The prerequisites for achieving Supply Chain Resilience

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ABSTRACT
The scholarship of Resilience has been analyzed over 3 decades and it is a multidimensional and multidisciplinary concept which is researched cross multiple disciplines such as psychology, ecosystems and economics. However, the study of Supply Chain Resilience has been paid attention only recent years and most of them are remaining on the arguments of the conceptual validity and lack of practical measures. In this paper, first of all, we follow previous researches related to the theme through organizing and analyzing topics of Emergency, Supply Chain Risk, and Resilient Supply Chain sequentially and systematically. With the review and understanding on the related concepts of Supply Chain Resilience, we conclude a suite of fundamental and common key points in order to establish Resilient Supply Chain. Furthermore, we derived a feasible conceptual framework concurrently so that it would be clearer how to achieve Supply Chain Resilience basically. And then, we focus on the manufacturing industries of Japan and several other counties during the March 11 earthquake in Japan and Thailand floods in October, 2011 to compare their supply chains' resilience and their responses afterwards. By means of analysis on the differences, we summarized two typical supply chains in terms of their sourcing and producing operations especially in the manufacturing industries of Japan and other several counties which are Modular Supply Chain and Integral Supply Chain. Moreover, based on the features of two typical supply chains, we discuss what kinds of operation strategies should be applied to the appropriate establishment of Supply Chain Resilience in manufacturing industries. In addition, we mentioned the importance of the decision-making process for building a resilient supply chain, and clarify significant conditions for visualizing the decision-making process so that operation strategies could be embedded in the resilient supply chain effectively.

Keywords: Supply Chain Resilience, Operation strategy, Emergency

INTRODUCTION

The research on Supply Chain Management (SCM) has been evolving and developing positively and vibrantly based on the exploration conducted by substantial amount of researchers in the last several decades. From the research on issues under environment of certainty including selection of provider, supply chain network design, coordination of enterprises, interest distribution and allocation, researchers come to realize that under environment of certainty, the practical and guiding efficiency and effectiveness of SCM research is restricted to a great extent. Therefore, researchers start to perform in-depth research on supply chain under environment of uncertainty,

especially the research on supply chain risk management. Supply chain uncertainty derives from various aspects, and the most important two aspects are uncertainty of demand and uncertainty of supply. Uncertainty can affect the performance of supply chain in a variety of ways. Random variations can occur in both demand and supply and they can be managed to reduce the amount and impact of uncertainty (Fildes and Kingsman, 2011). Uncertainty in supply and demand is recognized to have a major impact on the manufacturing function, propagating throughout the whole process and network and leading to inefficient processing and non-value adding activities. The presence of uncertainty stimulates the decision maker to prevent a bad chain performance (Jack and Beulens, 2002).

In recent years, due to the frequent occurrence of emergency incidents, a great amount of researchers have come to realized that research on Supply Chain Resilience (SCR) is of signality, while the current research conducted on it is limited or close to petty. Systematic research on SCR has to be established. In addition, the practical development of SCM also provokes the research on SCR. According to statistics, there are around 130 earthquakes of magnitude 6.0 – 6.9 and 20 earthquakes of magnitude 7.0 or above happening worldwide every year, damaging the facilities, infrastructures and the major economic activities around these areas and reflecting the fragility of global supply chain. The devastating blow caused by earthquake and tsunami reveals modern companies' dependence on infrastructure and network. After earthquake, disrupted tele-communication, electric power and traffic system usually cause the disruption of supply chain and economic challenges of government debts, raising commodity prices and a shrinking labor pool.

