Balancing lean and resilience in supply chain through analyzing the trade-off uncertainty factors by Probability-Impact Matrix*

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Abstract

This paper proposes a method for lean supply chain managers to control the trade-off factors that may lead to a disruptive incident to the whole supply chain, and to balance lean and resilience behavior of the supply chain. This model provides supply chain managers with a guideline to identify the likelihood and degree of impact of uncertainty factors on the supply chain. Probability-Impact Matrix is applied to measure the likelihood and degree of the impact.

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Ⅰ. Introduction

Every supply chain has its operational criteria and objective, for example, minimizing supply chain cost, cutting lead time, protecting environment, and shortening response time to disruption. Accordingly, there are various types of supply chain with different characteristics, such as lean supply chain, agile supply chain, resilient supply chain, and green supply chain. To assemble the supply chain with more utilities, some supply chain designers and managers may integrate two or more characteristics into one supply chain. This paper examines the integration of lean and resilience. As the operation objectives of lean and resilience are diverse, the management and controlling methods are not necessarily identical. For example, the purpose of lean is to maintain the minimized inventory and eliminate waste, with the aim to achieve lowest supply chain cost. Conversely, the purpose of resilience is to struggle for quick response to supply chain disruption and minimize the loss. In order to achieve this objective, sufficient safety stock is necessary. In other words, there is a trade-off relationship between lean and resilience in a supply chain. For example, due to the labor dispute that lasted for 9 months in 2014, the shipment traffic of west coast of the U.S. was severely disrupted (Lutz, 2015). As a result, Japanese automakers which were building vehicles in the US faced shortage in supplying components from Japan. Honda and Toyota were heavily affected by this affair because there is no inventory for them in the U.S. On the other hand, Nissan has seen only a minor loss because of its local supplier and reserve inventory. The lean method used by Honda and Toyota helps them reduce the inventory costs, meanwhile, it also constructs their supply chains vulnerable in disruption situations, which means not resilient enough. Thus, lean and resilience represent different utility, and if a supply chain aims to maintain the two characteristics at the same time, the trade-off relationship should be acknowledged. This paper proposes a method to measure the likelihood and impact of the level of uncertainties inherent in the supply chain through Probability-Impact Matrix in order to balance lean and resilience performance.

The three resources of uncertainty in supply chain are demand, manufacturing process, and supply uncertainty (Davis, 1993). In addition, planning and control uncertainty, government policy uncertainty and act of God uncertainty should be considered (Thongrattana, 2012). According to the research on supply-chain uncertainty (Simangunsong, Hendry, & Stevenson, 2012), the specified fourteen kinds of uncertainties sources could be classified into three groups as below:

1. Internal organization uncertainty: uncertainties from focal company, include product characteristics (U1), manufacturing process (U2), control/chaos (U3), decision complexity (U4), organization/behavioral (U5), and IT/IS complexity (U6).
2. Internal supply-chain uncertainty: uncertainties arises within the realm of control of the focal company or its supply chain partners, include end-customer demand (U7), demand amplification (U8), supplier (U9), parallel interaction (U10), order forecast horizon (U11), and chain configuration, infrastructure and facilities (U12).
3. External uncertainty: uncertainties from factors outside the supply chain, which are outside a company's direct areas of control, include environment (U13, e.g., Government regulation, competitor behavior and macroeconomic issues), and disasters (U14, e.g., earthquake, hurricane and high sea waves).

According to Birkie (2015) who studied the dilemma of leveraging from synergic practices, the trade-off factors between lean and resilience that should be focused on are sense, reconfiguration of resilience, JIT flow, and TPM of lean. The lean concept and resilience concept could co-exist in a supply chain in 3 ways:

1. Lean and resilience share a half-half proportion, which means the supply chain pursue minimized cost and minimized loss in disruptive situation at the same time.
2. The supply chain applies lean concept and pursues resilience in lean environment.
3. The supply chain applies resilient concept and pursues lean in resilient concept environment.

This paper only discusses the second situation which assumes that the supply chain applies lean concept and pursues maximum resilience in the lean environment. Based on this assumption, the trade-off factors belong to lean practice and may effect on resilience behavior, that are JIT flow and TPM. According to Simangunsong et al. (2012), the uncertainties related to these two trade-off factors are end-customer demand (U7), demand amplification (U8), supplier (U9), parallel interaction (U10), order forecast horizon (U11), and chain configuration, infrastructure and facilities (U12), and external uncertainty, which are environment (U13) and disasters (U14).

