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# Supply Chain Risks Analysis of a Logging Company: Conceptual Model

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## Abstract

Supply Chains today are vulnerable to uncertainties and risks that might disrupt their operations which could lead to a drastic loss in revenue, competitive advantage and profitability etc, if not managed effectively. This is a concern especially in logging companies where unfavourable weather conditions can hinder the production processes, deliveries and sales etc. This article will analyze the risks the supply chain of a logging company is facing, develop a conceptual model, and translates the conceptual model into a simulation model by exploiting MATLAB. The impact of the risks on the harvesting process is then investigated by utilizing simulation, and the results are discussed to enable the logging company to become well aware of the risks confronting their organization.

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*Keywords:* Supply chain risks; Conceptual model; Simulation model

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## 1. Introduction

Supply chains today face greater risks than their supply chain managers could recognize and in fact, Christopher and Peck clearly stated that ‘in today’s uncertain and turbulent markets, supply chain vulnerability has become an issue of significance for many companies and appropriate researches on resilient supply chain are yet to be conducted’<sup>1</sup>. In addition ‘the numbers and types of threats that can undermine a supply chain are now greater, and

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organizations are facing greater challenges in managing risks than ever<sup>2</sup>. According to Business Continuity Institute Report in 2015, the three top causes of supply chain disruptions are unplanned IT and telecommunications outage (64%), cyber attack and data breach (54%) and adverse weather (50%). Moreover, transport network or disruptions accounted for 38%, outsource failure 34% and Fire 20%<sup>3</sup>. In logging companies, adverse weather conditions, transport network disruptions, outsource failure and fire are detrimental to supply chain operations and should therefore be taken into consideration. This article therefore examines the risks facing a logging company in Latvia in which a conceptual model is developed and translated into a simulation model to portray the impact of the risks on the harvesting processes along the supply chain. The research method is a case study approach in which quantitative and qualitative data are collected from the ‘Central Statistical Bureau’, Latvia and a company ‘L’. Firstly, the article depicts various definitions of the supply chain and highlights their overlapping meanings. Next, the risks facing the supply chain of the logging company ‘L’ are discussed. A conceptual model is then developed and later translated into a simulation model. The results of the research and conclusion are then given finally.

## 2. Supply chain

The supply chain, with so many definitions consisting of overlapping terminology and meanings, has evolved greatly over the past 50 years from the traditional form where big and powerful companies used to be wholly and solely responsible for supplies, manufacturing and distribution to the modern innovative companies that are actually outsourcing almost all the processes in the supply chain’. In fact, ‘this has influenced the definition of the supply chain which now consists of several overlapping terminology and meanings’<sup>4</sup>.

Table 1 Various definitions of the supply chain<sup>4</sup>.

Author(s)	Year	Definition of Supply Chain
Lu, D.	2011	...a group of inter-connected participating companies that add value to a stream of transformed inputs from their source of origin to the end products or services that are demanded by the designated end-customers... <sup>5</sup>
Pienaar, W.	2009	...a general description of the process integration involving organizations to transform raw materials into finished goods and to transport them to the end-user... <sup>6</sup>
S, Cholette	n/a	...a sequenced network of facilities and activities that support the production and delivery of a good or service... <sup>7</sup>
Sunil, C., Meindl, P.	2004	...consists of all parties involved, directly or indirectly, in fulfilling a customer request. The supply chain not only includes the manufacturer and suppliers, but also transporters, warehouses, retailers, and customers themselves. Within each organization, such as manufacturer, the supply chain includes all functions involved in receiving and filling a customer request... <sup>8</sup>
Croker, J.	2003	...a total flow of materials, information and cash through a business network, all the way from the suppliers’ suppliers to the customers’ customers... <sup>9</sup>
Ayers, J. B.	2001	...life cycle processes involving physical goods, information, and financial flows whose objective is to satisfy end consumer requisites with goods and services from diverse, connected suppliers... <sup>10</sup>
Little, A.	1999	...the combined and coordinated flows of goods from origin to final destination, also the information flows that are linked with it... <sup>11</sup>
Beamon B.	1998	...a structured manufacturing process wherein raw materials are transformed into finished goods, then delivered to end customers... <sup>12</sup>

Some of the definitions of the supply chain are given in Table 1. With respect to Table 1, definitions by a few authors - Sunil, Meindl, Croker and Ayers- mainly include information, material and financial flows vital to the supply chain. The other definitions are too general and basically talk about processes starting from raw materials to finished goods and eventually reaching the customers. However, Mensah and Merkurjev define the supply chain as ‘a sequenced network of business partners involved in production processes that convert raw materials into finished goods or services in order to satisfy the consumers’ demand<sup>4</sup>.

