Development of a Prescription Framework for Supply Chain Risk Management: Cases of Asian MNCs

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ABSTRACT

In this paper we present the criteria for classifying types of supply chain risks and effective prescriptions for each risk type via case studies of global companies based in Asia. In the study, the level of impact and duration of risk are used as criteria for classifying risk types. The classification of supply chain risks and the presentation of countermeasures for each risk are conceptualized as a risk diagnosis and prescription matrix in the same way a doctor prescribes a prescription according to the patient's disease. From the company examples, we find a common pattern of risk response strategies depending on the impact and duration of supply chain risk.

The case companies quickly analyze the cause of risk and respond immediately as a risk acceptance strategy when the impact is low, and the duration short. On the other hand, when impact is high, and the duration short, substitute raw materials are considered, or production sites moved temporarily to nearby location from the perspective of risk avoidance strategy. New suppliers and new technologies are developed for complete replacement for risk mitigation when the duration of risk is long, and the impact low. For reengineering the supply chain new demand sources are developed, and diversifications of suppliers and production sites are pursued from the perspective of risk sharing when the risk duration is long, and the impact high. Novelty of our study is in considering the duration of risk as a variable in strategy establishment, unlike previous studies which were based solely on the source, probability, and impact of risk in establishing risk management strategies. This study has enormous academic and practical implications as it classifies risk types based on the impact level and duration of risk and presents a risk

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prescription matrix for managing each risk type.

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1. Introduction

To maximize the overall performance of a supply chain network, it is imperative that performance of all the participants in the supply chain network is optimized (Simchi-Levi et al., 2021). What makes overall optimization of supply chains difficult is the presence of uncertainties in the supply chain, uncertainties that lead to realized risks. Therefore, many researchers and practitioners have paid special attention to supply chain uncertainty and risk management.

To successfully cope with supply chain risk, it is necessary to first explore and define the various forms of uncertainties. The uncertainty classification criteria should be clear and facilitate strategic response at the corporate level. Response in supply chain according to the type of uncertainty can be called supply chain risk management (Park et al., 2015).

The main objective of this research is to present criteria for classifying types of supply chain risks and propose effective prescriptions for each risk type using examples of global companies operating in Asia. To this end, we review the literature related to supply chain risk management and classify the types of supply chain risks based on the impact and duration of risk. The classification of supply chain risks and the countermeasures for each risk are then conceptualized as a prescription matrix. To validate the proposed risk prescription matrix, cases of leading global companies with origins in Asia including Toyota, Nissan, TDK, Hitachi, Samsung Electronics, SK Hynix, and LG Display are reviewed.

As we study the response of the companies, we find a common pattern of risk response. The companies quickly analyze the cause of risk and respond immediately when the disruption impact is low, and the duration short, employing a risk acceptance strategy. If the impact is high and the duration short, the companies deploy what may be termed risk avoidance strategy, by considering alternative raw materials or temporarily relocating the production site. On the other hand, when the disruption duration is long, but the impact low, new suppliers and new technologies are developed for complete replacement to mitigate the risk long-term. However, if the disruption duration is long and the impact high, companies reengineer their supply chains by developing new sources of demand and diversifying suppliers and production sites with the objective of spreading the risk.

As this study was being conducted, COVID-19 pandemic spread throughout the world. COVID-19 pandemic is a once in a century type of disruption which not only lasts a long time, but also has a deep and widespread impact. It has disrupted the long-standing Global Value Chain (GVC) for supply networks. Over the last couple of years, COVID-19 has sparked a debate in academia about supply chain risk management (Gebhardt et al., 2022; Rajak et al., 2022) the consensus being that the pandemic has exposed the vulnerabilities of global supply chains, and going forward how best to restore the broken supply chains (Moosavi et al., 2022). After COVID-19 outbreak, companies have begun to pay attention to long-term response strategies (Gebhardt et al., 2022) and to seek technology-based solutions (Molinaro et al., 2022). In terms of operations, there is a need for stronger relationships between companies and suppliers through greater empowerment than in the past (Ozdemir et al., 2022), and that pre-allocation of inventory is positive for the company's performance (Rozhkov et al., 2022). Companies have also begun to localize the sourcing of key materials to secure inventory and improve supply chain resilience (Gatenholm and Hallórsson, 2022). In this regard, this study also considers COVID-19's impact on global supply chains.

One of the salient features of this study is the consideration of risk duration as a variable in strategy establishment, unlike previous studies which only consider the source, probability, and impact of risk in establishing risk management strategies. Our study has both academic and practical implications as we classify risk types based on the impact level and the duration of risk, based on real-life examples of Asia-based global companies, and present a risk strategy prescription matrix for each type of risk.

2. Background

2.1 Uncertainty and Risk in Supply Chains

Risk in a business environment can be defined as the impact of uncertainty on the achievement of objectives (ISO Guide 73, 2002). Uncertainty (about an event) refers to the fact that it is impossible to know whether the event will occur in the future (Hetland, 2003), whereas risk refers to the state where possibility of each event can be given. Therefore, risk can be defined as evolving from a state in which the probability of an event occurring is uncertain to a state in which the probability of an event occurring is significantly increased.

From this point of view, risk in supply chain can be simply defined as "the possibility and impact of mismatch between supply and demand" (Trkman and McCormack, 2009). The goal of supply chain management is to optimize the performance of all the participants by managing the flow of goods and information from the supply of raw materials to the final consumer. Therefore, the concept of supply chain risk can be more specifically defined as the interruption of the flow of goods and information arising from internal and external uncertainties that make it difficult to efficiently predict demand and manage supply chain networks (Knight, 1965).