The analysis tool for likelihood and impact of uncertainties is the Probability-Impact Matrix. It is one of the commonly used qualitative methods for risk assessment. The calculation of risk considers two aspects, including likelihood and impact of an event, and the total risk could be a particular classification that is based on the calculation (Dumbravă & Iacob, 2013). Therefore, the two components of risk, impact and likelihood of uncertain factors, are actually variables of such matrix, and through the Probability- Impact Matrix, the uncertainty factors that may influence lean and resilience performance in a trade-off relation could be classified to 5 degrees. As every supply chain has its own reality and characteristics, the valuation on likelihood and impact of uncertain factors should be gathered by supply chain designers and managers, and the valuation of impact should be constructed based on lean and resilience separately. Finally, supply chain managers could use the matrix to determine the degree of attention they should pay for each uncertainty factor and conclude a both lean and resilience supply chain.

The greatest benefit of this solution is flexibility. Companies could adopt it and conclude the result based on their realities. As every supply chain has different characteristics, some supply chains may be heavily affected by demand fluctuation, while some may be sensitive to government regulation. If every supply chain adopts the same solution to control uncertainties, the different consequences caused by the solution may confuse the whole supply chain. Furthermore, companies' valuation of the severity level of the risks inherent in their supply chains could improve the pertinence of solutions.

Another benefit is that companies could review their supply chain and confirm their supply chain condition through the valuation process and also discover the problems by summarizing the uncertain factors inherent in the supply chain. Among the uncertain factors, some may not be amended by the companies solely while some uncertainties are reparable. If the companies could struggle to fix the reparable uncertainties and prevent the occurrence of risks previously, consequently the resilience of the supply chain would be improved dramatically.

Through the self-uncertainty check and cross-uncertainty check process, companies in the supply chain could confirm the uncertainties from itself and from each other. Since some uncertainties may could not be recognized by self while they could be discovered by partners. As a result, this solution provides an opportunity to integrate and connect the whole supply chain closely.

II. Literature Review

Lean supply chain is the supply chain which applies with lean thinking, and connects raw materials supplement, manufacture, logistics, service, finance and information functions as an integrated chain. Furthermore, in order to satisfy each customer's need, lean supply chain adopts pull strategy to every component of the chain, and operates the whole chain collaboratively to reduce cost and waste (Vitasek, Manrodt, & Abbott, 2005). The application of lean thinking in a supply chain is reflected in two levels; one is individual company level and the other is the inter-company relationship which is guided by lean thinking. As the objective of lean supply chain is to reduce overall cost of the supply chain by eliminating nonvalue-added activities, merely the application of individual company is not enough and difficult to achieve cost saving in the whole supply chain. In other words, there is a need to co operate the participants and put information sharing into practice in order to enable the supply chain to be more forthright and objective-oriented (Jung, Chen, & Jeong, 2007). Alternatively, Ponis and Koronis (2012) dispensed a definition for supply chain resilience.

The ability to proactively plan and design the Supply Chain network for anticipating unexpected disruptive (negative) events, respond adaptively to disruptions while maintaining control over structure and function and transcending to a post-event robust state of operations, if possible, more favorable than the one prior to the event, thus gaining competitive advantage (Ponis, & Koronis, 2012, p. 925-926).

Furthermore, Waters (2011) insisted that creating a resilient supply chain should consider risk in the design process, because if supply chain managers ignore the potential risk in the supply chain and only focus on efficiency or leanness, the supply chain would be vulnerable and easy to be stunk in disruption situation. There are three main ways through which companies can develop resilience: increasing redundancy, building flexibility and changing the corporate culture (Sheffi, 2005).

In regards to the relationship between lean and resilience, a general opinion is a trade-off relationship between them. The simplest means to build redundancy in supply chain is maintaining extra inventory in case of disruption. However, this goes against with the principle of lean, which is reducing waste and maintaining zero inventory (Maslaric, Backalic, Nikolicic, & Mircetic, 2013). Due to this, the challenge is how to increase supply chain resilience while the lean manufacturing environment is not affected significantly (Machado, & Duarte, 2010). In order to solve this issue, one suggestion is to design an environmental system with the characteristics of lean and resilience at the same time, which aims to ensure the sustainability and benefit from lean could be maintained (Machado, & Duarte, 2010). Marinko et al. (2013) put forwarded a mean to assess the trade-off between lean and resilience through SCRM (supply chain risk management) model, which gives a method to consider the type and level of risk before deciding whether to apply lean principle in a supply chain. However, there are some articles suggest that besides of the trade-off relationship, there also exist synergetic relations between lean and resilience in a supply chain. They claimed that the performance losses resulted from the synergetic relation may outweigh the losses from the trade-off relation (Birkie, 2015).

