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CONCEPTUAL MODEL OF SUPPLY CHAIN IN RISKY ENVIRONMENT: CASE STUDY

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ABSTRACT
The supply chain faces uncertainties, especially with the flow of products and information that may affect the productivity, revenue and competitive advantages of many organizations. It is therefore necessary for these organizations to be agile and resilient enough to meet with these uncertainties so that they may be managed appropriately or even avoided. In a publication by Mensah et.al (2014), the authors introduce a theoretical approach where the 'conceptualization of risks for subsequent simulation-based analysis' is evaluated. This includes the description of 'a generic conceptual model of a retail node' followed by the introduction of performance indicators relevant for simulation base analysis. Hence, a concept for further studies from a practical point of view has now arisen. This article therefore introduces a new case study where the flow of products in a real company is conceptualized for simulation base analysis to raise the awareness of the organization in case of uncertainties.

Keywords: supply chain, uncertainties, risk impact,conceptual model, resilience

1. INTRODUCTION
According to Mensah et.al (2014), modern innovative companies are now outsourcing most of the processes within the supply chain unlike traditional companies that were 'wholly and solely responsible for supplies, manufacturing and distribution'. This outsourcing has made many innovative companies vulnerable to uncertainties including natural disasters, terrorism, cyber-attacks, credit crunch demand risks etc. In fact, Christopher and Peck (2004) support this point by expressing that 'In today's uncertain and turbulent markets, supply chain vulnerability has become an issue of significance for many companies'. An astonishing result of the survey conducted by the Business Continuity Institute (2011) undertaken in more than 60 countries globally involving over 550 organizations, shows that 'supply chain incidents led to a loss of productivity for almost half of businesses along with increased cost of working (38%) and loss of revenue (32%)' (The Business Continuity Institute, 2011). The above has also contributed to the new concept for further studies as discussed earlier in the abstract. The second chapter discuses the supply chain risks adapted from various relevant scientific publications. The third chapter emphasizes on the conceptual model and its benefits in developing a simulation base analysis study from a theoretical point of view. The fourth chapter is a case study analyzing the flow of materials and information etc., within the supply chain of a real company namely, CompanyX.The risk analysisof the supply chain of Company X is assessed in chapter five.This is followed by adeveloped conceptual model with a description of the original system of Company X with its objectives, input and output parameters in the sixthchapter,and possible further studies are discussed in the conclusion.

2. SUPPLY CHAIN RISKS
Although risks may be defined as the probability of occurrence of disruptive events, the supply chain risk is yet to be defined more appropriately. Nevertheless, March and Shapira (1987) define the supply chain risk as the 'variation in the distribution of possible supply chain outcomes, their likelihood, and their subjective values', whilst Peck (2006) states that it is 'anything that disrupts the information, material or product flows from original suppliers to the delivery of the final product to the ultimate end user'. From another perspective, Tang (2006a) classifies risks as 'high profile risks and operational risks'. The highprofile risks include natural disasters like tsunami, earthquakes, hurricane and cyclones etc., however, the more common risks are mainly operational (Tang, 2006). Additionally, Protiviti (2013), elaborates that operational risks are common and many, and they include the following:

- A variety of supply interruption risks
- Demand and supply planning and integration risks
- Purchase price risks
- Inventory and obsolescence risks
- Information privacy and security risks
- Customer satisfaction and service risks
- Contract compliance and legal risks
- Process inefficiency risks
- Product introduction and cycle time risks
- Human resource skills and qualifications risks
- Project management risks

