THE IMPACT OF RISKS ON THE DELIVERIES OF A LOGGING COMPANY: SIMULATION MODEL CASE STUDY

Peter Mensah[a], Yuri Merkuryev[b], Eric Klavins[c], Francesco Longo[d]

[a],[b]Riga Technical University, Department of Modelling and Simulation, 1 Kalku Street, Riga, LV-1658, Latvia
[c]Riga Technical University, Department of Computer Networks and System Technologies
[d]Modeling & Simulation Center, University of Calabria, Via P. Bucci, 87036, Rende, Italy

[a]peters.mensahs@rtu.lv, [b]jurijs.merkurjevs@rtu.lv, [c]eriks.kalvins@rtu.lv
[d]f.longo@unical.il

ABSTRACT
The supply chain today is vulnerable to risks that might affect the flow of materials, information and money anywhere between its upper and lower levels that could yield to a drastic loss in productivity, profitability as well as competitive advantages. Hence, it is vital for organizations to be agile and flexible enough to combat any form of risks that could be a threat to their success especially in deliveries. This paper therefore uses a case study approach to study and portray the effect of risks on the deliveries of a logging company. A simulation model is developed to represent the delivery process whereby the impact of the risks is discussed to raise awareness of uncertainties.

Keywords: supply chain, supply chain risks, deliveries, simulation model

1. INTRODUCTION
The essence of this article is to study and discuss the risks affecting the supply chain with reference to deliveries. By exploiting Simulink, a simulation model is developed utilizing both primary and secondary data obtained from a logging company and the government statistic office respectively. Risk variables are generated from the data and then used in the model to show how they affect deliveries in order to raise awareness of the logging company about uncertainties. The article is divided into three sections. The first section examines the supply chain and its overlapping definitions by various authors, whilst the second section considers the risk affecting the supply chain. The last section is a case study which is subdivided into the simulation model and the simulation results.

2. THE SUPPLY CHAIN
As various definitions have been given by different authors, in some cases with overlapping meanings of the supply chain, it is essential to take some of the definitions into consideration so as to grasp better understanding of the supply chain. According to Mensah and Merkuryev(2013), the supply chain is defined 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'. In this case, various factors like the quantity and quality of products together with on time delivery are vital to sustain customers' satisfaction. From a more global point of view, LU (2011) highlights that the supply chain is 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'. A shorter definition similar in meaning to the former is given by Cholette (2011), which states that it is 'a sequenced network of facilities and activities that support the production and delivery of a good or service'. From another perspective Croker (2003) defines the supply chain as the flow of materials, information and money between the upper and lower levels of the supply chain through a business network from the suppliers' suppliers to the customers' customers. Hence, taking figure 1 into consideration, the flow of information, materials and products is illustrated. In most cases, the customers can trail the origin of raw materials or products through barcodes. For example, after harvesting trees in a logging company, the logs are stamped with barcodes containing information about its origin, quantity and quality etc.

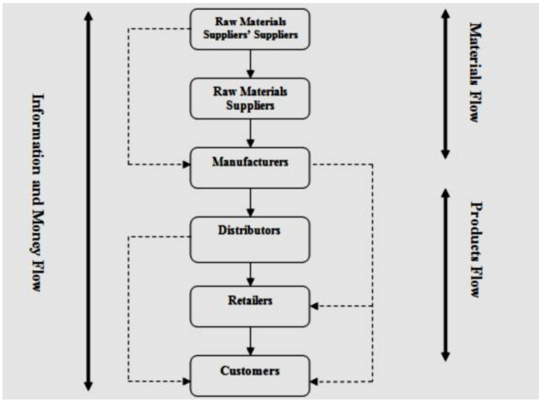

Figure 1: The Supply Chain (Mensah and Merkuryev, 2013)

These codes could be easily scanned by customers using their mobile phones or scanners to obtain appropriate pieces of information. Another example is in the gem industry where the diamonds are encrypted with codes so that their origin could be traced along the supply chain especially from areas with conflicts in order to avoid 'blood diamonds'. Figure 1 also portrays materials flow interchangeably between the suppliers' suppliers, likewise products between the manufacturers and customers.