In summary, the previous studies identified and assessed the trade-off relationship between lean and resilience in a supply chain. The differed objectives and operation rule contribute to the complexity in building a supply chain with resilience and lean method at the same time. As a result, if companies aim to build supply chains that could maintain the least inventory and reserve material cost while response quick in the emergency situation, they should pay attention to the trade-off relationship between lean and resilience. Furthermore, supply chain designers should attempt to get a balance point between lean and resilience in order to optimize their supply chains.

Ⅲ. Model

For the sake of balancing the inventory trade-off between lean and resilience, the uncertainty factors that could lead to inventory risk should be assessed and evaluated. This paper will use Probability-Impact Matrix to measure the impact level when uncertainty factors exposure, and control the factors in different degree based on the analysis result. Potential risk(R) is translated in mathematical terms as a result of the product of the size of the impact(I) and likelihood of (P).

$$R = I * P \qquad (1)$$

In the evaluation of the uncertainties, the sides of activity should be captured.

1. Risk probability (almost certain / likely / moderate / not likely / rare)
2. The level of risk (extreme / high / moderate / low / negligible)
3. Consequence (catastrophic / high / moderate / low / insignificant)

The two components of risk (equation 1) are actually variable of Probability-Impact Matrix. Risk calculation is very simple considering that likelihood and impact of an event is assigned a random basis to the total which can be a particular classification (Dumbravă & Iacob, 2013). Based on the steps of Probability-Impact Matrix, the analysis of uncertainty factors are as follows:

Step1:

The first step is to define the probability of uncertainty occurrence, the supply managers have to score the likelihood of uncertainty factors according to the reality and history record of their supply chains.

〈Table 1〉 likelihood score of uncertainty

Likelihood level	Score
Very low	0-20
Low	21-40
Medium	41-60
High	61-80
Very high	81-100

Step2:

The second step is to score the impact on a scale of 1-5. And the score of impact will be given in two aspects, one is the impact on lean, and the other one is the impact on resilience.

〈Table 2〉 Impact analysis

Magnitude of impact	Impact definition	Score of impact on lean	Score of impact on resilience	Rating
High impact/ High probability	Very high They are the biggest uncertainty factors that entrepreneurs should pay attention.	5	5	A
High impact/ Medium probability Medium impact/ High probability	High These uncertainty factors have either a high probability of occurrence, or a significant impact.	4	4	B
Medium impact/ Medium probability	Medium There is a medium chance that the uncertainty factors appear noticeable impact.	3	3	C
Medium impact/ Low probability Low impact/ Medium probability	Low These uncertainty factors can occur in some situations and have a low to medium impact.	2	2	D
Low impact/ Low probability	Insignificant There are uncertainty factors with low probability of occurrence and low impact. Therefore can be neglected.	1	1	E

Step3:

The third step is to determine the uncertainty factors exposure resulting value.

〈Table 3〉 Calculation of the exposure uncertainty factors

	Uncertainty factors	Occurrence likelihood		Impact on lean		Impact on resilience		Degree of uncertainty exposure	
		Pro.	Score	Pro.	Score	Pro.	Score	Rating	Score
1	end-customer demand (U7)	P_O1	S_O1	$P_{IL}1$	$S_{IL}1$	$P_{IR}1$	$S_{IR}1$	R1	S1
2	demand amplification (U8)	P_O2	S_O2	$P_{IL}2$	$S_{IL}2$	$P_{IR}2$	$S_{IR}2$	R2	S2
3	supplier (U9)	P_O3	S_O3	$P_{IL}3$	$S_{IL}3$	$P_{IR}3$	$S_{IR}3$	R3	S3
4	parallel interaction (U10)	P_O4	S_O4	$P_{IL}4$	$S_{IL}4$	$P_{IR}4$	$S_{IR}4$	R4	S4
5	order forecast horizon (U11)	P_O5	S_O5	$P_{IL}5$	$S_{IL}5$	$P_{IR}5$	$S_{IR}5$	R5	S5
6	facilities (U12)	P_O6	S_O6	$P_{IL}6$	$S_{IL}6$	$P_{IR}6$	$S_{IR}6$	R6	S6
7	environment (U13)	P_O7	S_O7	$P_{IL}7$	$S_{IL}7$	$P_{IR}7$	$S_{IR}7$	R7	S7
8	disasters (U14)	P_O8	S_O8	$P_{IL}8$	$S_{IL}8$	$P_{IR}8$	$S_{IR}8$	R8	S8

The score of occurrence likelihood should be given among 1-100.

