Improvement of Resilience on Smart Supply Chain

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Ⅰ. Introduction

The origin of supply chain informatization dates back to the 70s of last century. As the first generation of supply chain information platform, EDI emerged and settled the problem of cross-system information exchange and process control. When it comes to the 80s, with the establishment of supply chain concept, information exchange had been attached more and more importance for the integration management from upstream to downstream. In the 90s, after discovering the bullwhip effect developed in supply chain, researchers and practitioners started to realize that enterprises not only have to possess channels for information exchange, but also need the platform for sharing information. After 21st century, through the emergence and improvement of systems such as ERP, WMS and TMS, demand orientated supply chain operation was gradually consented by business operators. In the mean time, supply chain of types such as pull type and push + pull type (Simchi-Levi, et al., 2007) had also been confirmed in succession.

Nowadays, with the expanding of information and development of network technology, informatization and transformation of supply chain are confronted with new challenges. As the advent of new technologies such as mobile communication, big data, social networking sites, cloud computing brings strikes and impacts to enterprises successively, the internet of things came into being, furnishing enterprises and supply chain executors with new inspirations and solutions. Furthermore, supply chain informatization is propelled to a new step, rendering smart supply chain, which used to be regarded as an unreachable target by supply chain executors be actualized virtually.

The concept of Smart Supply Chain was initially put forward in a report written by IBM in 2009 and it is called "The Smarter Supply Chain of the Future", which enumerates numerous problems confronted by supply chain enterprises from industrial point. The faster business environment transfers, the more diversified and complicated supply chain demands are. When traditional supply chain operation modes are incompetent to settle the challenges faced by enterprises, the establishment of Smart Supply Chain will assist enterprises to apply uncertainty flexibly so as to enhance their competitive and realize the stable and sustainable development.

As a matter of fact, before the advent of Smart Supply Chain, concepts such as Smart Electric Power System, Smart Environmental Protection and Smart Logistics have already come out in succession. In manufacturing industry, especially, being represented by iMake, the concept of Smart Production was proposed back in the 70s of last century.

Nevertheless, what was stressed at that time was the utilization of robots and the automation during manufacturing process. Afterwards, along with the emergence of intellectual products including intelligent electric appliances, intelligent medical equipments, and etc, intelligent tools which can make a judgment and choice for human became prevalent, intelligent of that time not only indicated the automation of process, but also the combination of automation and informatization.

When it comes to the Internet era of today, merely adopting automatic collection technology to make a judgment and choice has become far from enough. Apart from that, connecting with network and applying it to transfer collected information to data process and service center (abbreviated as data center) and making real-time adjustment, it is such a combination of dynamic management, control and selecting can be called intelligent of this era. In other words, today's intelligent manufacturing has to embody the characteristic of automation, informatization and networking.

What represents the intelligent management of supply chain (iSCM) includes: 1, whole process of management; 2, centralization of information; 3, dynamics of system.

Whole-process of management is to fulfill the principle of integration and outsource upheld by supply chain. On one hand, information system of downstream vendor needs to be connected; purchase and supply system of upstream needs to be connected. On the other hand, supply chain system inside enterprise has to be unblocked for the whole-process management.

Centralization of information is to realize the new demand of enterprise internal integration. Based on the consideration of efficiency and vitality, data is orientated to adjust the contradiction between resource management and decision making authority of the whole enterprise so as to elevate the level of resource management and optimization.

Dynamic of system is to take identifying information and spatial-temporal information as the information source of supply chain dynamic management in order to raise real-time adjusting ability, which means it is possible to make judgment and adjustment at any time in accordance to external changes and satisfy the requirement from complicated and rapid developed external environment for enterprises. The basis of dynamic of system is locating information, so when enterprises contemplate how to achieve the above characteristics ought to be possessed by smart supply chain, the best choice for them is the integration of ever maturer Internet of Things and cloud computing.

Ⅱ. The Architecture of Smart Supply Chain

1. Technical architecture of Internet of Things

Internet of Things (IoT) is the internet connecting things. In detail, it is based on conventional agreements, through information sensing equipment concluding Radio-frequency identification (RFID), smartsens, GPS, laser scanning technology to connect things with internet for informationexchange and communication, realizing intelligent recognition, location, supervision,tracking and management (Zelbst et al., 2010).

Network architecture

Network architecture of IoT is constituted by Sensing Layer, Network layer and Application Layer.

Being similar to sense organs of human being, sensing layer is composed by sensors, sensor gateways, digital tags and RFID readers, which enable it to acquire information of objects at any time as the origin of object identification and information collection in IoT.