Table 1: Supply Chain Definitions

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...
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...
Bridgefield Group	2006	...a connected set of resources and processes that starts with the raw materials sourcing and expands through the delivery of finished goods to the end consumer...
S, Cholette	2011	...a sequenced network of facilities and activities that support the production and delivery of a good or service...
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...
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...
Tecc.com.au	2002	...a chain starting with raw materials and finishing with the sale of the finished good...
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...
Little, A.	1999	...the combined and coordinated flows of goods from origin to final destination, also the information flows that are linked with it...
Beamon B.	1998	...a structured manufacturing process wherein raw materials are transformed into finished goods, then delivered to end customers...

Looking back at the definitions of the supply chain, a tabular form is illustrated in table 1 with various definitions. This section has given a brief description of the definitions of the supply chain. The risks involved in the supply chain are considered next.

3. SUPPLY CHAIN RISKS

Uncertainties could lead to disruptions anywhere along the supply chain if not managed effectively in today's globalized and competitive world. In fact, Sheffi (2005) points out that organizations are now facing greater challenges in managing risks due to the increase in the number of threats that can undermine a supply chain. Furthermore, Christopher and Perk(2004) stress that the risks in supply chains increase as they become more complex due to global sourcing. This is evident in the Business Continuity Institute (BCI) report which states that 'business interruption and supply chain losses account for around 50-70% of all insured property losses, as much as $26bn a year for the insurance industry' with reference to the Allianz Risk Barometer (BCI 2014). Some of these risks in the supply chain are given below in bullet points, and if they are not managed accordingly, organizations could face a decrease in productivity, profitability and competitive advantages.

- adverse weather disruption
- natural disasters
- terrorism
- cyber attacks
- credit crunch
- shrinking product lifecycles
- volatile and unpredictable markets
- miscommunication
- deliveries/ transport disruptions etc.

A further study conducted by the BCI(2014) in 71 countries involving 519 organizations, shows a surprising result whereby, '75% of respondents still lack full visibility of their supply chain disruption levels, 55% of the respondents having their primary source of disruption as unplanned IT or telecom outages, 40 % of the respondents experienced adverse weather disruption and 37% of the respondents with outsourcer service provision failure'. When taking logging companies into consideration, they are quite vulnerable to natural disasters, weather disruptions, and transport disruptions. These could affect both harvesting and transportation, resulting in a delay in production and deliveries. Obviously, there would be an increase in lead time and decrease in profitability due to high costs. Risks could be managed by having a mitigation strategy, business continuity strategy or any other form of resilient strategy. In addition, Jansons et.al. (2016) specify that risks could be minimized by utilizing computer technology. However, Longo (2012) stresses the importance of using simulation as decision support tools to reduce risks and vulnerability whilst improving the supply chain management. Moreover, Merkuryeva and Bolshakov(2015), place emphases on the importance of simulation model when evaluating the performance of a system, whereas Klimov et. al(2010) point out that simulation processes can easily represent any network of the supply chain. Hence, by exploiting Simulink, a simulation model is developed in the next section to study the impact of risks on deliveries on the supply chain of a logging company.

4. CASE STUDY OF LOGGING COMPANY *X*

Company *X* is a logging company that harvests approximately 51% of country's *Y* forest. As it is a government company, it mainly uses a push strategy to inform its customers about the possible available products. Company *X* receives a quota with a five-year maximum allowable volume of trees, from the Ministry of Agriculture in country *Y*, it may cut down from the state forest. After tactical planning, Company *X* then decides on the volume to harvest on yearly basis to meet with the sustainable customer supply in each product group for the necessary sales. The sales are mainly conducted through negotiations and auctions depending on the type of agreement. Volumes are usually provided for negotiation for a three-year period and auctions for a six- month period two times a year. Having informed the customers about the available quotas and terms, the customers then place their orders, and if approved, planning is started which leads to the harvesting operations. Hence, forest harvesters, felling units and forwarders, cut, process and transport the logs respectively to the approximately 1000 warehouses located on roadsides in different areas of country *Y*. The local customers then receive their products by road whilst international customers receive theirs by sea on FOB basis. In order to keep transparent flow of information, an ICT infrastructure allows the machines and trucks to immediately send information concerning operations to the head office which in turn monitors operations. However, Company *X* faces challenges in harvesting and deliveries due to uncertainties mainly depending on weather conditions that leads to road closures and delays. For example, roads leading to the warehouses might not be accessible due to:

- damaged road
- heavy rainfall
- heavy snow
- foggy weather
- road works
- accidents

This case study focuses on how the risks affect deliveries and their impact on company *X* logging company. The percentage of yearly sales was obtained from company *X* from which sales were forecasted between the year 2017 and 2023. The actual sales figure in 2016 was included within the forecasted data and this brings it to a total of eight years data. The company actually planned to increase sales by 100,000 m^3 on yearly basis till 2023. This was verified by the supply chain manager of company *X*. Variables affecting deliveries and their coefficients, illustrated in table 2, were considered as road availability, car accidents, weather/precipitation and truck breakdown. The road availability coefficient was obtained from company *X*. On the other hand, the car accidents, weather/precipitation and truck breakdown coefficients were calculated from secondary data obtained from the government statistics office between 2011 and 2016.

Table 2: Variables affecting Deliveries and their Monthly Coefficients

Variables \ Months	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Road availability	0.95	0.8	0.70	0.45	0.87	0.91	0.87	0.83	0.97	0.92	0.84	0.63
Car accidents	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Weather/precipitation	0.47	0.33	0.36	0.31	0.58	0.68	0.82	0.85	0.60	0.7	0.59	0.56
Truck breakdown	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4

4.1. Simulation Model

By exploiting Simulink, a simulation model is developed as illustrated in figure 2. The yearly sales data was used as the input imported form an excel file to 'simulink_import.mat' as shown in figure 2. The variables (road availability, car accidents, weather/precipitation, and truck breakdown) receive input data from 'simulink_import.mat' supported up by the counter. The counter also inputs a vector indicating the number of months. The coefficients are used in the model as input interruptions in order to study how they affect deliveries. The output depicts the impact of the risks on deliveries namely the 'affected volume of logs by total risk' as well as affected volume on logs by road availability, car accidents and weather/precipitation risks.

4.1.1. Simulation Results

After running the model with eight years data and 200 simulation runs, the following results were obtained as illustrated in figure 3, which shows how the volume (m^3) of logs delivered by trucks to potential customers are affected by the total risks.