As risk is related to the impact of an (uncertain) event, supply chain risk management should aim to minimize the negative consequences of the impact. If the response to risks facing the supply chain is not prompt, the risk may increase. Thus, uncertainty can interact in an unexpected way, leading to a greater risk (Perrow, 1999). For example, if a production line is damaged by a natural disaster, to alleviate supply disruption, the customer can move the order to an alternate manufacturer, perhaps creating a new bottleneck elsewhere in the supply chain. At this time, an unexpected increase in alternative transportation can also affect logistics. In fact, natural disasters disrupt not only manufacturing facilities, but also transportation infrastructure. As such, risks are interconnected and correlated with each other (Ackermann et al., 2007; Ivanov, 2020). Thus, the structure of the supply chain and the dependencies between the actors participating in the supply chain affect the risk propagation in the supply chain. The more dependent the participants in the supply chain, the higher the probability of risk occurrence and its consequent propagation (Perrow, 1999; Speier et al., 2011).

Previous researchers have mainly focused on the sources and drivers of risk as that is an important issue in establishing a response strategy to mitigate risk. Supply chain risk should be managed by establishing a strategy to subdivide it into environmental, network, and organizational risk factors, to assess the source of risk, identify negative consequences of risk, track drivers of risk, and finally mitigate the risk (Jüttner, Peck and Christopher, 2003). There is another view that splits supply chain risk factors into endogenous and exogenous factors (Trkman and McCormack, 2009). Endogenous factors exist within the supply chain and refer to factors derived from the market, such as customer preferences and demand, the price and cost structure, constant challenge from competitors, and technological factors arising from obsolescence. Exogenous factors exist outside of the supply chain and refer to discrete events with severe impact such as terrorism, epidemics, and strikes, and ongoing risks such as inflation, consumer price index, and commodity price fluctuations.

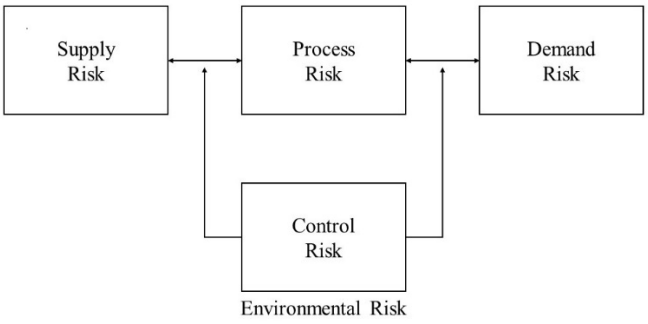

Figure1. Sources of Supply Chain Risk

The endogenous and exogenous factors of supply chain risk can be structured and identified as shown in Figure 1 (Christopher and Peck, 2004). Supply risk, process risk, and demand risk can be included in the category of endogenous risk. Supply risk occurs in the procurement of raw materials and parts, production operation, and logistics. These supply risks interact with process risks. For example, if a company readies the necessary manpower and equipment to produce a product within the schedule requested by the customer, but the raw materials and parts are not procured in a timely manner, production and supply are disrupted, leading to overall process disruption. Conversely, if a series of processes such as review and contract of parts for purchase cause schedule delays, it creates risks for suppliers of raw materials and parts. In this way risks in the supply chain influence each other.

Environmental risk (control risk) refers to exogenous risks caused by political, economic, legal, institutional, cultural, and ecological factors. The environmental risks affect the internals of a supply chain. In the global supply chain, when parts suppliers and producers are located in different regions and countries, uncertainty exists depending on the political situation of each country and changes in laws and regulations. In addition, economic factors such as exchange rates can act as risk by affecting production and logistics costs. The recent outbreak of diseases such as COVID-19 also has a devastating effect on the supply chain.

As described above, factors behind supply chain risk can be discussed from various perspectives. Regardless of the source of the risk, the characteristics of each risk are very different. Environmental causes, such as financial defaults of supply chain participants, or natural disasters that are extraneous to the supply network, have different attributes in terms of risk latency, risk occurrence probability, predictability, and severity (Scholten and Fynes, 2017). The implications from previous studies are that supply chain risk may be caused by environmental factors of the supply chain network or may occur from within the supply chain network, caused by one of the participants of the network. In this study, we propose to develop a prescription framework by looking at the risk responses of example companies operating in Asia, classifying risk types, and identifying the attributes of each risk type.

2.2 Supply Chain Risk Response Strategies

One of the necessary steps in the process of developing an appropriate prescription for supply chain risk management is to examine previous studies which have developed/proposed strategies for responding to supply chain risks. These studies can be divided into two types: one related to risk assessment and analysis, and the other related to risk prevention and post recovery strategies.

Assessment and analysis of supply chain risk is a precondition for establishing a risk response strategy (Christopher and Peck, 2004). A risk exists when a supply chain-related event is relatively probable and the associated impact and cost are likely to be incurred (Zsidisin et al., 2004). Since some risks can have serious consequences and others may not, companies need to evaluate the probability of occurrence of a risk and its impact (Cohen and Kunreuther, 2007). The probability of occurrence can be expressed in objective or subjective terms (Ritchie and Brindley, 2007b). Here, probability is used as a tool to measure the likelihood of a negative event occurring (Scholten and Fynes, 2017). As such, it is common to find, in previous studies, risk assessment and analysis being performed based on the likelihood of risk occurrence and the level of impact.