From the above, the supply interruption risks are to be considered with 'seriousness' as they may disrupt the flow of materials and products along the whole chain stimulating a ripple effect that may result in a loss of productivity and revenue. This is followed by the ‘demand and supply planning and integration risks’ or forecasting techniques that may result in the bullwhip effect. Besides, Lee et al. (1997) accentuate that bullwhip effect are caused by demand forecasting, lead times, batch ordering, supply shortages and price variations. In addition, Merkuryeva et al. (2019) accentuate on the impact of demand risks on the supply chain that may stimulate the bullwhip effect.Another research by BCI involving 519 organizations from 71 countries shows that ‘75% of respondents still do not have full visibility of their supply chain disruption levels’(BCI,2013). Figure 1 portrays that unplanned IT or telecom outages was the primary source of disruption experienced by 55% of the respondents. Additionally, adverse weather disruption was experienced by 40% of the respondents and outsource service provision failure experienced by 37 % of the respondents. In addition, a study by Juttner et al. (2003) classifies supply chain risks sources into three categories namely; environmental risk sources, organizational risk sources and network-related risk sources as shown in figure 2.

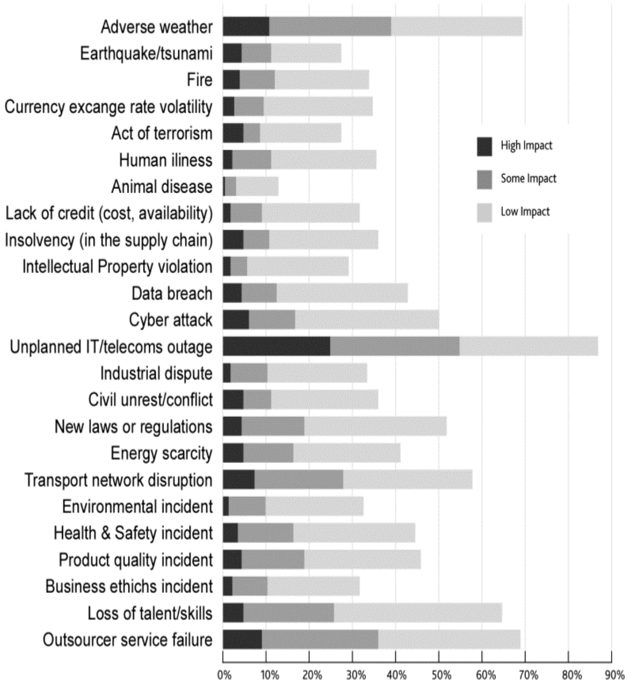

Figure 1: Source of Disruption (BCI, 2013)

The environmental risk sources are ‘any uncertainties arising from the supply chain environment interaction’ (Juttneret al., 2003). They include natural disasters like earthquakes and extreme weather conditions, socio-political actions like fuel protests or terrorist attacks.

The organizational risk sources are within the organization, and may include labor strikes, production uncertainties such as machine failure and IT system failures. The third category of risks given as the ‘network-related risk source’ arises due to uncertainties between organizations interacting along the supply chain. It is important for organizations to be aware of the potential risks they may be affected by, and the impact of these risks along their supply chain. In fact, Romanovs (2017) stresses on the importance of mitigating risks within the supply chain. Hence, with appropriate mitigation strategies,organizations will most likely be able to thwart disruptions anywhere along the supply chain.

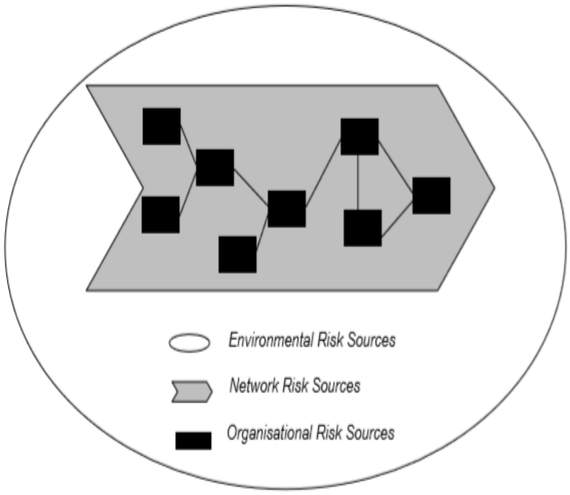

Figure 2: Risks Sources in the Supply Chain (Juttneret al., 2003).