Table1 - Related concepts of Emergency

Name	Definition
Event	Something that happens at a given place and time
Accident	A mishap; especially one causing injury or death
Disaster	An act that has disastrous consequences
Incident	A single distinct event or a public disturbance
Disruption	An event that results in a displacement or discontinuity
Crisis	An unstable situation of extreme danger or difficulty
Emergency	A sudden unforeseen crisis (usually involving danger) that requires immediate action
Risk	The probability of becoming infected given that exposure to an infectious agent has occurred

THE STUDIES ON EMERGENCY

Definitions of Emergency

Currently there is no standard or unified definition of emergency. Definitions of emergency include:

- Any unplanned event that can lead to death or serious injuries to employees, customers or the public, close your business or disrupt operation, cause physical or environmental damage, or threaten the facility's financial standing or public image (Wahle and Beaty, 1993);

- Disruption of normal life and work of people in the building or on a certain territory, caused by catastrophes, natural disasters or ecological incidents, epidemics etc, which causes or may cause human and material losses (Arhipova and Kulba, 1998);

- Situation whereby normal living and working conditions of people in the building, on a certain

territory or aquatory are destroyed, people's lives and health are threatened, their property are damaged and environment is threatened (Menshikov and Shvirajev, 2003) or

Characteristics of Emergencies

Characteristics of emergencies include: 1, emergencies are unpredicted and unforeseen, they arise out of a sudden hence there is no effective way to prevent; 2, emergencies are usually disruptive; 3, the response must be equally swift, if not immediate; 4, there is no way to eradicate emergencies.

In 1995, Burkholder et al. (1995) put forward the 3-step model of emergencies and pointed out that there should be different obstacles and measures on the basis of characteristics at different stage. Emergency management has to be prompt, accessible, effective and active and it can be only successful if the source information, as well as the response protocols, are readily available throughout the organization (Renaud and Phillips, 2003). Moreover, emergencies also can be divided into different types from various aspects as following.

However, raising the management of emergency in the field of supply chain initially is the research of Jens Clausen and his colleagues. They state that Operations Management can be applied in a new field, which is called Disruption (as the same meaning of emergency) Management. That is to say, since emergency is able to lead the implement of operating plans to deviate from the real situation, when the deviation exceeds a critical level, the original plans have to be arranged extremely (Clausen et al., 2001). And what is conducted at that time is the management of emergency. Their studies and the concept of Emergency (or Disruption) Management have been diffused and quoted extensively in the related disciplines.

Table2 - Classification of Emergencies

Classification Criteria	Categories
Time of duration	Temporary emergencies and Progressive emergencies
Disruptive Level	Non-disaster emergencies and Disaster emergencies
Sphere of Influence	Global emergencies, National emergencies, Region emergencies and Organizational emergencies
Emergency Subject	Consistency emergencies and Conflict emergencies
Emergency Inducement	Natural emergencies and Artificial emergencies

THE STUDIES OF SUPPLY CHAIN RISK MANAGEMENT

Definitions from different perspectives

There are various paradigms being related to the definitions of risk and supply chain risk and they typically encompass the issues of uncertainty, unpredictability, decision-making and potential losses. For example, Sitkin and Pablo define risk as “the extent to which there is uncertainty about whether potentially significant and/or disappointing outcomes of decisions will be realized.” (Sitkin and Pablo, 1992) Simon et al. (1997) perceive risk in terms of the likelihood of an uncertain event or series of circumstances happening which would have an adverse effect on the achievement of a project's objectives. Zsidisin et al. (2004) defines risk from operational aspect as 'risk is perceived to exist when there is a relatively high likelihood that a detrimental event can occur and that event has a significant associated impact or cost.' Supply chain risks refer to the possibilities and effects of a mismatch between supply and demand. Risks for the information, material and product flows from original supplier to the delivery of the final product for the end user are

comprised in supply chain risks. Risk sources are those environmental, organizational or supply chain-related variables which cannot be predicted with certainty and which exert influence on the supply chain outcome variables. Risk consequences are the focused supply chain outcome variables such as the costs or quality or the different forms in which the variance becomes manifest (Jüttner et al., 2003). While according to Peck (2006), supply chain risks are anything that may disrupt or impede the information, material or product flows from original suppliers to the delivery of the final product to the ultimate end-user. The conceptual similarity of the definitions implies that risks and supply chain risks are unpredicted disruptive variables that will affect decision – making and lead to losses.