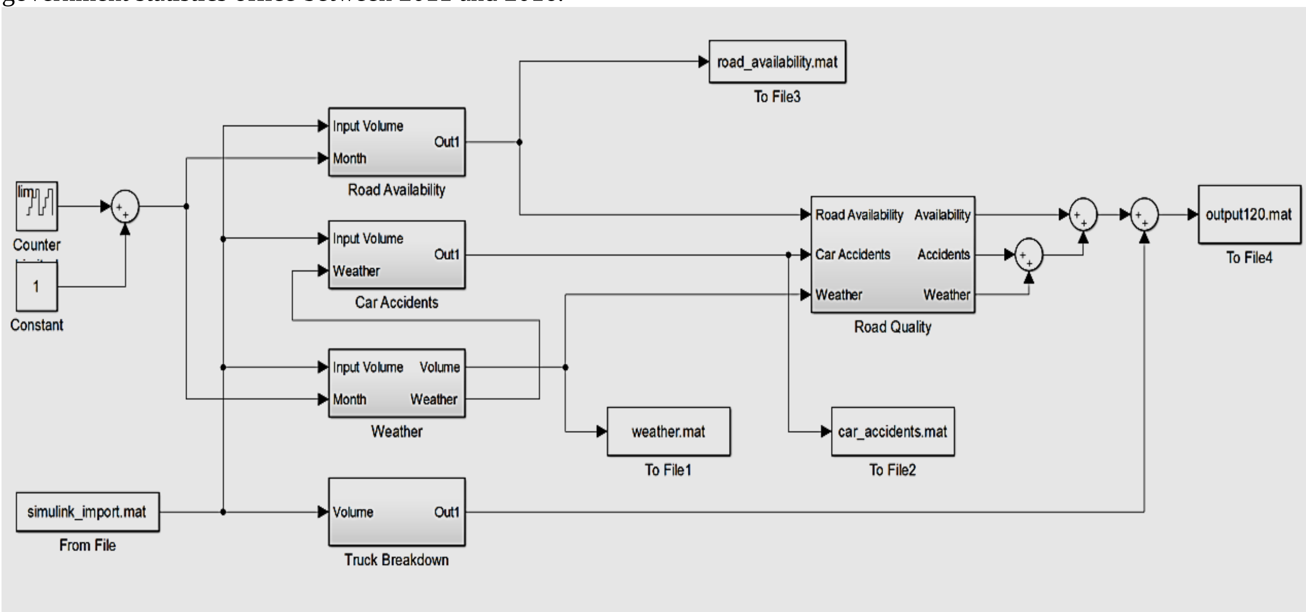

Figure 2: Simulation Model

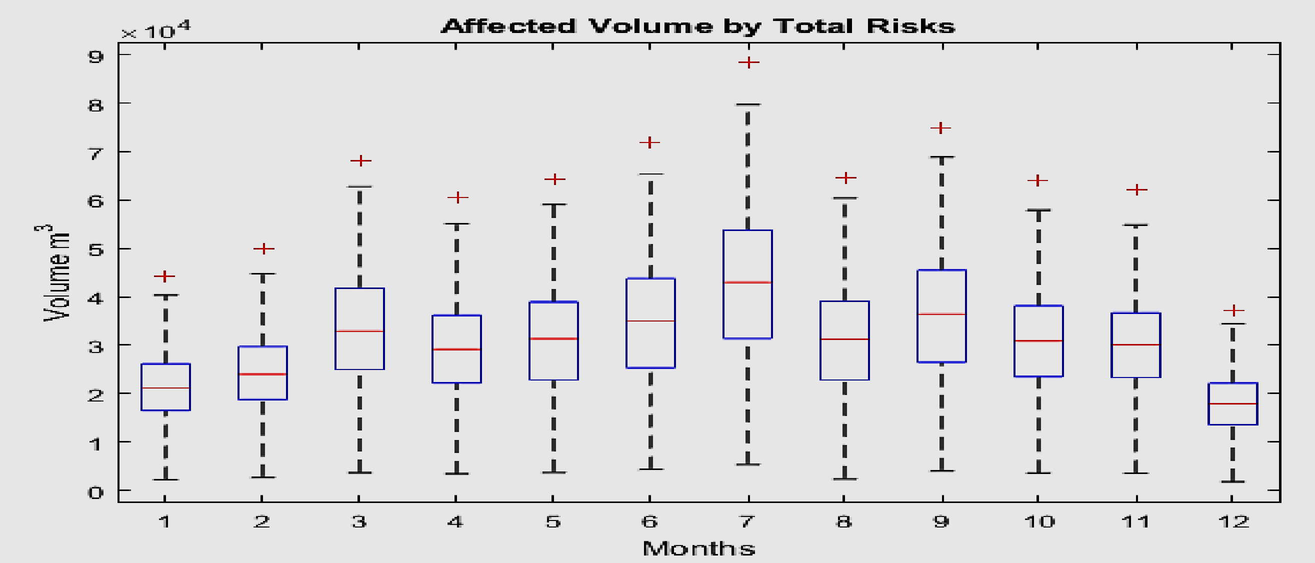

Figure 3: Simulation Results: Affected Volume (m^3) by Total Risks

The total risks is derived as the sum of all the risks, where;

- T_r – *total risk*
- R_{ra} - *road availability risk*
- R_{rca} - *car accidents risk*
- $R_{rw/p}$ - *weather/precipitation risk*
- R_{rtb} - *truck breakdown risk*
- C_R_{ra} - *road availability coefficient*
- C_R_{rca} - *car accidents coefficient*
- $C\_R_{rw/p}$ - *weather/precipitation coefficient*
- C_R_{rtb} - *truck breakdown coefficient*
- *Iv - Input volume*

From the model;