The score of impact on lean and resilience should be given from 1-5.

Rating of degree of uncertainty exposure is defined as A(1-22), B(23-44), C(45-66), D(67-88), E(89-110).

The score of degree of uncertainty factors exposure= (the score of occurrence likelihood + the score of impact on lean + the score of impact on resilience)/3

Step4:

The last step is to build an uncertainty factor matrix.

〈Figure1〉 Probability-Impact Matrix

		IMPACT		
LIKELIHOOD		Low (insignificant, just notice)	Medium (reasonable impact, need mention)	High (pay attention)
	Low (unlikely to occur)	E	D	C
	Medium (may occur at a time)	D	C	B
	High (likely to occur)	C	B	A

The uncertainty factors that belong to A should be tracked and controlled tightly, then B, C, D. The uncertainty factors that belong to E could only be noticed.

Ⅳ. Conclusion

In order to minimize the overall cost of the supply chain and to eliminate nonvalue-added activities, many companies choose to adopt lean thinking to their supply chains. Lean thinking helps companies reduce inventory cost and waste, also lighten the whole supply chain. However, along with globalization of manufacturing industry and outsourcing, the component suppliers may locate in different countries, and a whole supply chain may disperse in several countries. As a result, if one node of the supply chain gets in trouble, then the whole supply chain will paralyze. This means a lean supply chain is not resilience enough under the situation of a disruptive incident. Supply chain managers have to think about how to make quick response to disruptive incident and minimize the corresponding lost in a lean supply chain. Previous study indicated that there exists a trade-off relation between lean and resilience in a supply chain, and the task for supply chain manager is to increase supply chain resilience while not do great harm to lean environment. The existing literature also proposed that the trade-off relationship between lean and resilience could be balanced by defining and analyzing the uncertainties and risks inherent in the supply chain.

This paper aims to provide a measurement method to supply chain managers to confirm the uncertainty and risk which may effect on the lean and resilience behavior of their supply chains. The precondition of this paper is assuming that the supply chain applies lean concept and pursues maximum resilience in lean environment. With this assumption, the trade-off factors and the corresponding uncertainties were defined based on previous study. The trade-off factors are JIT flow and TPM, and the uncertainties related to these two trade-off factors are end-customer demand, demand amplification, supplier, parallel interaction, order forecast horizon, chain configuration, infrastructure and facilities, lastly environment and disasters. Then supply chain managers are asked to score the degree of likelihood and impact of every uncertain factor according to their own situations, where the impact degree should be scored on lean and resilience separately. Furthermore, managers could input the result in a Probability-Impact Matrix to confirm which uncertainty should be managed or monitored with respect to their own supply chains. They could also use the matrix to determine the degree of attention they should pay for each uncertainty factor. This solution provides a comprehensive overview of the uncertainties inherent in the supply chain and offers a method to evaluate the likelihood and their impact on lean and resilience. As some uncertainties could be controlled and prevented by previous attention while some uncertainties are unpredictable, supply chain managers should take both kinds of uncertainty into account when they build the supply chain. If the managers find that uncertainty factor is scored highly of a component supplier, then they should ask the supplier pay attention to that part and report about the situation of that part regularly. Additional, for the situation that a component supplier faces high possibility of disaster, it would be best to disperse the supply to two or more suppliers to divide the risk.

This paper contributes to the practical operation of lean supply chains, especially those are composed across several countries and more likely to encounter disruptive incident. The proposed method could be used by both node managers of supply chains and managers of the whole supply chain. In the perspective of node managers like the supply chain managers of certain suppliers, they could use this method to measure the uncertainties in their small-scale supply chain. In the perspective of the whole supply chain managers like the managers of global enterprises, they could ask every node manager to provide related measurement result and conduct an evaluation of the whole supply chain. As the reason for disruptive incidents are diverse, prior prevention and quick response are of great concern to the whole supply chain and terminal enterprises. This paper provides a tool for supply chain managers and terminal enterprises to identify the uncertainties that may lead to supply chain disruptions and provide a guideline for prevention.

The limitation of this paper is that the measurement of uncertain factor is based on the knowledge related to their own supply chain of every supply chain manager, and that the measurement is qualitative but not quantitative. This may lead to cognition difference according to different manager. Even managers of every supplier in a common supply chain may have different evaluation criterion, this could result in a deviation of the final measurement conclusion. Further research could develop a quantitative model to unify the measurement criterion, like identity a certain index to represent each uncertain factor and collect the data of these indexes to evaluate the likelihood and impact.

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