Various Classifications

Based on our previous research, we classify supply chain risks into two general categories: ordinary supply chain risks and emergency induced supply chain risks.

Ordinary supply chain risks comprise three types: enterprise risks, inter-firm risks and supply chain external risks. In detail, enterprise risks, as the internal risks generated during enterprise operation or due to the misusage of enterprise regulation, can be divided into operation risks and control risks. Operation risks refer to the risks generated at the process of enterprise operation such as the manufacturing of products, quality control, inventory or delivery. Operation risks arise from enterprise operation and in the mean time affect the business operation. In an appropriately managed operation and production flow, operation risks could be effectively mitigated or avoided. Control refers to the regulations, systems and procedures adopted by business for management. In a supply chain, assets and delivery regulations and policies including order and batch quantity, inventory policies and deliveries are all comprised. Controls risks are the risks caused by the misusage or false execution of these relevant regulations and policies.

Rather than being generated inside a business, inter-firm risks arise as raw materials, products and information flow between businesses. Inter-firm risks include demand risks and supply risks. When the capital, material and information flow of business downstream supply chain is influenced by potential factor, these factor lead to the generation of demand risks. Generally speaking, any fluctuation of capital, material or information flow could cause the demand risks. Supply risks refer to the demand risks of upstream businesses and are associated with the upstream product or information flow of core enterprises. Supply risks originate from upstream enterprises in a supply chain and comprise the potential or present disarrangements originating from the flow of raw materials, accessory parts and information.

Supply chain external risks refer to environmental risks which are caused by variation of external environment and are usually uncontrollable or unpredictable. Typical environmental risks include risks caused by natural disasters such as earthquakes, tsunamis or hurricanes, wars or military actions such as the war in Iraq, terrorisms such as 911 and diseases such as the foot and mouth outbreak in the UK in 2001 and 2007 or SARS. All the above seriously influence the fragility and flexibility of supply chain. For enterprises, these uncontrollable and unpredictable risks could directly affect the core enterprises or the market itself. And due to the low frequency of these events' occurrence, large amount of enterprises ignore their graveness and severe consequences.

The complexity of supply chain network, the lean production that managers are going after, and

the various uncertainties of supply chain have all led to the fragility and vulnerability of supply chain. The occurrence of emergencies may cause destructive influences and losses to supply chain and enterprises and could even lead to the complete rupture of supply chain. Emergency induced supply chain risks are categorized into 4 categories: logistic risks, financial risks, information risks and organizational risks. Logistic risks refers to the risks arise from inventory and delivery. For example, delay in delivery, traffic suspension, goods damage and short supply caused by emergencies are all logistic risks. Financial risks are the risks related to capital flow, including the discontinuity of cash flow and no return of investment generated at the link of payment, cash flow, loan, investment or accounting. Information risks are associated with information flow and comprise data transfer, process and systematic breakdown caused by malicious network attacks. Organizational risks refers to the risks arise from the inappropriate cooperation, alliance and interest allocation among organizations. Typical paradigms of this type of risks include poor communication, poor supply and legal disputes between enterprises.

INTRODUCTION OF RESILIENT SUPPLY CHAIN

Background

SCM concludes the designing and management of all activities involved in souring, purchasing, transformation, and all logistic management activities and is the strategic and efficient coordination of business functions and strategies for the aim of developing sustainable business performance and management. Reality proves that currently there remain some problems and obstacles in supply chain and supply chain management:

(1) In current supply chain, products flow to customers from manufacturers, leading to the passiveness of downstream enterprises. Downstream enterprises have to increase safety stock to cope with variations in demand, leading to considerable increase of stock in the whole supply chain and the decrease of sensitivity.