- $R_{ra} = Iv * C\_R_{ra}$
- $R_{rw/p} = Iv * C\_R_{rw/p}$
- $R_{rca} = (Iv * C\_R_{rca}) + R_{rw/p}$
- $R_{rtb} = Iv * C\_R_{rtb}$

Hence, the total risk is given as:

$\boldsymbol{T_r = R_{ra} + R_{rw/p} + R_{rca} + R_{rtb}}$

With reference to figure 3, the risks are divided into three parts, low, medium and high and they indicate the volume of logs (m^3) that could be affected in the delivery process between January and December. The impact of the risks will definitely increase the lead time due to delays and the customers might not be able to receive the ordered logs on time. The low risk is shown by the bottom 'dash line' just above zero with respect to the *y* axis. This indicates that there are almost no disturbances in deliveries as the risks are almost negligible. In other words, it shows the volume of logs that could be delivered to customers assuming the risks are negligible. However, when considering the medium risks level, indicated in the blue rectangle equally divided by a red line showing the average, there is a trend in the volume of trees to be delivered due to the risks. For example, it increases steadily from 21000 m^3 in January to 31000 m^3 in March. There is a slight drop in May followed by a slight increase but peaks at approximately 41000 m^3 in July. This is significant due to the rise in car accidents and unfavourable weather conditions yielding to a decrease in road availability as shown in figures 4, 5 and 6 respectively. Furthermore, there is a drop in the volume in August, but slightly increase in September before falling steadily with the lowest indicator in December (month 12) around 18000 m^3. Interestingly, the patterns of the low, medium and high risk levels affecting the volumes seem to be identical. The high risk level is indicated with the red plus (+) sign in figure 3. This is the worst scenario that could occur in case of uncertainties. The highest risk level affects approximately 90000 m^3 in July as a result of very high precipitation, car accidents yielding to very low road availability. This is a disaster, as 90000 m^3 may be delayed July and this might lead to higher costs and dramatic drop in profitability.

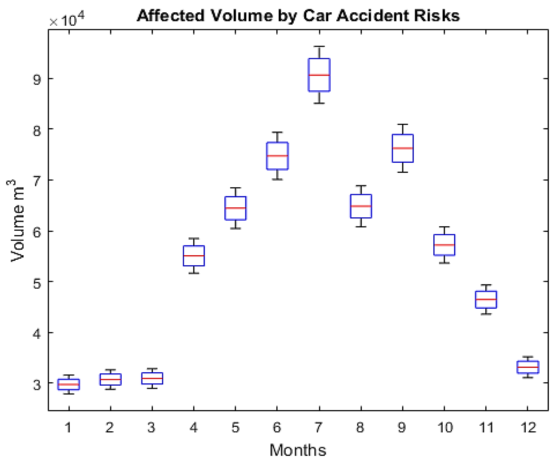

Figure 4: Affected Volume by Car Accidents Risks

Between 2011 and 2016, car accident historical data was obtained from the government statistics office. The coefficient of car accident risk *($C\_R_{rw/p}$)* was obtained from the mean of car accident data with respect to the average number of cars with the same time period.

Hence, the car accident risk is the product of the data input, and its coefficient is given as, R_{rca} = (Iv* C_R_{rca}) + $R_{rw/p}$. The affected volume by car accident risks displayed in figure 4, is derived from the display '*To File 2*'of the simulation model, figure 2. Figure 4 shows the way car accidents can affect deliveries. For example, in January, 30000m^3 of logs could be delayed or not delivered due to accidents. January to March is marked as car accidents at their minimum. This is followed by a dramatic increase from April and continues rising until it peaks at 90000 m^3 in July. Furthermore, there is a drop to approximately 65000m^3 in August which unexpectedly jumps to 76000 cm^3 in September before falling steadily till December at almost 35000m^3.

Figure 5 illustrates the effect of weather/precipitation risks on volumes of logs. Interestingly it has a trend similar to that of the car accident risks. This clearly shows that adverse weather conditions contribute greatly to car accidents. As indicated earlier, the weather/precipitation risks is given as $R_{rw/p}$ = Iv* $C\_R_{rw/p}$. The coefficient was calculated as the average monthly precipitation 2011 and 2016 (obtained from the government statistics office) with respect to the arear covered which is 0.77%of the total area of country *Y*. December, January, February and March put the impact of adverse weather condition at low. However, a significant increase is experienced in April that continues to rise until it peaks at 450000m^3 in July. This indicates that, approximately 450000m^3 of logs might be delayed or not be delivered in July. The trend between August and December is quite similar to the trend pattern of figure 4.