If a risk has a minimal impact on the business and the probability of occurrence is low, the vulnerability of the supply chain may be evaluated as low. The most important objective of assessing and analyzing the vulnerability of a supply chain to risk is to establish a proactive plan to reduce the likelihood of occurrence of a risk and reduce its impact (Spekman and Davis, 2004).

Risk avoidance is used when the organization cannot accept operating risk in a specific market, which is an environment risk, or cooperation with a specific supplier or customer, which is an example of network risk. A strategy that eliminates the types of events that lead to the risk reduces the probability of risk (Manuj and Mentzer, 2008).

Risk reduction and mitigation is a strategy aimed at reducing both the probability and consequence of an event that is likely to impact the supply chain (Manuj and Mentzer, 2008). Mitigation tactics take some action even before supply chain disruption to achieve organizational robustness (Tomlin, 2006). This requires information sharing, incentive coordination, risk sharing and corporate social responsibility (Chopra and Sodhi, 2004; Faisal

et al., 2006; Spekman and Davics, 2004).

Risk sharing or transfer is a strategy for moving some of the risk from one organization in the supply chain to another via a contract, such as outsourcing (Waters, 2011). This strategy can also be considered a way to disperse the impact across the supply chain so that an organization better able to manage the risk carries out the task, rather than the participants of the supply chain; another way to achieve this is to cover costs by using an insurance company. But this strategy does not eliminate or reduce the probability of occurrence and the impact. While insurance can cover the costs of supply chain disruption, it cannot mitigate the real disruption (Scholten and Fynes, 2017).

Risk reduction, mitigation, and avoidance can be used as proactive prevention strategies, while risk acceptance, sharing, and transfer can be used as a resilience strategy. These strategies are based on the premise that it is possible to evaluate and analyze the likelihood and impact of risk. However, in case of supply chain disruption due to ecological risks, such as natural disasters, it is almost impossible to predict the likelihood and impact of risks, so a different perspective of risk management is required.

Uncertainty in its extreme form refers to situations where there is a complete lack of information, knowledge, understanding, or awareness of the occurrence of a potential event (Ritchie and Brindley 2007a). Thus, it is necessary to accept the fact that not all risks can be predicted, controlled, or eliminated (Jüttner and Maklan 2011). Restoring disrupted supply chains complements traditional risk management processes by allowing firms to deal with uncertainties that can only be identified and predicted to a limited extent (Scholten and Schilder 2015). It is important for a supply chain recovery strategy to identify what happens when the supply chain is disrupted and to establish a mechanism to quickly restore the operating system (Waters, 2011).

In contrast to other risk factors, extreme natural disasters such as earthquake and tsunami are difficult to predict but have a huge impact on the supply chain. In such cases, strategies and processes are needed for rapid restoration of the supply chain; supply chain recovery strategies and processes should therefore be a part of the risk management process.

Risk management strategy focuses on managing, in advance, possible future uncertain events. A recovery strategy is activated when a disruption to supply chain occurs resulting in reduction in its performance. Thus, the risk management process should be replaced by a recovery process. If a risk management strategy consists of the processes of risk identification, quantification, evaluation, treatment, and monitoring, a recovery strategy should consist of the processes of disruption detection, reaction, recovery, and learning. The two strategies can be related across time in that the information on disruption collected in the learning phase, the last phase of the recovery strategy, can be used as input for risk identification, the first phase of the risk management strategy.

As described above, the response strategies for supply chain risk are divided into risk management strategy and recovery strategy. Risk management strategy can be said to be a proactive preparation strategy implemented through risk assessment and analysis, while recovery strategy can be said to be a strategy to recover from the disruption of the supply chain once the risk has manifested itself.

2.3 Framework of Risk Types

As we have seen so far, frameworks for evaluating and analyzing supply chain risks discussed in previous studies are mainly based on the likelihood of risk occurrence and the level of impact. These studies look at the issue a priori, by trying to predict risks that have not yet occurred. However, there are limits to predicting and mitigating risks in the real world. As disruptive events occur in supply chains despite risk prevention, what is important from the perspective of a company is understanding how to respond to risks that have already occurred and are currently impacting their supply chains. The purpose of our study is to present a response strategy that supply chain participants should choose for each type of risk, once a potential risk has manifested itself and is disrupting their supply chain. In this study, for classifying risk types, the impact level of risk is used as a primary criterion for risk assessment, while the duration of risk is used as an additional classification criterion.

The reason the duration of impact is used as the classification criterion in this study is that the risk may decrease or increase over time once a disruptive event has occurred (Ritchie and Brindley, 2007b). As more information

becomes available, the nature and scale of the risk can be updated, making the associated risk more amenable to address. On the other hand, if the resolution of risk is delayed and the duration is prolonged, the negative impact on the company's performance will increase. Therefore, if a risk-accompanied event is not quickly resolved but is prolonged, risk recovery tactics would need to be revised.

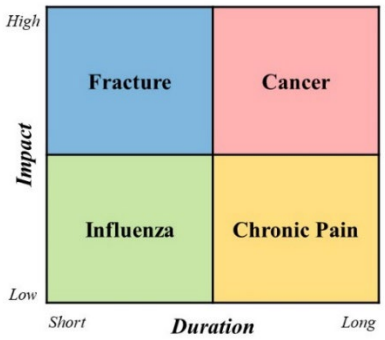

Fig.2 Risk Diagnosis Matrix

We present the risk diagnosis matrix as a conceptual framework for classifying risk types using risk impact level and risk duration (Figure 2). The risk diagnosis matrix is conceptualized along the same lines a doctor diagnoses a patient's condition: based on the level of the disease's effect on the human body and the duration of the disease's treatment period.

Each quadrant of the risk diagnosis matrix is described next.

