very simple example has been taken to show a relationship between the demand fluctuation and the overall supply chain costs, if we apply the simulation to a more complex experiment where we include all the elements of supply chain i.e. Supply, Production etc., the demand fluctuation will have a great impact on the overall elements and costs. But with this simple example it is obvious that the demand fluctuation has a real impact on the supply chain.

In any supply chain, it is important to keep a close eye on the demand fluctuation, the supply chain managers should be well aware of the impact, which the demand fluctuation could cause to the supply chain. They should study the market from the experiences and should use very effective techniques to forecast the demand and based on that information the production should take place.

4. CONCLUSION

Almost all the big size firms and manufacturer spends roughly half its revenue to purchase goods and services and this is because of the increasing reliance to outsource of many of the complex services and products, so this makes the success of the firms dependent on their relationships and interactions with the suppliers, this has made the role of the procurement department of the firms more challenging because it involves a lot of money.

Previously the main focus of any supply chain management used to be only on the material, financial and information flow processes, but currently the supply chain management is more than that. The supply chains are always expose to many direct or indirect influences which could lead to negative impact on the organizations. In today's world of highly competitive environment, an effective demand management process is very important; this could lead to the success of any organization.

Demand risks are one of the most prominent risks associated with any supply chain. Demands are the soul of collaboration and the companies have to achieve a great level of demand management to achieve their combined targets. A small error in the demand planning can lead to devastating results for businesses, that is why these the demand risks should be taken very seriously and have be identified and mitigated well in time. We constantly face uncertainties and ambiguities in our lives and even, despite we have

access to many information we cannot predict the future. Monte Carlo simulation gives us a possibility to see all the possible outcomes of our decisions and access the impact of risk. This allow us to make better decisions under uncertainties and ambiguities.

The demand risks associated with supply chains must be taken very seriously because it can affect the actual operations, which leads to a bad reputation of the business firms. The risks associated with the demands have to be properly identified, analyzed and mitigated. Monte Carlo simulation can provide a platform to look into the future, therefore the using Monte Carlo simulation models in the suppliers selection process can help the firms to select the best suppliers out of the available and can reduce the risks related to the suppliers to extent.

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Mr. Dr. Ing. Alexander Goudz, Is a lecturer at department of Transport and Logistics university of Duisburg Essen and his research field is Industry 4.0, automation of logistics processes, digitization of supply chain management, Block chain technologies and procurement 4.0.