As many research programs have also shown that modern supply chains are at greater risks than their supply chain managers recognize, supply chain vulnerability has become a very significant issue for many companies. These risks including natural disasters, terrorism, cyber attacks, credit crunch and many more could yield to a drastic loss in productivity, revenue, competitive advantage, profitability etc, if not managed appropriately. Should in case one of the risks occurs and therefore deforming the supply chain, the possibility of the supply chain returning back to its original state is a concern and that is why it is important for organizations to have a better understanding of the impact of these risks along their supply chains. A case study approach investigating the risks within the supply chain of a logging company is discussed next.

### 3. Risks in the supply chain of a logging company : Case studies approach

The risks facing the logging companies in general, mainly depend on weather conditions which could hinder harvesting and deliveries. With extreme weather conditions like snow storms, hurricane, strong winds etc., it is highly unlikely to proceed with harvesting and other operations along the supply chain of logging companies. Consequently, there is a production standstill yielding to a delay of deliveries to the customers. Other risk factors include temporary and long term road closure due to damaged roads, road works, heavy snow and heavy rainfall that can also cause excessive delays in the logistic process.

The forest itself which is a system consisting of huge volume of variety of trees faces risks like forest fires in hot weather conditions. This is evident in the EU JRC Technical Reports<sup>13</sup> which states that ‘698 forest fires were discovered and extinguished in 2014 during which 591 hectares were burnt’. Fig. 1 below shows the number of forest fires in Latvia between 1993 and 2014 with the highest number of fires recorded in 2006 with nearly 2000 fires, and therefore this type of risk should be considered seriously<sup>13</sup>.

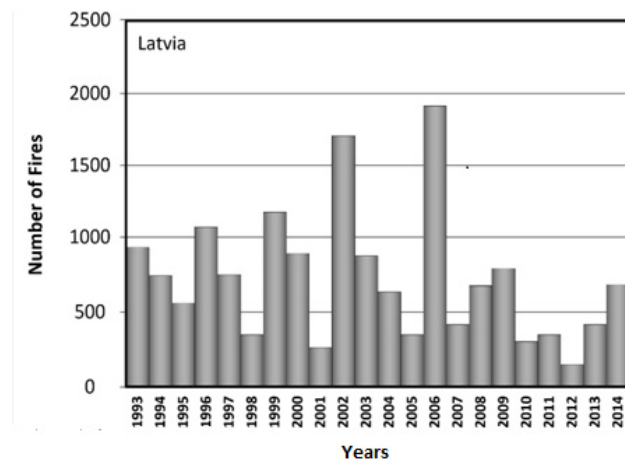


Fig. 1. Number of forest fires in Latvia<sup>13</sup>.

From another perspective, the number of trees with defects due to bugs etc., could be higher than expected and this can lower productivity leading to loss in sales. What is critical, is when some of these defected logs are only noticed on delivery. As a result, there would be an increase in customers’ complaint and dissatisfaction.

The risks facing harvesting machines are also vital as they have to produce almost 340 m<sup>3</sup> logs operating 24hrs a

day. The machines are very heavy and can sink into the soil when it is soft due to heavy rainfall and floods. In addition, they can also breakdown which means harvesting is on a halt until the machines are repaired. Moreover, due to the heat of the machines, the possibility of explosions and fires is highly likely especially in hot weather (see Fig. 2).

Factors affecting the delivery trucks include age of the trucks, road closure, extreme weather conditions and reliable drivers. It is logical that old trucks are more likely to breakdown than new trucks and if this occurs especially on the way, the lead time is automatically affected. With road closures, trucks can divert using available roads, but, if there is only one road from the forest warehouse, then there is a major delay and other means of delivery needs to be implemented in the shortest possible time. Just like the harvesting processes, extreme weather conditions also have negative impact on deliveries increasing lead times and nothing could be done in this case except to wait until the weather is back to normal.