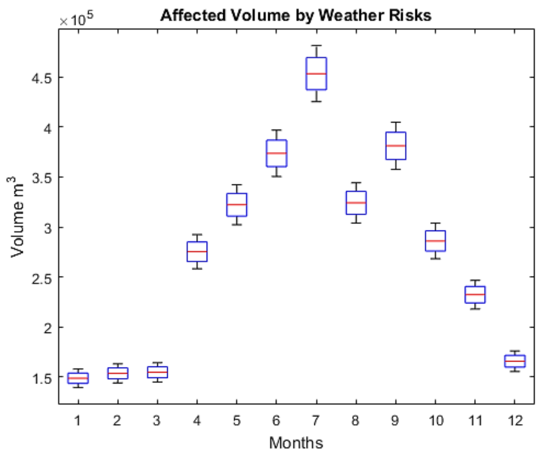

Figure 5: Affected Volume by Weather Risks

The road availability is enforced by the government as a strategy to protect the roads from damages caused by heavy trucks. As a result, the coefficient (as shown in table 2) was obtained from the government statistics office by the company's supply chain manager. The road availability risks was derived as R_{ra} = Iv* $C\_ R_{ra}$. After 200 simulation runs with respect to eight years data, the road availability risks in figure 6 was obtained from the display *'To File3'* of the simulation model in figure 2. Figure 6 shows that the road is available to a specific volume of logs through the whole country. For example, in January, approximately 60000 m^3 is the total volume of logs allowed to be transported by trucks in the country as a whole. The simulation runs show March as the month with the highest volume of logs allowed to be transported by trucks.

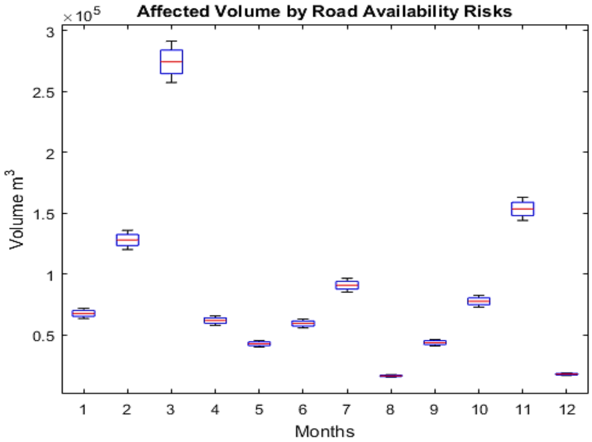

Figure 6: Affected Volume by Road Availability Risks

The truck breakdown risks were derived as *Rrtb* = *Iv** *C_Rrtb*. The coefficient was obtained through assumptions after consulting the supply chain manager; this include data of the average truck breakdown with respect to the average number of trucks between 2008 and 2016.

5. CONCLUSION

The supply chain and its risks have been analysed theoretically and then applied practically in a case study exploiting a logging company. Eight years forecasted data generated which was verified by the supply chain manager of company *X*, and the coefficients of variables were the input. These variables that could affect the deliveries of the input data to the customers were given as R_{ra} - *road availability*, R_{rca} - *car accidents*, $R_{rw/p}$ - *weather/precipitation and* R_{rtb} - *truck breakdown*. These are all interdependent and contributed to the affected volume by total risks in figure 3. After running the simulation model with 200 simulation runs, the results showed three levels of volume of logs affected by risks. The levels are low, medium and high with almost identical patterns. Interestingly, the highest risk occurred in July for all three categories of risks and they were obviously affected by the variables in figures 4, 5 and 6. Hence, this model could be used as a managerial tool for decision making processes in the deliveries of a logging company.

Further Research:

Although it has been recommended that the model could be used for decision making processes, a further research is still needed to combat uncertainties more effectively, and to develop a resilient strategy for company *X* to be able to bounce back and start operations in the shortest possible time after disruptions in deliveries.