(2) As data of demand forecast, inventory and manufacturing are located in different link of supply chain, information cannot pass promptly, especially when emergencies occur, result in the efficiency of the whole supply chain.

(3) Enterprises in links response to customers without coordination: in addition, the complexity of supply chain network, the lean production that managers are going after, and the various uncertainties of supply chain have all led to the vulnerability of supply chain and the occurrence of emergencies, leading to destructive influences and losses to supply chain and enterprises and even the disruption of supply chain. Incorporating event readiness, resilient supply chains is capable of providing an efficient and effective response and recovering to their original state or even better post the disruptive event. Establishing resilient supply chain is a proactive method that can complement and enhance traditional risk management and business continuity (Ponomarov and Holcomb, 2009).

SCR originates from the problem that supply chain becomes more vulnerable under the occurrence of emergencies, while the vulnerability of supply chain arises from supply chain risks. Influencing factors of supply chain vulnerability include: the current operational mode of supply chain focus on efficiency; trend of globalization of supply chain; centralization of production and distribution; increasingly prevalence of outsourcing; reduction of supplier amount; demand fluctuation and the

deficiency of transparency and regulatory measures amongst supply chain partners.

The first wide-spread study on SCR began in the United Kingdom, following transportation disruptions from fuel protests in 2000 and the outbreak of the Foot and Mouth Disease in early 2001 (Pettit et al., 2010). Christopher and Peck (2004) developed an initial framework for a resilient supply chain and asserted that SCR can be established through four key principles: (1) resilience can be built into a system before the occurrence of a disruption (i.e., re-engineering), (2) high level of collaboration and cooperation are necessary to identify and manage risks, (3) agility is essential to react quickly to unforeseen events, and (4) the culture of risk management is a necessity. Other characteristics such as agility, availability, efficiency, flexibility, redundancy, velocity, and visibility are treated as secondary factors.

ESTABLISHMENT OF RESILIENT SUPPLY CHAIN

Essential capabilities of resilient supply chain

In order to build up a resilient supply chain, there are some essential capabilities which have to be equipped. The detail and their relationship are as followings:

Agility of supply chain refers to the ability to react promptly to the unpredictable changes of demand or supply during operation or under the occurrence of emergencies based on the strategic objectives or situations of enterprise. When emergencies occur, supply chain usually lags in reacting to the changes and place itself in risks. Hence it is imperative to raise the velocity of reaction and reduce the reaction time. Link enterprises on supply chain should manage to diminish the time that materials or products flow in interior process and supply chain so as to raise the velocity of reaction and reduce the reaction time. In detail, three steps must be conducted: the first step is to optimize operation process, which means rather than executing activities in sequence, multiple activities should be executed so as to reduce the activities and time involved; secondly, important materials or products should be delivered directly with speed; last but not least, non-added value time should be reduced because a variety of evidences and researches have proved that substantial amount of the time spent on supply chain does not add value.

Supply chain flexibility is the capability of promptness and the degree to which the supply chain is able to adjust its speed, destinations and volume in line with changes in client demand (Lummus et al., 2003). Vickery et al. (1999) define five supply chain flexibilities based on previous operations literature and state that supply chain flexibility "should be examined from an integrative, customer-oriented perspective." Flexibilities viewed as directly impacting a firm's customers and the responsibility of two or more functions, whether internal or external to the firm, are concluded. The five defined flexibilities include: product flexibility or the ability to customize product to meet specific customer demand; volume flexibility or the ability to adjust capacity to meet changes in customer quantities; new product flexibility or the ability to launch new or revised products; distribution flexibility or the ability to provide widespread access to products and responsiveness flexibility or the ability to respond to target market needs. Raising the flexibility of supply chain is an efficient and economical way for enterprise to cope with fluctuations and minimize the influences caused by emergencies.