Consequence/ Impact	High	Extreme Weather Conditions Forest Fires	Road Closure Trucks Breakdown Machine Breakdown Defected Trees	Soft Soil Damaged Roads Road Works
	Low	Heavy Rainfall Heavy Snow	Temporary Road Signs	Theft
		Low	Medium	High

Probability of Occurrence

Fig. 2. Challenges in risk management in company L.

Fig. 2 shows the challenges in risk management facing company L in Latvia. The figure shows high, medium and low probability of occurrence of the risks factors as well as the high and low consequences/impacts they have on the company’s supply chain. The probability of occurrence of soft soil, damaged roads and road works is high and has a high impact on harvesting and delivery in which there is a halt leading to a delay in deliveries. Road closures, trucks breakdown, machines breakdown and defected trees all have medium probability of occurrence, however, their impact is high and this can also increase the lead time. Although the probability of occurrence of extreme weather conditions and forest fires is low, there is still a significant impact on productivity and deliveries. Forest fires can cause serious problems especially when they are uncontrollable for a while. This can even increase the lead time for more than 6 months. From another perspective, theft could have a high probability of occurrence, nevertheless, the impact in low as the volume of trees stolen is negligible. Temporary road signs occur randomly but for a short period of time, and even if they cause delay, it is not severe and the impact is quite low. Likewise, heavy rainfall and heavy snow, which occur mainly in autumn and winter respectively, have low probability of occurrence with low impact on productivity as it is just a couple of days halt before production resumes.

**4. Conceptual model**

‘Conceptual modelling is a non-software specific description of the computer simulation model describing the objectives, inputs, outputs, content, assumptions and simplifications of the model’<sup>14</sup>. In addition, conceptual model is formed by the ‘hypothetical complete description of the original system’<sup>15</sup>. Therefore, in order to develop a conceptual model, it is important to have a very good understanding of the objectives, inputs and outputs of the real world system. Furthermore, it is necessary to make assumptions and simplifications when there are uncertainties<sup>14</sup>. Fig. 3 below, shows the conceptual of the logging company L in which the operations start by planning of the felling sites which are then marketed to customers. If the customers are interested in the available products, the trees are then harvested until the volume of harvested trees matches demand. The trees are then forwarded to the roadside

warehouses and then delivered by trucks to the respected customers. If the volume of harvested trees is higher than the demand, then more marketing needs to be done to persuade the customer to buy more and or sell to other customers. Likewise, if there are fewer trucks available for delivery than expected, it is necessary to negotiate for more trucks in other to avoid delay. On receiving the products, the customers measure to see if the volume corresponds to that of the demand. The quality of the wood is also checked and in most cases it is highly likely that a small percentage of the product has some defect. The customers then make a complaint about the volume and quality if necessary. If not, operations for that particular order ends, payments are made and other necessary transactions executed. If it happens that a complaint has been made, the planning of felling sites unit has to make a quick decision to correct the mistakes and ensure the customers are satisfied.

4.1. Risks considered

The risks considered in this model are limited to the impact of soft soil on production and the impact of ‘harvesting machine’ breakdown on production. Soft soils in the production areas occur due to high precipitation in summer and autumn, as well as floods from melting snow in spring. Hence, as the soil is very soft, the heavy harvesting machines could easily sink into the soil and hardly operate as movements are restricted. On the other hand, ‘harvesting machines’ are most likely to breakdown or deliver poor performance due to overheating in hot weather conditions with temperatures above 30°C (degrees Celsius), or when the temperature is below -20°C in winter which can even freeze the machines making it difficult to start operations.