Network layer is responsible for the delivery of information acquired by Sensing Layer and it is formed by private networks, internet, wired and wireless communication networks and network management system.

Application Layer is the interface between IoT and users. After being analyzed and processed through cloud computing, information captured by sensing layer provides users with identification, location, supervision, tracking and management of objects in accordance with demands of different industries, realizing smart utilization of Internet of Things.

In practical application, RFID has been applied in product logistics tracking, product counterfeit proof, and etc; GPS technology has been applied in location, tracking, detection

and networking of objects; WSN (Wireless Sensor Network) has been utilized for monitoring logistic equipment and warehouse surroundings (Sánchez et al., 2012).
Key technologies of IoT is indicated in Table 1.

Tab.1 Key technologies of Internet of Things

Name of technology	Brief Introduction
Coding Technology	Codes for differentiating enterprises, products and series.
RFID Technology	Wireless radio frequency identification technology. During high-speed mobilization, it is possible to read information saved by tags through transmission of materials. Mainly be applied in product follow-up and mobile payment.
Sensor Network	Wireless network formed by tiny nodes according to rules, being ablet o carry out information collection, judgment and upload.
M2M Technology	Assembly of technologies for enhancing communication and network capacity of machines and equipments.

2. Technical architecture of cloud computing

Cloud computing is a mode of making on demand visits to configurable and shared computing resource pools which are based on networks. Concluding network, server, storage, application and service, these configurable and shared resource pools can be provided or released through the most economically efficient management or interaction with service providers (Ferguson, et al., 2011).
After the advent of computing concepts such as distributed computing, grid computing, utility computing, P2P computing and market-orientation computing, cloud computing was presented by Google CEO Eric Schmidt based on the fully development and popularization of internet (Schrodl, et al., 2012).
Key technologies of cloud computing are presented in Table 2.

Tab. 2 Key technologies of Cloud Computing

Name of Technology	Brief Introduction
Virtualization Technology	Principal technical basis for realizing cloud computing. Being capable of blocking transformation caused by diversifications of physical equipments.
Mass data distributed storage technology	Adopt redundance storage technology to guarantee the reliability of stored data.
Mass data management technology	Process and analyze large dataset and provide efficient services to users.

3. Through IoT and Cloud Computing Technology to realize Smart SC

The technology of IoT was applied in supply chain management long time ago. What restraints big scale application of the new technology is how to process the huge amount of information collected by Sensing layer of IoT and to actualize intelligent control on objects through analysis on collected information. The advent of cloud computing solves the technical bottleneck of IoT and accelerates massive application of the technology of Internet of Things.

All the links in supply chain are source of data. In detail, products with RFID tags or all the information regarding changes of position, amount and property of parts will be recorded in tags by terminal device, in the meantime, be uploaded to database located at cloud through network. System can monitor all the steps throughout production in accordance to predetermined conditions so as to guarantee the security and order of production.

Enterprises on supply chain can apply the mode of mixed cloud. To be specific, core data that enterprise must keep confidential be processed by private cloud; data and operations that are related to supply chain coordination be processed by public cloud. Based on public cloud, data base which can be shared by all the members on supply chain is built up, and an appropriate link between private cloud and public cloud is establish for the coordination of data flow in supply chain.

Technology of Internet of Things applied in supply chain mainly plays the role of product real-time tracking and product process efficiency acceleration, while cloud computing technology primarily conducts the storage and process of mass information gathered through technology of IoT.

If we divide iSC throughout practical operation into three layers to construct. These layers can be set up as Sensing layer, Interconnected layer and Application layer.

Sensing layer

Enterprises can promptly sense all kinds of information that is related to them through sensing network. Sensing network aggregates information from various enterprises, users, procedures, devices and systems. At the same time, sensing network serve for diverse

Figure. 1 Layer architeture of iSC

Application Layer	Real-time visible monitor	Production whole-process tracking	Information centralized management	Design materials on spot	Electronic Commerce Platform	Spatial Mapping
Interconnected layer	Data Center		Information Center		Internal Network	
	Cloud computing platform					
Sensing Layer	RFID Tags		Access Gateway		Intelligent Terminal	
	RFID Sensor		Intelligent Device		Motion Sensing Device	

enterprises, enabling the range of information that enterprises sense extends and the depth of information deepens. The scope and accuracy rate of information search ultimately be enhanced to a great extent.

Interconnected layer

Enterprises can utilize internet, wireless network and Internet of Things to actualize the connection of enterprise internal and external information. By doing so, precise and prompt satisfaction of user demands, optimum use of resources, maximum work efficiency, minimum waste, energy saving and emission reduction can all be achieved successfully.