During the occurrence of emergencies, core enterprises in supply chain utilize information technology to establish information sharing online trading system for distribution enterprises and

downstream customers. The information sharing platform joins downstream customers and upstream suppliers into the supply chain management system and equips downstream customers and upstream suppliers with functions such as online order, new product inquiry, information feedback, process monitor, account settlement and sales promotion. In the mean time, core enterprises can target at downstream customers of different scales and set up appropriate services on the basis of information platform so as to promote the sales and services for customers. Through information platform, upstream suppliers can join resilient supply chain management system. When emergencies happen, the platform can perform arrangement and analysis on inventory and sales data and assist in the realization of automatic remind of order quantity, variety and distribution in resilient management system. In addition, enterprise can realize trans-regional and multi-layer distribution management with the utilization of information technology. The overall integration of operation data of enterprise and the predication of risks of supply chain can be also actualized.

A Concept framework for achieving SCR

In the way of taking measures concretely, the supply chain is supposed to equip capabilities which are able to exert the resilience. We would restate these essential capabilities briefly through reviewing some study outcomes so far.

Figure 1 - A conceptual framework for achieving SCR

In the figure 1, there are necessary capabilities for achieving SCR upside, and key points which represent supply chain vulnerabilities are lined up downside. As we mentioned in previous section, supply chain vulnerabilities are disclosed in accordance with internal and external interruptions of supply chain, so that barriers may interrupt operations of the whole supply chain and the recovery from supply chain disruptions. In response, with equipping essential capabilities for achieving SCR, it is possible to remove the supply chain vulnerabilities and promptly recover from emergencies and damages of the whole supply chain. In addition, it can be expected to evolve much superior situation.

THE NECESSITY OF SCR VIEWED FROM CASE STUDIES IN MANUFACTURING

INDUSTRY

The differences of respective correspondences after supply chain disruptions

Recently, emergencies happened frequently in the world, disasters such as massive earthquakes and tsunamis influence ordinary management of supply chains as significant problems. The two disasters - the 3.11 Great East Japan Earthquake (the 3.11 earthquake for short) and Thailand Floods happened sequentially in 2011 cutting off supply chains of Japanese companies miserably and inflicting great damage on regular management of supply chains. However, the catastrophe led to severe problems for many Japanese companies such as car maker Toyota, while for companies in US and Europe, effects have been minimal. American and European companies have generally suffered only small-scale and temporary disruption as a result of the 3.11 earthquake in Japan, executives and analysts notify people of emphasizing the resilience of global supply chains. Moreover, devastated Japanese companies reached 460 ones in Thailand. There are 260 companies of other countries devastated in Thailand though, Japanese companies are much greater than those.

If we draw a comparison only for Japanese companies during these two disasters, the damage caused by the 3.11 earthquake is sufficiently more serious than the one caused by Thailand floods. This not only can be explained by differences on sudden property, scale of disaster and so on. From the viewpoint of supply chain, it is obvious that the products and parts which can be produced alternately are majority. In contrast, in the event of the 3.11, there are many parts only can be produced in Kandon area, and the majority is critical parts for which alternate production cannot be conducted.

To compare the correspondences of Japanese and Western companies after supply chain disruptions, especially in manufacturing industry, we found underlying causes based on their respective production systems. Many Japanese companies, such as Toyota, adhere to implement JIT and conform to approaches such as Zero inventory and contracting with certain suppliers. In comparison, Western companies have constructed a structure in case of emergencies such as dispersion of suppliers and securement of parts in stock. Furthermore, Western companies have conducted modular production system thoroughly with standardization strategy consistently, whereas Japanese companies have emphasized integral production system in order to give differentiation first priority. That was why totally different correspondences emerge after supply chain disruptions respectively.