2.1. Mitigating Risks

Organizations should to be able to analyze the uncertainties they are facing and implement adequate mitigation strategies to mange and or avoid the risks they are concerned with.Consequently, a framework for risk management process, given in figure 3, may be applied to analyze and mitigate risks. The framework is divided into three main parts; establishing the content, risk assessment and treating risks.Communicating and consulting are enforced continuously at each stage of the risk management process with the relevant stake holders. After establishing the content pertaining to risk management, the risks are then assessed. The risk assessment is in three stages; identify risks, analyze risks and evaluate risks. Upon identifying the risks, it is necessary for suitable analysis to be made, to be able to determine the impact, frequency and the risk levels. The former leads to evaluating the risks where priorities are made on which risks to manage, to share and or to avoid etc. This makes it possible for the application of resilient managerial strategies for risk treatment in the next stage which must be monitored and controlled to ensure continuous improvements (Council of Standards Australia & Council of Standards New Zealand, 2004). Another framework introduced by Hale and Moberg (2005), consists of five stages that stress on planning, mitigation, detection, response, and recovery in order to mitigate risks. A more detailed framework with nine stages, introduced by Tang (2006b), comprises of postponement, strategic stock, flexible supply base, make-and-buy, economic supply incentives, flexible transportation, revenue management, dynamic assortment planning, and silent product rollover.

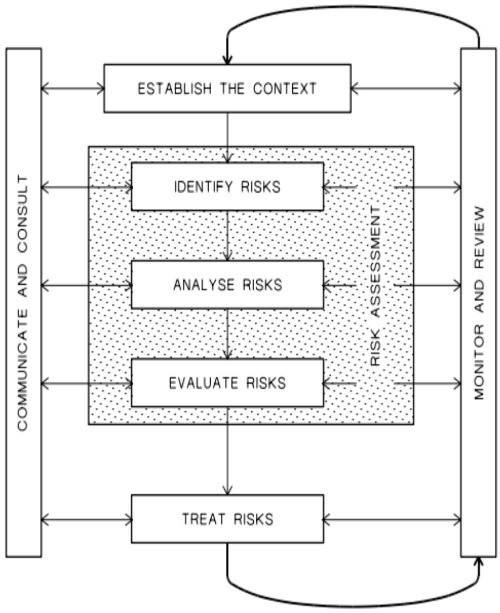

Figure 3: Risk Management Process (Council of Standards Australia & Council of Standards New Zealand, 2004)

Although some managerial strategies for mitigating risks have been discussed above, an effective way of obtaining mitigating strategies and resilience most probably is by exploiting modelling and simulation where it is possible to experiment with various scenarios. This makes it important to have an appropriate conceptual model for simulation base analysis as discussed in the next chapter.

3. CONCEPTUAL MODEL

The conceptual model, which is a 'steppingstone' towards developing a simulation model, is being defined by various authors form their own perspectives although they may have some overlapping contents. For instance, Wagner (2014) defines the conceptual model as a ' solution independent description of a real world problem domain, from which a platform independent simulation design model can be derived for a given set of research questions' whilst Robinson (2008) states that the 'conceptual modelling is the abstraction of a simulation model from the real world system that is being modelled'. In addition, Robinson (2004) further describes the conceptual model as 'a non-software specific description of the computer simulation model (that will be, is or has been developed), describing the objectives, inputs, outputs, content, assumptions and simplifications of the model'. Furthermore, Becker and Parker (2011) highlight that 'the conceptual model forms the hypothetically complete description of the original system'. Besides the definitions, Merkuryeva and Bolshakov (2015) emphasize on the importance of developing a conceptual model before translating it into a simulation model.The above given definitions synchronize with the introduction of Robinson's (2014) 'Artifacts of Conceptual Modelling' framework, as shown in figure 4. The figure consists of the problem and model domain. The problem situation is within the 'cloud', and it is the root cause of the simulation study. After identifying and analyzing the problem, knowledge is acquired, and necessary assumptions are made especially with the absence of some data. The system is then described within the system description artifact enabling model abstraction and simplification leading to the next artifact which is the conceptual model within the model domain. The former then guides the design and development of the next artifact, followed by the model and finally the coding for the computer model (Robinson, 2014).