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AUTHORS BIOGRAPHY

PETER MENSAH has an MBA in Business Management, MSc in Computer Science, and is also a Cambridge CELTA qualified English language teacher. He is currently a lecturer in Management System Analysis, Corporate Social Responsibly and Organizational Behavior at Riga Technical University, Latvia. He is also an English Language tutor at Riga Business School, Riga, Latvia. He has also worked as a PSE tutor, and guest lecturer in areas of Project Management, Systems Thinking and Teaching and Learning from a Cultural Perspective' at Coventry University for the past five years. He is currently a PhD Candidate and a researcher at Riga Technical University, Department of Modelling and Simulation. He is interested in Supply Chain Resilient Strategy Simulation and Management. He has written several publications, and his research area is mainly in 'Using Simulation to Develop a Resilient Supply Chain Strategy'.

YURI MERKURYEV is a Professor and Head of the Department of Modelling and Simulation at Riga Technical University. He obtained the Dr.sc.ing. degree in System Identification in 1982, and Dr.habil.sc.ing. degree in Systems Simulation in 1997, both from Riga Technical University. His professional interests include modelling and simulation of complex systems, methodology of discrete-event simulation, supply chain simulation and management, as well as education in the areas of simulation and logistics management. Professor Merkuryev is Full Member of the Latvian Academy of Sciences, Fellow of the European Academy for Industrial Management, president of Latvian Simulation Society, board member of the Federation of European Simulation Societies (EUROSIM), senior member of the Society for Modelling and Simulation International (SCS), senior member of the Institute of Electrical and Electronics Engineers (IEEE), and Chartered Fellow of British Computer Society, FBCS CITP. He is an associate editor of "Simulation: Transactions of The

Society for Modelling and Simulation International", and editorial board member of "International Journal of Simulation and Process Modelling". He has authored/co-authored more than 340 scientific publications, including 8 books, as well as 6 textbooks.

ERIC KLAVINS graduated with a bachelor degree in computer science in 2010 and master degree in 2012 at Riga Technical University(RTU). He is currently a PhD student and works at RTU as researcher. His research includes Unmanned Aerial Vehicle control system, sensor fusion filters and sensor data processing techniques. He specializes in use of MATLAB and C/C++ programing languages for mathematical modeling and control system development on ARM processors. His PhD thesis main research is on UAV control system, which is independent to other external systems, in which one UAV without additional modifications can be used for both indoor and outdoor flights.

FRANCESCO LONGO graduated with a Masters degree in Mechanical Engineering, 'summa cum Laude', in October 2002 from University of Calabria, and a PhD in Mechanical Engineering from the same university in January 2006. He is currently the Director of the Modeling & Simulation Center – Laboratory of Enterprise Solutions (MSC-LES), a laboratory operating at the Department of Mechanical, Energy and Management Engineeringof University of Calabria. Moreover, he is the General Co-Chair of the European Modeling & Simulation Symposium (EMSS 2008-2017) and Program Chair of the International Multidisciplinary Modeling & Simulation Multi-conference (2007 and 2008, 2011-2017). Furthermore, he actively cooperates with many research institutions worldwide including DIPTEM, University of Genoa, Kennedy Space Center, NASA (Cape Canaveral, USA), University of Ottawa (Canada), and Rutgers University (The State University of New Jersey). In addition, he lectures "Industrial Plants and Facilities" and "Industrial Plant Management" for Master Degree Students in Mechanical and Management Engineering. He was also the General Chair of the International Conference on Modeling & Applied Simulation (MAS 2009, 2010), Vice General Chair of Summer Simulation Multiconference (SummerSim2011) as well as the Program Chair of Summer Simulation Multiconference (2012 and 2013). He has published more than 150 scientific papers on international conferences and journals, and has also been a speaker and chairman in different international conferences. His research interests include Modeling & Simulation for production systems design and supply chain management. Since 2003, he has been working on private research projects involving manufacturing and logistics systems operating in Italy. He has acquired lots of experiences in consulting different areas of Business Process Re-engineering and Logistics.