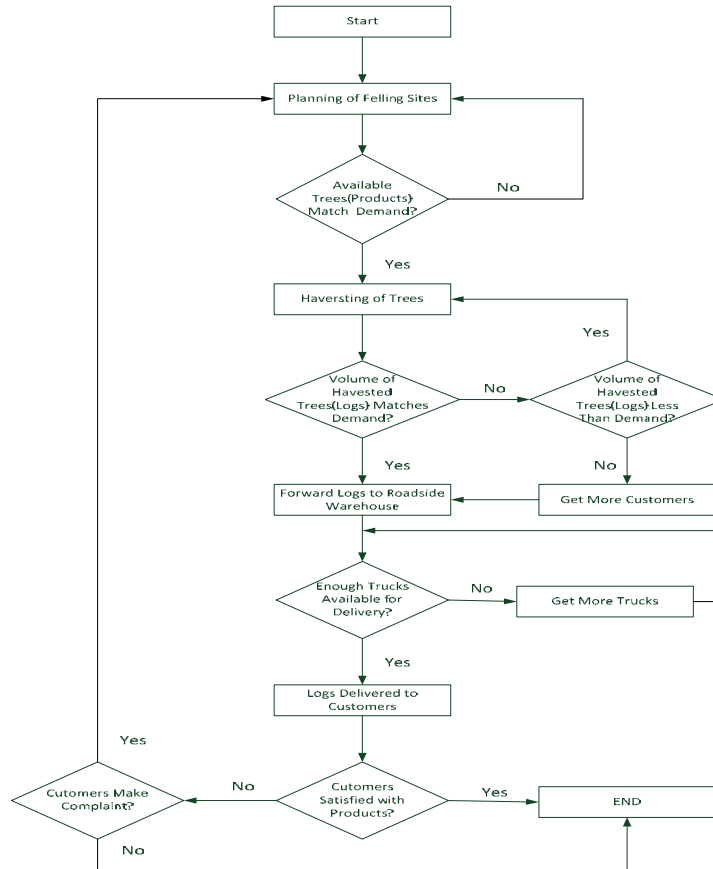


Fig. 3. Operations conceptual model of a logging company L.

### 4.2. Simulation model

Longo highlighted that ‘simulation can be used as decision support tools in order to improve the supply chain management, reduce risks and vulnerability’<sup>16</sup>, in addition, Jansons et.al. stressed that the risks in logistic processes could be stabilized by exploiting dynamic modelling<sup>17</sup>.

Hence, by exploiting MATLAB, the conceptual model is translated into a simulation model in which the following processes were realized. The total volume of trees in Latvia is approximately 502million m3 covering an area of about 3.383 million hectares of land, or 52% of Latvia’s territory<sup>18</sup>. Since the Ministry of Agriculture is responsible for allocating the volume of trees to be harvested, the authors have considered a small percentage (0.0005%) of the total volume of trees to be harvested, that is 251000 m3. As one harvesting machine operating can produce a maximum of 340m3 per day, two machines can produce two times more as applied in this model. Mathematically, it will take 369.12 days to produce this amount. However, if we consider the risks involved, this will increase the number of days to be harvested by company L in a period of approximately one year leading to an increase in the lead time. Due to the limitation of this article, only the risks affecting harvesting/production are considered with respect to soft soil and harvesting machine breakdown.

Thus, variables affecting the soil and machines are given as:

$$X = \{t_{avg}, t_1, t_2, p_{avg}, c_s, c_m\} \tag{1}$$

where:  $t_{avg}$  - average temperature (in Celsius),  $t_1$  - minimum temperature,  $t_2$  - maximum temperature,  $p_{avg}$  - average precipitation,  $c_s$  - coefficient for soil,  $c_m$  - coefficient for machine.

The data in Table 2 apart from the coefficients were obtained from calculations between 2004 and 2015 from statistics given by the Central Statistical Bureau<sup>19</sup> and the coefficients generated accordingly by the authors.

Table 2. Temperature \_soil coefficient on monthly basis.

Variables	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Ave Temp( $t_{avg}$ )	-4.24	-4.49	-0.05	6.75	11.93	15.32	18.41	17.13	12.71	6.94	2.93	-0.53
Min Temp( $t_1$ )	-19.85	-18.43	-12.39	-4.5	-0.4	4.91	8.56	6.8	2.35	-3.47	-7.29	-11.31
Max Temp ( $t_2$ )	5.48	4.48	11.89	21.12	25.95	26.96	29.90	29.07	23.18	16.68	10.65	6.98
Ave Precipitation ( $p_{avg}$ )	11.83	8.94	9.0	6.66	9.58	10.08	10.39	11.22	9.62	11.16	12.45	13.48
Coefficient( $c_s$ )	0.15	0.06	0.06	0.17	0.38	0.66	0.85	0.78	0.44	0.28	0.24	0.15
Coefficient ( $c_m$ )	0.01	0.04	0.01	0.09	0.25	0.42	0.58	0.54	0.33	0.12	0.02	0.01

The lower the coefficient the lower the risks, likewise the risks are higher when the coefficients are high. For example, the coldest months -Jan, Feb, March and December- have the lowest coefficient as the soil is hard making the machines to operate effectively. The coefficients are higher when the soil becomes softer as this could yield to a decrease in productivity.