Application layer

With the establishment of relationship between knowledge and the relationship between knowledge and people, enterprise knowledge network becomes complete and ordered, and innovation network becomes more intelligent. The more innovation network is applied, the smarter it becomes. Innovation network will automatically propel the information and knowledge needed throughout innovation process, in the meantime, massive repetitive work during innovation process is automatically finish by innovation network.

The establishment of iSC enables enterprises and even the whole supply chain to react immediately to complicated and variable market, strengthening the adaptability of supply chain. Meanwhile, industry sharing of information is boosted by the acceleration of enterprise informatization and networking.

For IoT, for the movement and circulation of objects in internet, the incessant development of data transfer technology, trading market has to be constructed, and software system has to be developed. We need to attach more importance to the network services which presents Internet of Things with communication function. In the meantime, standardized services also need to be equipped, with standard setting organizations such as CEN, ISO and ETS play a crucial role.

Real-time dynamic indicators of supply chain, such as inventory analysis, customer analysis and data of this sort, have to be transferred to server through network after the detection of sensor. Data of huge amount are delivered to centralized cloud computing data center of IoT. From here, data and information from various channelsare collected through cloud computing. With the assistance of business analysis software,information al strategies that ignites a great profit are extracted.

The application of IoT can improve the visibility of supply and information transparency of supply chain management (SCM). With the fully utilization internet and various technologies, RFID technology can effectively recognize tagged products in batch and acquire accurate product information. Products from raw materials, semi-finished products to finishedproducts are conducted real-time supervision throughout the processes of delivery, storage, distribution, sales and recycling. By doing so, product information can be acquired at any time, automation degree can be raised, and rate of error can be diminished, ultimately, transparency of SCM comes true.

Agility and integration of SCM and compact conformity of supply chain links are also realized through IoT. Supply chain information system based on IoT can coordinate and integrate internal and external production activities of enterprise. Through the execution of automatic production line, production situation is acquired timely. Enterprise can make replenishment information on the basis of manufacturing schedule so as to realize the balance of assembly-line, achieving better flexibility of production. High level agility and integration of SCM incessantly lower the inventory of enterprise and supply chain channel, productivity is also elevated without cease.

Ⅲ Supply Chain Resilience

During the construction of iSC, not only should we consider the issues mentioned before, such as information sharing, standardized service, excellent cost-effectiveness, visibility, transparency, agility and integration which have been studied and carried out as primary topics of supply chain, but also should we strive to resolve the fragility problem of supply chain which currently agitates enterprise most.

Advanced management modes such as globalization purchasing pattern, JIT production, and concepts of precise and agile supply chain have been applied and promoted in numerous enterprises. Though efficiency of supply chain operation is enhanced, risk coping capability of supply chain is weakened in the meantime. Upon events that affect regular production occur at any link of supply chain, upstream and downstream enterprises will be influenced immediately, further than that, the impact will spread to all the member enterprise on supply chain.

Ultimately, partial invalidation event occurred in joint enterprises will disrupt ordinary operation of supply chain and even cause the termination of supply chain. Accordingly, operation cost of supply chain will rapidly raise, and customer service level will be lowered. Examples of this sort arise from time to time recently, for instance, the 3.11 Great East Japan Earthquake of 2011 and the severe flood occurred in Thailand in the same year seriously struck enterprises. In the meantime, due to the cascade effect of supply chain, countless big-scale manufacturing enterprises suffered a blow more or less.

Integrating with the managerial theory and technique of network technology and modern SCM such as IoT and cloud computing, iSC is a comprehensive and integrated system of technology and management which is constructed in or among enterprises for the intelligence, networking and automation of supply chain. iSC of futurenot only can effectuate the better efficiency of supply chain, but also the robustness of supply chain operation. The robustness of today's supply chain is not merely embodied in the attainment of crisis intervention of supply chain enterprises, but also is reflected in its self-healing ability, in other words, it is an ability reflecting the degree of completionof Supply Chain Resilience (SCR).

1. The research on SCR

The research on SCR started from the beginning of 21st century. 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.