Influenza: Influenza is a mild disease and can be cured naturally with only minor treatment, such as enough rest. Risks where the time required for resolution is short and the economic loss to the company small fall under this category.

Chronic Pain: Although chronic pain does not affect quality of life as much, it is a disease that requires long-term treatment, so a treatment to reduce the risk step by step is necessary. Similarly, if the time required for risk resolution is long, and the economic loss to companies small, the risk falls under chronic pain.

Fracture: Fracture greatly affects the human body due to its sudden incidence, and in some cases can lead to serious consequences that can be life-threatening. Similarly, if the level of damage caused by a risk is quite large, and the time required to resolve the risk short, the risk would fall under the category of Fracture.

Cancer: Cancer in human body is caused over a long period of time, by the environment, genes, and other factors, and can be fatal. A “Cancer” risk is where the time required for risk resolution may be long but the economic loss to the company can also be quite large.

3. Risk Response Strategies: Example Cases

Having introduced the risk diagnosis matrix above, in this section we look at cases of global companies operating in Asia. Each company considered next adopts an appropriate strategy when faced with a particular type of risk. These examples are then distilled to propose a risk prescription matrix to align with the diagnosis matrix.

3.1 Great East Japan Earthquake

Japan, which is a part of the Pacific Rim earthquake zone, suffers from earthquakes every year, as 10% of the world's volcanoes originate in the Japanese archipelago. In addition to large-scale earthquakes such as the 7.9

Richter Kanto Earthquake of 1923 and the 7.2 Richter Kobe Earthquake of 1995, more than 1,500 large and small earthquakes occur annually in the Japanese archipelago. The Great East Japan Earthquake that occurred in the Pacific Ocean in the Tohoku region in 2011 was 9.1 on the Richter scale, the largest earthquake ever observed in Japan in recent times (Israel, 2011).

The Great East Japan Earthquake of March 2011 caused major disruption to companies with supply chain nodes located in the affected region. In particular, the Great East Japan Earthquake was the trigger that revealed the structural weakness of Toyota Motor's Just in Time (JIT) strategy, an efficiency-oriented Japanese-style supply chain management model of minimizing inventory and centralizing suppliers (Tajitsu, 2016).

As is widely known, JIT is the production method that produces products only when needed and with minimum work-in-process and raw material inventory. To keep inventory costs as low as possible, products are produced and sold only when requested by the customers (Sugimori et al., 1977). Automobile industry is especially prone to carry large stock as not only are there many types of finished cars, but a finished car is assembled from 20,000 to 30,000 parts. Therefore, to reduce the cost of finished product and minimize work-in-process, starting in late 20th century automobile industry started to adopt small batch production. The Japanese automobile industry, led by Toyota, has become a leader in the global automobile market by actively pursuing lean production methods, such as JIT.

However, the Great East Japan Earthquake revealed the downside of maintaining lean inventories in the supply chain, a strategy that reduces cost during normal times, but exposes the supply chain to serious risks in case of even a minor disruption anywhere in the supply chain. In the wake of the 2011 Japanese earthquake, the areas most severely damaged were Tohoku and Kanto, which are home to key factories in Japan's automobile, electronics, and steel supply chains. Some of these suppliers were sole suppliers of multi-national companies, such as Toyota who procured from these suppliers not only for their Japanese production plants, but also plants located in North America. As Toyota and other automakers maintained lean supply chains with the objective of minimizing inventory and achieving economy of scale (with their suppliers), they were heavily reliant on parts suppliers such as Bosch, Denso, and Delphi. However, these lean and efficient supply chains came to a standstill once the suppliers' operations were disrupted in March 2011.

Toyota's supply chains were severely impacted as production stopped for 12 days in all their factories. Production volume decreased by about 190,000 units, while sales volume decreased by about 94,000 units month-to-month, resulting in 46% drop in sales. The crisis lowered Toyota's domestic market share to below 40% while at the same time highlighting the potential risk of the JIT system that had so far led to their remarkable growth (Jung et al., 2011).

On the other hand, Nissan which maintained safety stocks of about 40% of the total volume, was able to maintain limited normal operation, even as their parts supply chain collapsed due to the Earthquake. This strategy however comes with increased inventory costs. Therefore, after the Great East Japan Earthquake, Toyota started to promote the restoration of the supply chain based on securing stability of parts procurement, rather than strategic inventory holding.

To restore the heavily disrupted supply chain, Toyota followed the strategy of diversifying its suppliers, strengthening relations with them, and promoting parts standardization. One of Toyota's key supply chain resilience strategies for the future is localizing (regionalizing) supply chains so that sources of parts are located in the vicinity of the car assembly plants. This way a disruption in one region (one part of the supply chain) can be contained within that region, and not allowed to spread to other parts of their supply chain. In addition, production flexibility was secured by establishing a seamless mutual supply system for production vehicles and parts among production bases. Toyota has also started standardizing parts used across different models and increased the number of common parts manifolds. With the increased compatibility of parts, in the event of an emergency, a production facility can easily obtain substitute components from other suppliers, minimizing disruption to the supply chain.

Toyota has also developed a database of components of approximately 1,500 parts and obtained detailed and clear information about suppliers at almost every stage. In the event of an emergency, the company can respond promptly by quickly identifying suppliers who can produce alternative parts (Kim, 2020). In addition, Toyota has promoted the transformation to a globally distributed production system, to diversify the risks. Japanese

automakers, including Toyota, have distributed production bases and parts and material procurement networks around the world to prevent them from being paralyzed during times of unexpected disruption. Toyota, e.g., has expanded its production base to Brazil, China, Russia, and Egypt, and increased the local procurement ratio of parts from 85% to 92% (Koo et al., 2012).