### 5. Conclusion

The simulation run verifies the mathematical calculation that it can take approximately 369 days to produce 251000m<sup>3</sup> of logs. However, the simulation model is more effective because different scenarios can be tested to illustrate the way the risks can affect production. After several runs Fig. 4 shows/predicts the total number of production from January 2017 to August 2018. It is clearly seen that the highest production is in March of 2017 and 2018, and after there is a sudden drop in production in summer, but start to increase in September. Fig. 5 shows how the soil risks could affect production. From the figures, it is noticed that, the lower the bar, the lower the risks and vice versa. For example, Fig. 5 portray that the risks are low in March in which the impact is illustrated in Fig. 4 where it is clearly indicated that the month with the highest production is March. Additionally, 100 simulations runs were made and the average production per month was obtained. It also shows March as the month with the highest production.

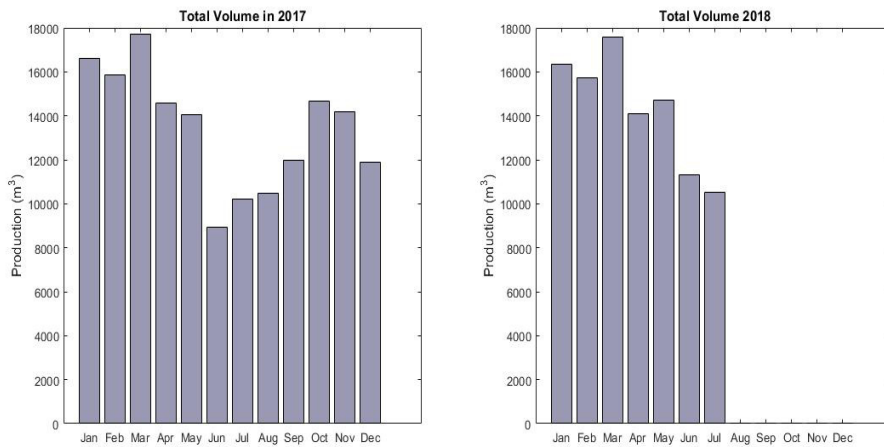


Fig. 4. Total production in 2017 and 2018.

In conclusion, a case study has been exploited to study the supply chain of a logging company with respect to production. Although several risks factors were discovered, only the risks of machinery and soil affecting production were considered. Secondary data about temperatures and precipitations between 2004 and 2015 were obtained from the Latvian Statistical Bureau from which the soil and machinery coefficients were generated. The conceptual model was then translated into a simulation model and various scenarios were executed. After 100 runs it was realized that the month with the highest productivity is March.

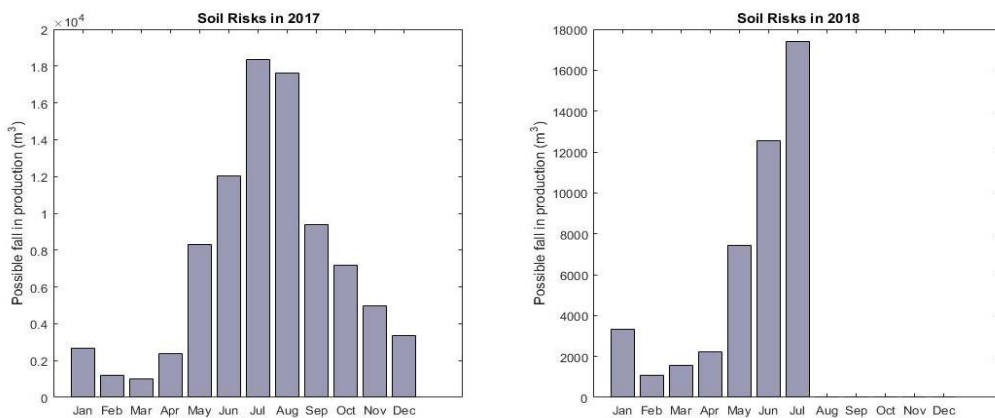


Fig. 5. Soil risks in 2017 and 2018.

However, the other risk factors need to be considered in order to have a more precise result. As indicated earlier, the other risks factors will be integrated in the conceptual model and translated into a simulation model. The impact of the risks would be analyzed, and then stabilized resulting in a supply chain resilient strategy.

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