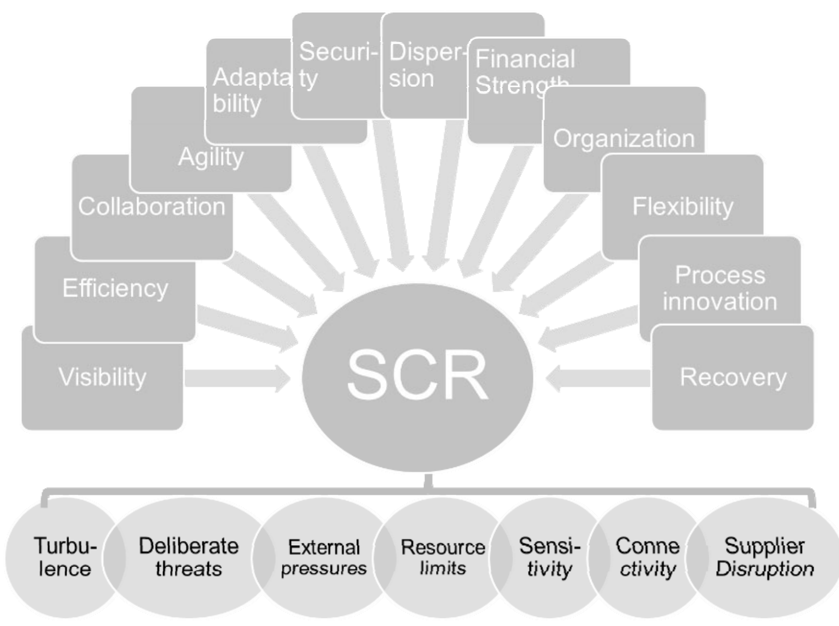
During the occurrence of emergencies, core enterprises in supply chain utilize information technology to establish information sharing online trading system for distribution enter prises and downstream customers. The information sharing platform joins downstream customers and upstream suppliers into 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.

2. 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.

In the figure 2, 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.

Figure. 2 A conceptual framework for achieving SCR



3. Differences in Response to Supply Chain Disruptions

Emergencies occur frequently, and disasters such as massive earthquakes and tsunamis cause significant problems for the management of supply chains. In 2011, two disasters happened sequentially: the 3.11 Great East Japan Earthquake and floods in Thailand, which cut off the supply chains of Japanese companies, inflicting great damage on regular management of supply chains. These catastrophes led to severe problems for Japanese companies such as Toyota, while for companies in US and Europe, the effects were minimal. American and European companies generally suffered only small-scale and temporary disruptions as a result of the 3.11 earthquake in Japan because their executives and analysts emphasized the importance of resilient global supply chains in addressing such events. In Thailand, 460 Japanese companies were affected by flooding, compared to 260 companies from other countries.

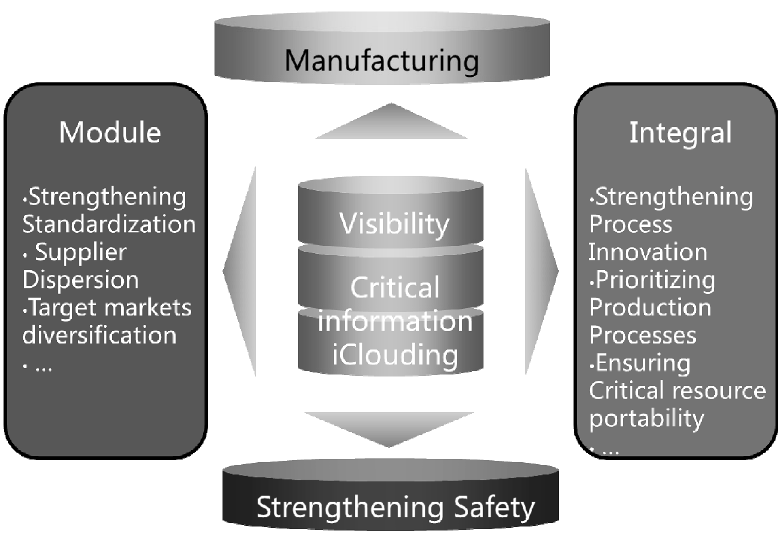
For Japanese companies, the damage caused by the 3.11 earthquake is significantly more serious than that caused by the floods in Thailand. This can be explained not only by the differences in properties and scale of disaster, but also by the fact that the majority of the products and parts produced in Thailand can also be produced by alternate sources in alternate locations, unlike the parts produced in Japan.

4. Applicable Operation Strategies for Different Production Systems

The responses of Japanese and Western companies to supply chain disruptions, especially in the manufacturing industry, can be compared in terms of the underlying aspects of their respective production systems. Many Japanese companies, such as Toyota, adhere to the implementation of JIT and conform to approaches such as zero inventory and contracting out to certain suppliers. In comparison, Western companies have constructed a structure that prepares them for emergencies such as the dispersion of suppliers and securing of parts in stock. Furthermore, western companies consistently maintain modular production systems thoroughly with standardization strategy, whereas Japanese companies focus on integral production systems in order to prioritize differentiation. For these reasons, completely different correspondences emerge after supply chain disruptions.