The decision making model for achieving SCR

In order to achieve SCR, the expected capabilities are generally unanimous for both Japanese and Western companies. However, according to fundamental differences of production systems in manufacturing industry, they encounter different supply chain vulnerabilities respectively, thus accompanying applicable operation strategies separately is indispensable. That is to say, the capabilities such as visibility and collaboration that we mentioned before are necessary for respective SCRs. However, Western companies conduct their operation strategies such as dispersion of multiple suppliers with standardization of parts and securement of certain inventory based on modular production system, whereas Japanese companies should have their own applicable operation strategies based on integral production system. Fujimoto (2011) states "Virtual Duplexing" and proposes to equip portability as an essential capability for achieving SCR. In other words, it is crucial to ensure design information be transferable from devastated processes to other processes, and it is possible to implement emergency evacuation constantly.

Furthermore, in addition to portability, in order to achieve SCR in integral production system, it is essential to ensure the resources imperative to production in great shape, and to innovate production processes so that they can be set priorities. The most prioritized process should be "black boxed", and the ways to rapidly conduct protective measures for the process when emergencies happen have to be contrived. Likewise, in order to thoroughly ensure the critical information of recovering production processes, clouding the whole system should come to realization.

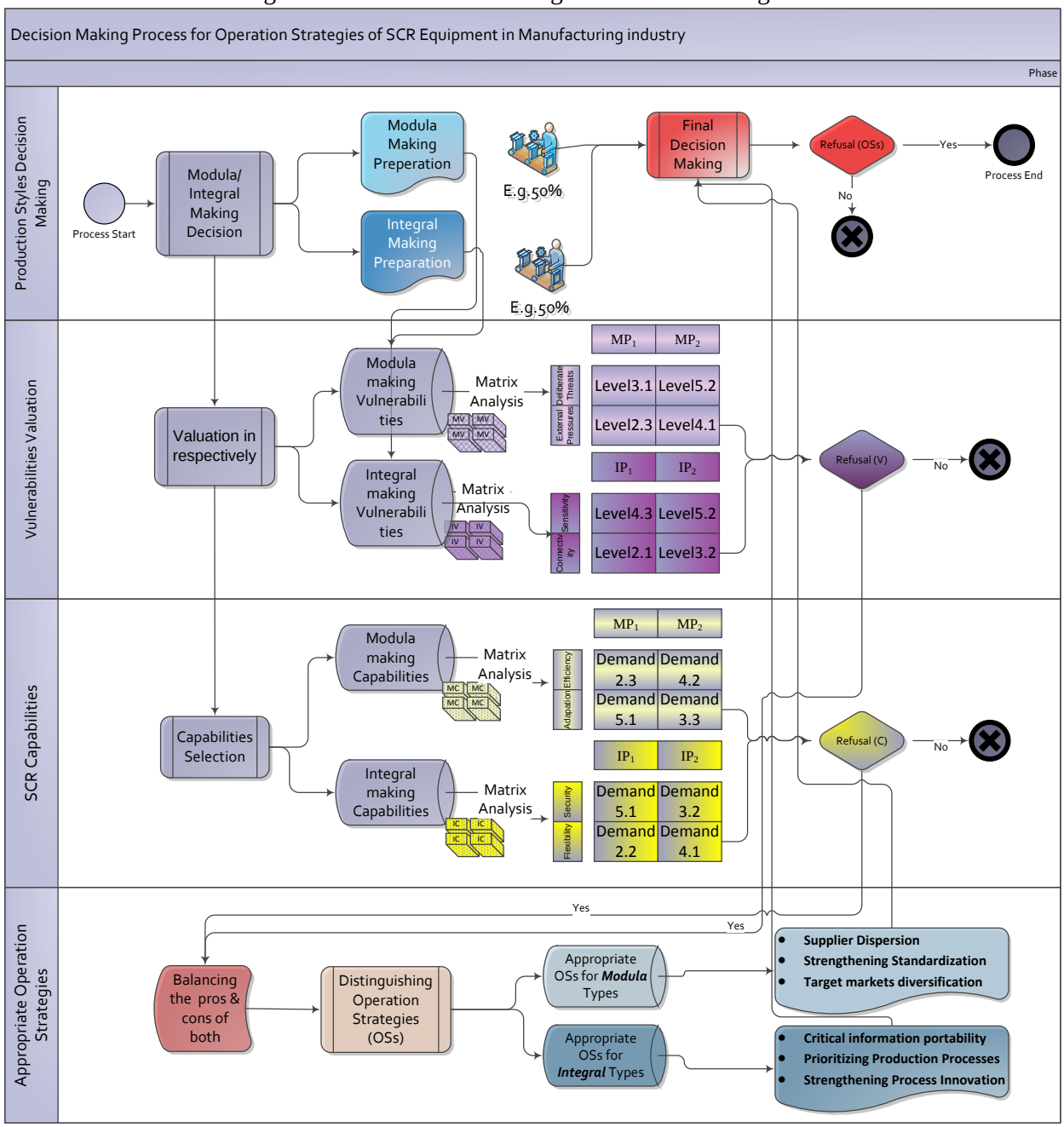
In order to describe the procedures more clearly for achieving SCR especially in manufacturing industries, we provide a decision making model as following (as shown in Figure 2) which could be divided into 4 stages: first of all, on the Production Styles Decision Making stage, the ratio between module and integral production systems for the company or the whole supply chain's products and parts, should be estimated. Secondly, on the Vulnerabilities Valuation stage, according to the decision making of the previous stage, all of related vulnerabilities will be valuated. At the same time, based on the different production patterns, the capabilities selection stage will be promoted on the Capabilities Selection stage. In the last stage, both of module and integral patterns' pros and cons will be balanced. Finally, consider the company or the whole SC's allocation of business resource such as budget, we have to make the final decision and define final operation strategies.