It is almost impossible to anticipate the probability of the risk of natural disasters such as earthquakes and floods. What is important, thus, is to minimize the time required to respond to the crisis as the damage from such risks can be wide-ranging. In the end, risk avoidance strategy through proactive preparation is the key to containing the disruption caused by such risks.

3.2 Great Thai Flood

Since the 1980s, Thai government has focused on attracting foreign companies by creating large-scale industrial complexes. As a result, production bases of various global companies in the automobile and electronics industries have become concentrated in an industrial complex called “Oriental Detroit”. Many of the foreign companies that entered Thailand during this time were Japanese, such as Honda, Sony, Canon, and Nikon (Im and Kim, 2011).

Starting July of 2011, Thailand experienced heavy rain for more than 3 months, resulting in the worst flooding Thailand has ever seen. The amount of rainfall in Thailand over those 3 months exceeded the annual average of 1,400 mm, inundating more than half of the country's landmass. The flood caused damage across all Thai industries, including automobile, electric and electronics, tourism, and agriculture. In particular, the central plains, which housed major Thai industry, suffered great damage from flooding. This was the area where many Japanese automobile companies and electric and electronic companies were located. Japanese companies had already suffered from production disruptions due to the Great East Japan Earthquake earlier that year and were hit even more severely by the Thai flood that occurred just a few months later.

It is estimated that the damage suffered by major Japanese companies due to the flood in Thailand amounted to more than 700 billion yen. Specifically, Toyota and Honda suffered the most damage, 120 billion and 110 billion yen, respectively (Cho, 2012).

Honda's four-wheeler vehicle plant was flooded, shutting down its operations, and had a big impact on parts suppliers. The motorcycle plant also stopped operating due to a shortage of parts as the supplier’s plant was affected by the floods. In addition, the production of four-wheeler vehicles was stopped at Honda’s Malaysian factory which also procured parts from the same Thai supplier.

Toyota’s Thai factory produces IMV models, the flagship vehicle for export, for which more than 90% of the parts were procured from Thai suppliers, resulting in significant disruption. Due to the nature of the automobile production line, flood damage from factories in Thailand affected the entire supply chain, and factories around the world that used parts supplied from Thailand also had to adjust production or stop production altogether.

The electronic parts industry also suffered a great deal from the Thai floods of 2011. Nidec Corporation’s production plant of hard disk drive (HDD) motors suffered flood damage; at Nikon, the production stopped due to flooding. At Canon, the camera manufacturing plant was not located in the affected region, but the parts supplier was damaged, disrupting the supply. On the other hand, the inkjet printer factory, which had a local production base, had to transfer production to other regions, including factories in Vietnam. Sony's digital camera factory, TDK and Minebea's HDD production plants were also shut down due to flood damage.

In the wake of the disruption, Japanese companies temporarily transferred production to neighboring Southeast Asian countries or Japan and promoted alternative production through overseas procurement of parts. In addition, policies were implemented to prevent disruptions in the production skills of manpower, by temporarily transferring idle manpower from the plants in Thailand to Japanese plants (Im and Kim, 2011).

TDK, which produced HDD, transferred production to another factory in Thailand; Minebea responded by procuring parts from outside Thailand. Ajinomoto, a frozen food company, responded to the disruption by receiving delivery from a subsidiary in Thailand.

Overall, Japanese companies minimized the impact on shipments by dipping into their inventory, and reduced risk by procuring substitute parts, and followed a diversification strategy, using alternative production sites. In the short term, they used factories in the Philippines, China, and Japan as alternative production sites, while for long term resilience they promoted relocating production bases to industrial complexes in eastern Thailand which has lower risk of flooding.

3.3 Samsung Galaxy Note 7 Recall

Samsung Electronics, a Korean multinational company, entered the smartphone market in June 2010 under the brand Galaxy. After the successful launch of Galaxy S, a basic smartphone, Samsung went on to launch the Galaxy Note series, which built on Galaxy S with a wider screen and a stylus for writing, gaining popularity with many consumers. Samsung Electronics had greatly increased its brand awareness thanks to the success of the Galaxy S and Note series. As of the end of 2019, Galaxy S series had sold 450 million units, and the Note series 70 million units.

In August 2016, just a week after it was launched, a photo of the Galaxy Note 7 which exploded while charging, was shared online in South Korea. A few days later, a second explosion occurred, followed by a third accident. The third accident was especially considered a serious problem as it occurred while the phone was not being charged. Recognizing the seriousness of the situation as the video of the explosion was transmitted on YouTube to more and more countries outside South Korea, Samsung Electronics immediately stopped selling the product and announced a major recall within 10 days. When the major recall of the Galaxy Note 7 was announced, airlines in the United States, Japan, Singapore, Australia, and other countries disallowed the phone in carry-on or checked-in baggage; even high-speed rail and stations in the United States banned the phone. Instead of repairing the phone, Samsung Electronics replaced the Note 7 with a new product or provided refund if the customer so wished. While the media only expected a battery recall, Samsung decided to implement exchange and refund policies to get ahead in the media narrative (Samsung, 2016a).

It turned out that there were problems even with the exchanged Note 7, so Samsung Electronics decided to discontinue the Note 7 just 54 days after its release. The move was estimated to cost about USD 1.3 billion for the first global recall and USD 2.2 billion for the second recall in the third quarter earnings announcement of that year. Opportunity losses, profits until the next launch due to discontinuation of the current product, were projected to be in the vicinity of USD 3 billion, with total losses amounting to over USD 6.5 billion (Samsung, 2016b).