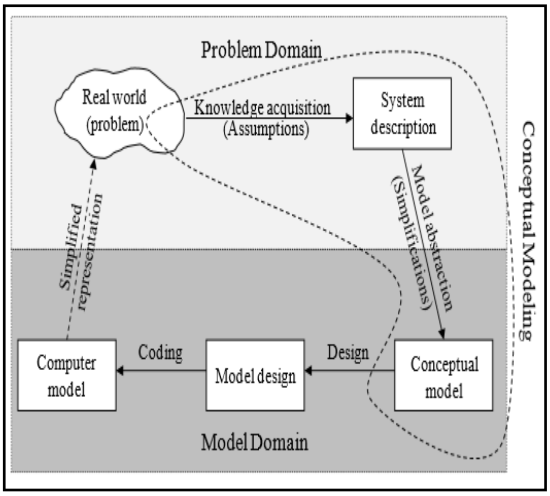

Figure 4: Artifacts of Conceptual Modelling (Robison, 2014)

One of the main benefits of the conceptual model, apart from 'expressing the modeling objectives, and model inputs and outputs',is to 'determine the appropriateness of the model or its parts for model reuse and distributed simulation' (Robinson, 2014). What is more, Birta and Arbez (2013) highlight that the 'conceptual model ensures that the key system under investigation features evolve from discussion with all stakeholders rather than from a programming bias'. Likewise, 'the conceptual model can help to clarify questions about the scope and purpose of a simulation project, and it is an asset that can be reused for making different solution designs for different research questions' (Wagner, 2014). With reference to the aforementioned, a case study about the supply chain of a real company in risky environment is discussed next.

4. CASE STUDY

Company X, as portrayed in figure 4, is a major distributor for electric stoves and operates in a business to business (B2B) environment. It receives the electric stoves form three factories in Europe and distributes them to four retailers in Latvia. The stoves come in two sizes 'a' and 'b' with 'a' being the largest size.Company X operates under the governance of Factory A, Factory B and Factory C which belong to a Group of company.

The products are sent by trucks from the factories to Company X. Factory A is the main supplier and produces 90% of Company's X total stocks. Factory B and Factory C manufacture the remaining 10% of Company's X total stocks. All the factories are responsible for transportation and its costs from their warehouses to Company X.

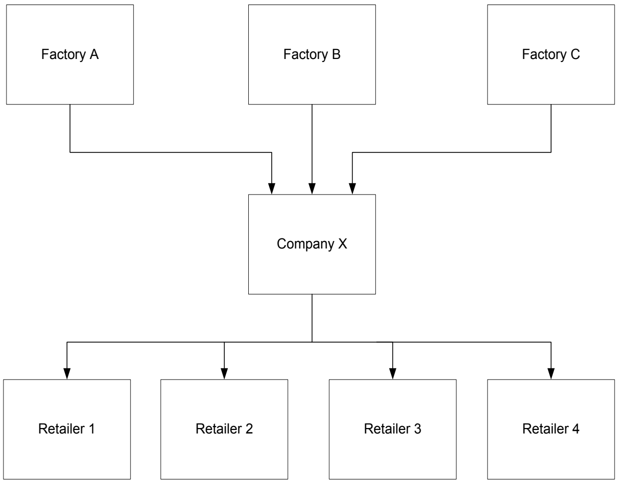

Figure 4: Company X

Factory A has a warehouse with a maximum capacity of 100,000 pieces with 52 delivery trucks with a capacity of 700 pieces per truck. One truck departs Factory A every Monday and offloads at Company X every Wednesday. The factory closes 14 days in July for the overhauling of its machines and equipment etc.