The capabilities needed to achieve SCR are uniform for both Japanese and Western companies. However, as there are fundamental differences in the production systems employed in manufacturing industry, different supply chain vulnerabilities are encountered, meaning that applying applicable operation strategies separately is indispensable. This is to say, the capabilities mentioned above, such as visibility and collaboration, are necessary for respective SCRs. However, Western companies conduct their operation strategies such as the dispersion of multiple suppliers with standardization of parts, and securement of certain inventory based on modular production system, while Japanese companies should have their own applicable operation strategies based on integral production system (see Figure.3). Fujimoto (2011) states "virtual duplexing" and proposes portability as an essential capability for the achievement of SCR. In other words, it is crucial to ensure that design information is transferable from devastated processes to other processes and that it is possible to implement emergency evacuation constantly.

Figure. 3 Selection of appropriate operation strategies



In order to achieve SCR in integral production systems, it is essential to ensure that the resources imperative to production are properly maintained and that production processes are innovative and operate with priorities in mind. The most highly prioritized processes should be "black boxed," and methods for rapidly conducting protective measures in response to emergencies must be devised. Likewise, to ensure that critical information for production processes can be recovered, clouding the whole system should be realized.

Ⅳ Establishing A Smart Supply Chain with Enhanced Resilience

To sum up, through the conduction of continuous online self-assessment, resilient supply chain predicts eventualities and occurrent events during supply chain operation and adopts measures to restrain or rectify promptly. To diminish the discontinuity between supply and service of production to the maximum, applying data obtaining technique fully and implementing decision support algorithm are imperative. By doing so, discontinue frequency and duration of product supply will be decreased, and production and supply will be normalized after the occurrence of discontinuity. In essence, resilience is the immune system of smart supply chain and embody the most substantial characteristic of smart supply chain.

Through the relation table of the degree of smart and resilience below, we illustrate the mutual effect between them and their influence on supply chain.

The two dimensions on the graph are Resilience grade (x-axis) and Smart grade (y-axis) that we believe represent the core differences between, say, high-tech electronics and consumer chemicals. These differences are extremely instructive when considering Smart supply chain and will drive different supply chain resiliencies. In detail:

- Engineering-oriented manufacturers will focus intelligence efforts and resiliency improvement both on their supply chain.

- Technology-oriented manufacturers will focus intelligence efforts and promote standardization of products and parts and decentralization in order to provide against emergency.

- Asset-oriented manufacturers will focus on resiliency improvement on their supply chains and keep to grasp the basic standard of the Smart grade in the industry.

- Brand-oriented manufacturers keep to grasp the basic standard of both and gradually strengthen their weak points on respectively.

The purpose of this examination is to suggest to the top management persons of enterprises to "find themselves" on the Figure 4. Do you indeed experience delay of Smart SC establishment or resiliency improvement (some fortunate businesses do not) and do those delays drive problems that are manifested through your supply chain?

Figure 4. The blending effects of iSC and SCR

High	The degree of Smart	*Technology-oriented manufacturers* (Electronics, semiconductor) Focus on intelligence efforts, promote standardization and decentralization	*Engineering-oriented manufacturers* (automotive, aerospace, and defense) Focus on both of intelligence efforts and resiliency improvement
Low		*Brand-oriented manufacturers* (consumer products) Focus on keeping to grasp the basic standard and strengthening their weak points	*Asset-oriented manufacturers* (chemicals, metals, paper) Focus on resiliency improvement and keeping to grasp the basic standard of the Smart grade
		The degree of Resilience	
		Low	High

V Conclusions

With the establishment of highly advanced and sophisticated Smart SC, enterprises are able to improve their competitiveness, and meanwhile, effortlessly overcome the issues which cannot be resolved under the traditional supply chain operation. When we intensely show our concern to the construction of Smart SC, the fragility of supply chain caused by continuous pursue of high efficiency cannot be neglected. Resilience resembles to the immune system of supply chain, the more we pay attention to it, the more robust and stable the supply chain is. Henceforth, through the synergy effect of the acquired experience during the enhancement of resilience and the accumulation of information and network technology which progresses during the establishment of supply chain, operation of supply chain will turn out to be more simple and secure. Meanwhile, improvement of customer satisfaction degree will also benefit from it.

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