The cause of the Galaxy Note 7's explosion was a defect in the manufacturing process of the battery. At a press conference in September of that year, Samsung management revealed the reason for the battery defect: a minute error in the manufacturing process causing a short circuit at the intersection of the cathode and anode. Forbes, a US based media company, however reported that the cause of the explosion was the defects in product design, and blamed Samsung for hastily launching the product in face of innovation-based competition (Lee, 2016).

Galaxy Note 7 explosion can be cited as an example of the risk posed by an attempt to ride a technological trend. In the smartphone market, the ever-growing competition to make thinner products has led companies to fit components in a narrow enclosure, requiring advanced design technology. This in turn increases the risk of adopting and implementing new technologies for products with ever-shrinking lifecycles.

On their part, once the problem arose, Samsung responded by quickly accepting the risk arising from the explosion of the Galaxy Note 7. Although it came at a huge cost, the company decided to discontinue the product less than two months after its release, implementing an exchange and refund policy. By doing so, it managed to arrest the fall in its brand image that had been growing in the US and other overseas markets. Fortune, an American economics magazine, praised Samsung Electronics for its quick action and response (Colvin, 2016). The Financial Times of the UK analyzed that Samsung Electronics' recall of 1 million Galaxy Note 7s in the US alone cost USD 1 billion. Samsung Electronics, with a net cash reserve of 59 billion dollars, was able to afford it (Kim, 2016). In the end Samsung Electronics came out financially stronger.

3.4 Toyotas' recall of Lexus

The level of uncertainty in supply chains increases in direct proportion to the level of technology incorporated in the product, sometimes leading to quality issues. Any attempt by the company in question to either conceal or reduce the severity of the issue may end up destroying the brand value and corporate image which takes a long time to build.

Toyota is a Japanese automobile company with the largest global market share. In 2019 it was ranked by Fortune 500 as the world's 10th largest company with sales of $271.2 billion (http://fortune.com/global500/2019/). Toyota makes automobiles in various categories, such as sedans, SUVs, trucks, and buses; some of their bestselling sedan models include Prius, Camry, and Avalon. In addition, Toyota has also launched a separate brand called Lexus, which has a high market share in the luxury car segment.

In August of 2009, one of Toyota's luxury brand Lexus ES350 while sprinting at a speed of 125 MPH crashed over the guard rail of the highway, killing four members of a California family. It could easily have been an accident due to speeding or inexperienced driving. However, thanks to the record and call history the driver reported to 911 at the time of the accident, the investigators began suspecting a defect in the vehicle. Immediately after the accident and as the recording of the 911 call was released Toyota claimed that the accident was not caused by any mechanical defect, but by a badly designed mat restricting the accelerator. Afterwards, they announced the recall of 3.8 million vehicles, including the ES350 model that was in the news (Evans and McKenzie, 2010).

The National Highway Traffic Safety Administration (NHTSA) conducted an official investigation into this traffic accident and investigated all the vehicles subject to recall. As a result of the investigation, NHTSA concluded that the cause of the accident was not simply the problem mat, but the electronic control device. In response, Toyota consistently denied any defects in the vehicle. By early 2010, the brand image of Toyota had fallen sharply as the sales of the model were halted and a further recall of about 9 million vehicles was announced (Toyota, 2010).

On February 8, 2011, more than a year after the incident, the US Department of Transportation announced that there was no connection between Toyota's electronic control unit (ECU) and a sudden unintended acceleration. The conclusion was reached by engineers from NASA and NHTSA who, over a 10-month period, led an investigation into the recalled Toyota vehicles. This announcement supported Toyota's position from the very beginning that the cause of the sudden acceleration was a poorly designed floor mat restricting the accelerator pedal (Vartabedian, 2011).

However, Toyota's troubles returned when the BARR group, an embedded software expert group, released their report into investigation of "Toyota's Sudden unintended acceleration." Their report showed that the sudden acceleration was caused by an error in the software embedded in Toyota's ECU (Barr, 2013). In addition, it was shown that Toyota paid off engineers from NASA and NHTSA who participated in the investigation at the time of the announcement by the US Department of Transportation, which tilted the investigation results in its favor. On March 19, 2014, the U.S. Department of Justice imposed a fine of $1.2 billion on Toyota for denying the sudden unintended acceleration for 6 years and deceiving consumers. Toyota accepted the ruling on condition of a suspension of prosecution (Vlasic and Apuzzo, 2014).

Toyota's failure to respond immediately and decisively to a risk led to deterioration in their brand image. Instead, Toyota responded with a strategy of risk avoidance, a technical and quality risk any automobile company might face and failed to respond to the crisis due to the inactive attitude of management and lack of ethical leadership in identifying and accepting the real cause of the problem.

The examples of Samsung Electronics and Toyota show the importance of a company's attitude toward a crisis. The quicker a risk is recognized, the faster a response can be made. In case of risks that arise from intrinsic problems, it is imperative that the company adopt a risk acceptance perspective, respond quickly, and solve the problem. Only then can the company hope to prevent damage to its brand and maintain profits.

3.5 China’s Export Restriction of Rare Earth Minerals to Japan

Japan has been in dispute with China for a long time over the Senkaku Islands (Japanese) aka Diaoyudao (Chinese). In 2010, the conflict between the two countries reached its peak. On September 7th, a Chinese captain was arrested by the Japanese Coast Guard on the Senkaku Islands. After this incident, China took measures such as boycotting Japanese products, banning tourism to Japan, and restricting exports of rare earth minerals. As a result, the prices of major rare earths imported by Japan skyrocketed. Japan complained that China's actions were in violation of the World Trade Organization (WTO) agreement. However, the Chinese government responded that the restrictions on exports of rare earths were to protect the country’s environment (Park, S.J. 2019).