Factory B has a warehouse with a maximum capacity of 5,000 pieces with 12 delivery trucks with a capacity of 500 pieces per truck. The factory closes 14 days in July for the overhauling of its machines and equipment etc. Factory C has a smaller warehouse and suppliers only on 'Just in Time' (JIT) basis. It possesses 12 delivery trucks with a capacity of 200 pieces per truck. The factory closes 7 days in July for the overhauling of its machines and equipment etc. The warehouse at Company X has a total capacity of 8,000 pieces, however, it holds a maximum of 4,500 pieces in peak seasons and automatically orders when the stock drops to 3,800 pieces.

The four retailers place their orders daily from Mondays to Fridays. The orders are accumulated and sent to the factories every Friday. The retailers also provide their own trucks when picking up their goods from Company X.Retailer 1 is the largest retailer and constitutes 65% of Company's X sales. It collects its products every Mondays and Wednesdays and ordered a maximum of 36,000 pieces in the year 2018.Retailer 2 is the second largest retailer and constitutes 15% of Company's X sales. It collects its products every Friday and ordered a maximum of 8,000 pieces in the year 2018.Retailers 3 and 4 only are the smallest with each constituting 10% of Company's X sales. They can collect their goods any day as the number of products is relatively small. They ordered a maximum of 6,000 pieces each in the year 2018.Only Company X, Factory A and the retailers will be considered in this case study due to the limitation of data. Consequently, the supply chain operations of Company X have been developed as shown in figure 5.With reference to figure 5, Factory A receives order every Friday from Company X. After receiving the order, Factory A checks to see if the ordered products are available at the warehouse. If the products are available, they are uploaded and transported to Company X, provided the trucks are available, on the immediate Monday.