Practitioners should investigate the vulnerabilities which they have to face and evaluate them by 2 axes which time and consequence. At the same time, they also should to select which capabilities they really need. Through these procedures, companies can comprehend what kinds of vulnerabilities they need to face and make a priority list for equipping essential capabilities to build up their resilient supply chain. Therefore, they can anticipate the loss when they suffered damages generated by vulnerabilities and cognize which capabilities they need to equip and estimate how many investments they need to ensure on each essential capability.

Furthermore, for supply chains in manufacturing industries, practitioners also need to distinguish which production processes are aimed at integral products or modular ones and calculate a clear ratio of two types of products or parts. Thus, they will be clearer regarding which vulnerabilities they have to face and which capabilities they need to emphasize and so on. Accordingly, companies will obtain the entire picture about their supply chain and can make balanced countermeasures between vulnerabilities and capabilities for achieving SCR.

In the last place, companies will make a suite of practical operation strategies based on the balanced countermeasures. For instance, when the supply chain mainly engages in modular products, they will choose the strategies such as Supplier Dispersion, Strengthening Standardization, and Target markets diversification. In contrast, when the supply chain will continues to engage in integral products, they have to challenge more difficult conditions and Critical information portability, Prioritizing Production Processes and Strengthening Process Innovation will be their best choices for achieving their SCR. In addition, for the accomplishment of it, it is necessary to convince all key suppliers to conduct the same strategy as well and the philosophy of process innovation should be reflected on the production engineering thoroughly.

Figure 2 – The decision making model for achieving SCR



CONCLUSION

In this paper, first of all, we follow previous researches related to the theme through organizing and analyzing topics of Emergency, Supply Chain Risk, and Resilient Supply Chain sequentially and systematically. With the review and understanding on the related concepts of Supply Chain Resilience, we conclude a suite of fundamental and common key points in order to establish Resilient Supply Chain. Furthermore, we derived a feasible conceptual framework concurrently so that it would be clearer how to achieve Supply Chain Resilience basically. And then, we focus on the manufacturing industries of Japan and several other counties during the March 11

earthquake in Japan and Thailand floods in October, 2011 to compare their supply chains' resilience and their responses afterwards. By means of analysis on the differences, we summarized two typical supply chains in terms of their sourcing and producing operations and deduced two contrary suites of operation strategies. At last, on the basis of the essential capabilities and appropriate operation strategies as we mentioned above, we proposed a comprehensive decision-making model in order to guide a suite of more explicit methodologies for achieving SCR.