Rare earth is an important industrial resource for major Japanese industries. Rare earth literally refers to 17 kinds of rare earth elements which are 15 lanthanum elements with element symbols 57 through 71, scandium (Sc), number 15, and yttrium (Y), number 39. These elements have similar properties and are called rare earths because they are rare in mineral form. These rare earths are chemically very stable, can withstand dryness, and conduct heat well. Rare earths have particularly excellent radiation shielding effect, and the loss of light can be reduced to 1% of general optical fibers even if only a small amount of gadolinium or erbium is added in manufacturing optical fibers. Alloys using terbium lose their magnetism when heated and restore magnetism when cooled; they are used to make music MDs or magneto-optical disks that can record and store information. Due to these characteristics, rare earths are used as essential raw materials in high-tech industries such as high-definition TVs, smartphones, hybrid and electric vehicles, solar power generation, and the aerospace industry (Kim, 2010).

At the time of dispute with Japan, China was producing more than 95% of the world's rare earth minerals. According to data from the United States Geological Survey (USGS) in 2011, China has approximately 55 million tons of rare earths. The second country, after China, with large reserves is the Independent States Union (CIS), which has 19 million tons of rare earth reserves, followed by the United States, which is known to have 13 million tons of rare earth (USGS, 2011).

When difficulty in importing rare earths from China arose, Japan took several actions to overcome the crisis, such as the development of alternative materials, development of technologies to reduce the use of rare earths, and recycling.

Through its affiliate Aichi Steel, Toyota developed bond magnets that do not use dysprosium. To develop the technology to reduce the reliance on rare earths, it applied its capabilities in the old magnetic field. Shin-Etsu Chemical, Hitachi Metals, and TDK succeeded in developing technology that drastically reduced the use of rare earths in the process of manufacturing high-performance old magnets. Daido Steel and Daido Electronics jointly developed a magnet with improved magnetic force even though the amount of dysprosium was reduced by half. The New Energy and Industrial Technology Development Organization (NEDO) has developed a high-performance magnetic motor for hybrid vehicles that does not use rare earths such as neodymium or dysprosium. In addition, recycling businesses such as recovery and recycling of cutting waste from the manufacturing process of metal products were actively encouraged, centering on magnet and alloy manufacturers. Chuo Denki Kogyo built a rare earth recycling plant in Vietnam with plans to treat waste metals purchased from Japanese companies and sell as recycled materials back to them. Since October 2009, Mitsubishi Materials has invested in the development of technology to recover dysprosium by dismantling the air conditioner compressors and extracting magnets (Kim, 2010).

Japan also responded to China's restrictions on rare earth exports at the government level. In March 2012, Japan, together with the United States and the European Union, filed a lawsuit with the WTO against China's rare earth export restrictions. In August 2014, the WTO ruled that China's export restrictions on rare earths were a violation of trade agreements, which led Chinese government to completely withdraw restrictions on exports of rare earths in January 2015 (Park, S. J. 2019).

Even though China's restrictions on rare earth exports to Japan were rolled back by the WTO's ruling, it took 4 to 5 years from the time of the dispute. If Japanese companies had not set up and implemented an immediate response plan, the Japanese economy might have been more seriously hit. Therefore, when political or diplomatic conflicts arise, it is necessary to establish countermeasures from a long-term perspective rather than look for a short-term response.

3.6 Japan’s Export Restriction of Semiconductor Material to Korea

As Korea and Japan are very close geographically, there have been many exchanges between the two countries in fields such as politics, economy, and culture over a long period of time. Even now, cooperation and competition between the two countries has a great influence on politics and economy in Northeast Asia.

In July 2019, the Japanese government announced that it would restrict export of some of the semiconductor materials to Korea. Semiconductor materials included in the restricted items were Fluorine Polyimide used in smartphone displays, Photoresist used in manufacturing of semiconductor substrates, and Etching Gas used for semiconductor cleaning (Park, J. 2019).

This incident followed the pattern of China's restriction on rare earth materials exports to Japan that occurred back in 2010. At that time, Japan’s position was that China's export restriction on rare earths were a retaliatory measure for the arrest of a Chinese captain by the Japanese maritime police on the Senkaku Islands, while China maintained that the two incidents were not related, but that its actions were taken only to protect its own environment. Korea similarly argued that Japan's export restriction on semiconductor materials were in retaliation to compulsory Japanese imprisonment compensation issued by the Supreme Court of Korea in 2018. Japanese government, on the other hand, argued that as Korea smuggles strategic materials to North Korea, regulation of semiconductor materials to South Korea is to enhance its own security. The Korean government immediately went through the WTO dispute resolution procedure. In the second quarter of 2020, Korea and Japan temporarily suspended the dispute resolution process following the resumption of dialogue between the two governments (Choi, 2019b).

Samsung Electronics and SK Hynix, the leading semiconductor companies in Korea, and LG Display, a global display company, began redesigning their supply chain immediately after the announcement of Japanese export restriction. Until then, Korean companies imported 90% of these materials from Japan (Kim et al., 2019). Obviously, the semiconductor restriction was a big crisis for Korean companies. The redesign of the semiconductor supply chains in Korea was carried out along two dimensions: diversifying supply lines and securing core technologies.