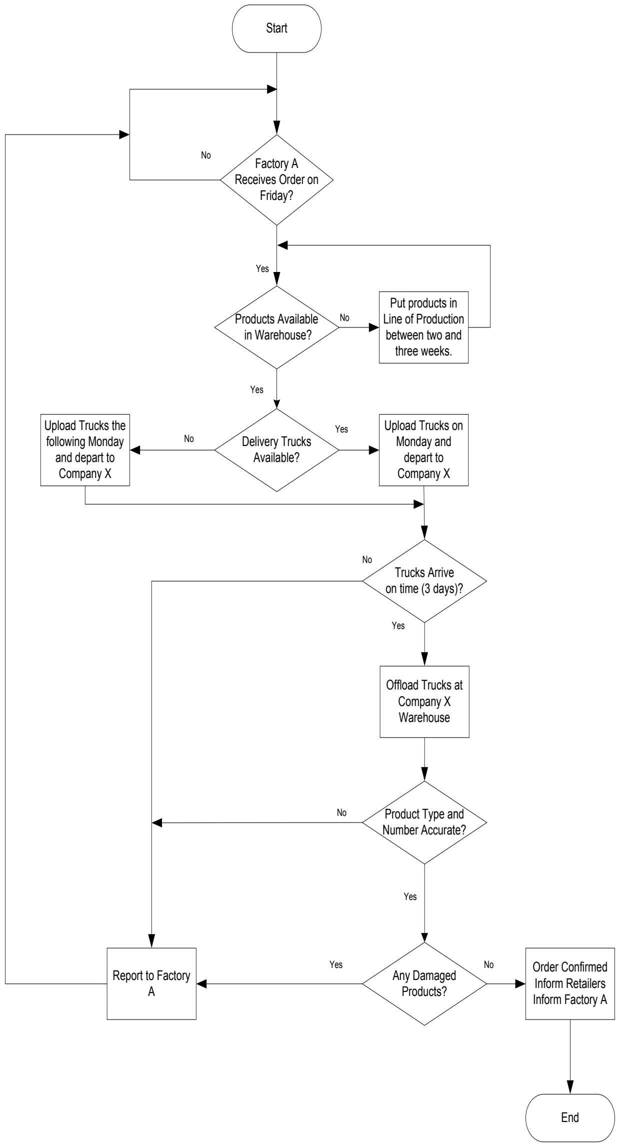

Figure 5: Company X Supply Chain Operations

On the other hand, unavailable products are put in line of production between two and three weeks and delivered to Company X the following Monday after availability. The delivery time is usually three days. On arrival, Company X offloads the goods and checks to see if the product type and number are accurate. Assuming that the product types and number are accurate with no damaged products, the delivery is confirmed, and the retailers are informed. In case ofinaccuracies with the number and or quality of products, a report is sent to Factory A.

5. RISK ANALYSIS OF COMPANY X

The risks within the supply chain of the Company X that may affect product flow are being considered in this case study. As there is only one major supplier providing 90% of Company X products, any disruption with the major supplier will create a ripple effect down to the retailers whereby the retailers are not provided with their products on time. Risks affecting Company X include demand risks, delayed delivery risks, inventory risks, IT breakdown, delayed products and damaged products etc., as shown in figure6. The demand risk most probably is due to the bullwhip effect yielding to inaccurate forecasting. Seasonality also affects demand as the high season is from May to September. Delayed delivery is mainly affected by unavailable products as they are put in line of production between two and three weeks. Additionally, transportation problems such as truck breakdown, unavailable trucks and even bad weather conditions may hinder on the time of delivery.

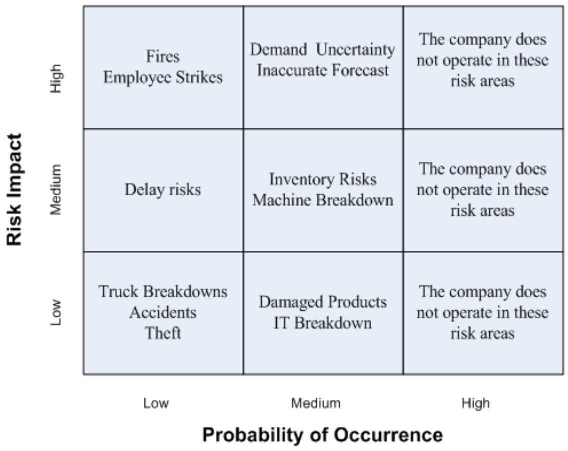

Figure 6: Probability of Risk Occurrence and Impact: Company X

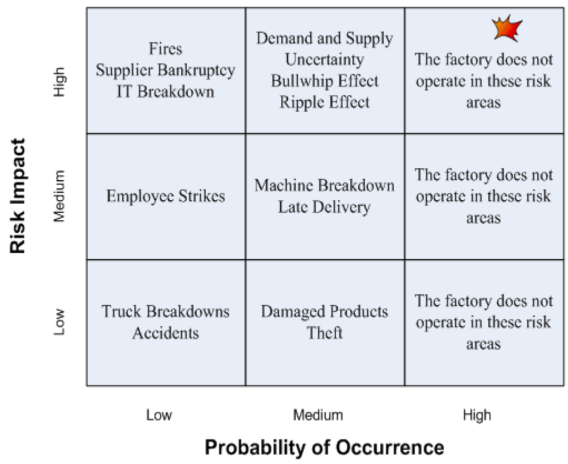

Figure 7: Probability of Risk Occurrence and Impact: Factory A

The cost ofholding inventories is mainly considered as inventory risks at Company X. Factory A, on the other hand, may face disruptions like machine breakdown, transportation risks including truck breakdowns and accidents, employee strikes, damaged products, IT breakdown and theft as illustrated in figure 7.

6. CONCEPTUAL MODEL OF COMPANY X

The conceptual model of Company X is provided in figure 8 with reference to Robinson's (2004) approach. From the figure, the input data are the experimental data and events whilst the output data are the performance measure and estimates.