REFERENCES

Arhipova, N.I. and Kulba, V.V. (1998) "*Emergency management*," Russian State University, Moscow.

Burkholder, Brent and Toole, Michael (1995) "Evolution of complex disaster", National Emergency Training Center, National Emergency Training Center, pp.1-4.

Christopher Martin and Helen Peck (2004) "The Five Principles of Supply Chain Resilience," *Logistics Europe*, Vol. 12 No. 1, pp.16-21.

Clausen, Jens; Jesper Larsen; Allan Larsen; Jesper Hansen (2001) "Disruption Management-Operations Research between planning and execution", *OR/MS Today*, Vol.28 No.5, pp.40-43.

Fildes, R and Kingsman, B. (2011) "Incorporating demand uncertainty and forecast error in supply chain planning models", *The Journal of the Operational Research Society,* Vol. 62 No. 3 , pp.483-500.

Fujimoto, T (2011) "Be entrenched in 'devastated mind', don't lose 'competitive logic'", *Nikkei Information Strategy (in Japanese)*, September 2011, pp.30-31.

Holsapple, C. and Jin, H. (2007) "Connecting some dots: e-commerce, supply chains, and collaborative decision making", *Decision Line,* Vol. 38 No. 5, pp.14-21.

Jack G. A. J. van der Vorst and Beulens, Adrie J. M. (2002) "Identifying sources of uncertainty to generate supply chain redesign strategies", *International Journal of Physical Distribution & Logistics Management*, Vol. 32 No. 6, pp.409-430.

Jüttner, U., Peck, H., Christopher, M. (2003) "Supply chain risk management: outlining an agenda for future research", *International Journal of Logistics : Research & Applications*, Vol. 6 No. 4, pp.197-210.

Lummus, Rhonda R, Duclos, Leslie K, Vokurka, Robert J, (2003) "Supply Chain Flexibility : Building a New Model", *Global Journal of Flexible Systems Management,* Vol.4 No. 4, pp.1-14.

Menshikov, B.B. and Shvirajev, A.A. (2003) "*Hazards, chemical objects and technological risk*," Lomonosov University, Moscow.

Peck, H. (2006) "Reconciling supply chain vulnerability, risk and supply chain management", *International Journal of Logistics: Research and Applications,* Vol. 9 No. 2, pp.127-142.

Pettit, Timothy J; Fiksel, Joseph; Croxton, Keely L.(2010) "Ensuring supply chain resilience: development of a conceptual framework", *Journal of Business Logistics,* Vol. 31 No. 1, pp.I-VII.

Renaud, Richard and Phillips, Sarah (2003) "Developing an integrated emergency response program for facilities: The experience of Public Works and Government Services Canada", *Journal of Facilities Management*, Vol. 1 No. 4 , pp.347-364.

Simon, P., Hillson, D. and Newland, K. (1997) "*Project Risk Analysis and Management Guide (PRAM)"*, Association for Project Management, Norwich.

Sitkin S.B. and Pablo A.L. (1992) "Reconceptualizing the determinants of risk behaviour." *Acad Management Review,* Vol .17 No. 1, pp.9-38.

Wahle, T. and Beatty, G. (1993) "Emergency management guide for business & industry: a step-by-step approach to planning, response and recovery for companies of all sizes", *Federal Emergency Management Agency (FEMA)*, Washington, DC.

Zsidisin G.A., Ellram L.M., Carter J.R. and Cavinato X. (2004) "An analysis of supply risk assessment techniques" *Int J Phys Distrib Logist Mngt* , Vol. 34 No. 5, pp.397-413.