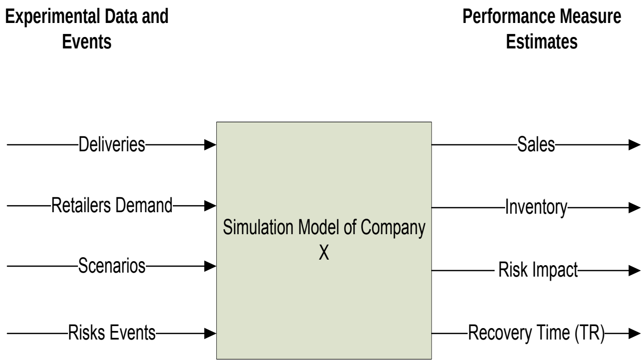

Figure 8: Conceptual model of Company X

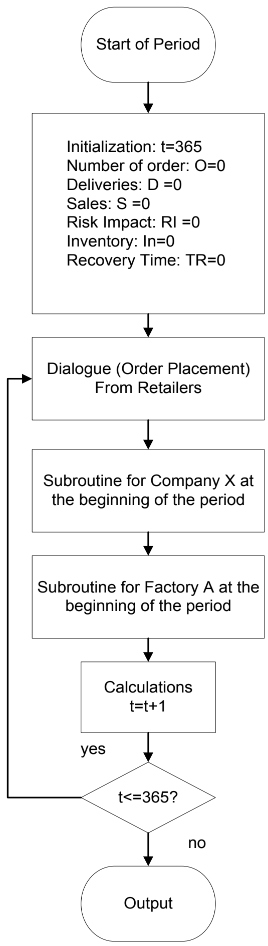

Figure 9: Basic Algorithm of the Simulation Model of Company X

The simulation model of Company X accepts input data from the left and provides output on the left. Deliveries, retailers' demand, different scenarios and risk events are the experimental data and events, and the performance measure and estimates are represented by sales, inventory, risks impact and recovery time.

As indicated earlier in chapter 4, Company X accumulates orders and sends them to the factories by email every Friday. The factories deliver available products every Wednesday and the non-available products are put in line of production between one and two weeks increasing the lead time as mentioned earlier on in the case study. A basic algorithm of the simulation model of Company X is given in figure 9. The initialization period is 365 days, but the number of orders, sales, delivery time, risk impact and time to recovery are all set to zero at the beginning of the simulation. The simulation repeats *(t=t+1)* if the time is less than 365 days and equal to zero, and ends when the time is greater than 365 days.

Further studies: Since the conceptual model is available, two simulation models have to be developed:

- simulation model without the risks
- simulation model with the risks

The simulation model with the risks is used for experimental purposes to study the ripple effect of the product along the supply chain of Company X from the upper stream down to the bottom stream of the supply chain of Company X. The study will also the examine the maximum time it will take Company X to match supply and demand after disruptions and how long it will take Company X to fully recover after disruptions.

7. CONCLUSION

A conceptual model has been developed as a novel approach to foster resilient strategies within the supply chain, whereby managers would be able to make appropriate decisions in case of uncertainties. The article has analyzed the risks and their impacts within the supply chain as well as conceptual models from both theoretical and practical perspectives. After having some dialogues with the supply chain manager of Company X about its supply chain operations and possible risks events that might hamper the flow of materials, the authors have developed a 'Flowchart of Company X Operations' and a conceptual model of Company X. The conceptual model is essential for the development of the simulation model to make it possible to study the impact of disruptions on the flow of products from the factories down to the retailers by experimenting various risks scenarios. This will make it possible for the company to be aware of the impact of the risks on sales and inventories. As a result, appropriate resilient strategies may be developed to reduce the lead times during disruptions as well as the time to recovery for normal operations. However, more historical data need to be collected on the flow of products and demand within the supply chain of Company X to make this possible. Simulation software such as AnyLogistix and or Simul8 will be used for the simulation model.

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