Samsung Electronics and SK Hynix began to redesign their supply chain by proactively securing from alternate sources Japanese export-regulated items and adjusting their investment plans. They diversified their suppliers to Taiwan and Europe, securing the largest possible inventory of related materials. In addition, they focused on minimizing the amount of material input into the process and preventing production disruption.

At Samsung Electronics, Vice Chairman Lee personally visited Japan to take measures. Samsung Electronics, in cooperation with Soulbrain and ENF Technology, began to introduce hydrogen fluoride, imported from China and Taiwan, into some processes (Cho, 2019). SK Hynix CEO also visited local companies and implored them to develop alternatives. In the case of Photoresist, insufficient inventory was raised through RMQC, a joint venture between JSR in Japan and IMEC in Belgium (Kim, 2019).

In adjusting production and investment, SK Hynix pushed to grow CIS (CMOS image sensor) business by reducing the scale of DRAM production from 4Q. Towards this end, part of the DRAM production of the M10 plant in Icheon was converted to CIS production. In addition, SK Hynix received significant amounts of alternative material through a Korean company, RAM Technology, thus preventing disruptions in production of parts that previously depended on Japan, establishing a new supply chain.

LG Display succeeded in localizing semiconductor-related materials in Korea. Just three months after Japan's export restriction was announced, LG Display replaced all the Japanese liquid hydrogen fluoride used in the production lines of organic light-emitting diode (OLED) panels and liquid crystal display (LCD) panels with Korean products (Kang, 2019).

In June 2020, a year after Japan's export restriction began, SK-Materials, a subsidiary of SK Hynix, successfully developed gaseous ultra-high purity hydrogen fluoride and applied the mass production system. Hydrogen fluoride plays a role in removing only the circuits engraved with gold and platinum on the semiconductor wafer (substrate), and the rest of the material. As the level of micro-processing of semiconductors increases, more gaseous hydrogen fluoride is used than liquids, so securing self-technological power of gaseous hydrogen fluoride is of great significance to Korean companies, in order to secure the supply chain of

semiconductor materials.

The export restriction of semiconductor materials arising out of the conflict between Korea and Japan served as an opportunity for Korean companies to rebuild their supply chains and enhance their own semiconductor material technology. The same is true of China's export restriction of rare earth mentioned above which led Japanese companies to secure new sources of rare earths or discover other raw materials and technologies to replace rare earths. Thus, risk factors in supply chains can also lead to the creation of new opportunities.

3.7 COVID-19 and Toyota Motors

Toyota, a global automaker headquartered in Japan, reported disastrous results in the second quarter of 2020. As shown in Fig. 3, compared to the same quarter of the previous year, sales and operating profit dropped 39.9% and 98.1%, respectively. The trend has continued in first half of 2021 as newer variants of COVID-19 have emerged.

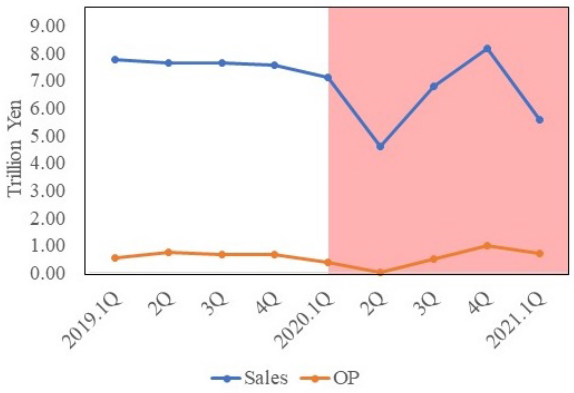

Fig.3 Toyota's quarterly performance 2019.1Q-2021.1Q
Source: http://global.toyota/en/ir/financial-results/archives/

At that time, Reuters predicted that Toyota's annual operating profit in 2020 would decline by 20% (from 2.58 trillion Yen to about 2 trillion Yen) compared to the previous year due to the impact of COVID-19 (Tajitsu, 2020). The estimate was based on the premise that the global automobile market will gradually recover from the trough in the second quarter and return to the previous level between the end of 2020 and the first half of 2021. This prediction is quite shocking considering that in the first half of 2020 Toyota Motor Company was the largest automaker (by % share) in the world. In Toyota's fiscal 2020 financial report one year after the outbreak of COVID-19, the annual operating profit was reported to be 1.8 trillion yen, down 27.4% compared to 2019.

Compared to other global automakers in the second quarter of 2020, Toyota's performance is slightly better. Major automakers in the United States such as GM (-76 billion yen), Fiat Chrysler (-128 billion yen), Volkswagen (-198 billion yen), and Daimler (-246 billion yen) showed even poorer performance due to the impact of COVID-19 (Chung, 2020).

Like other automakers, Toyota's overall earnings were sluggish due to a sharp decline in auto demand, but its sales volume declined in the Chinese market in the first half by only 2%. On the other hand, Volkswagen and Renault-Nissan's sales in China dropped 17% and 20%, respectively.

Toyota has improved its inventory management and production response capabilities after the 2011 Great East Japan Earthquake. Thanks to the increased visibility of the supply network and other measures implemented after the last major disruption their supply chain experienced, Toyota was able to prevent inventory build-up by quickly halting production of models facing declining demand.

Meanwhile, the Korean automobile industry faced the risk of parts ecosystem collapsing. In the early days of

pandemic, Korean automakers stopped operating their parts factories in China, and most of their production plants stopped as they were unable to receive the wiring harness, a bundle of wiring that acts as the neural network for automobiles.

Many Korean auto parts makers have an exclusive transaction structure, and because of the spread of COVID-19, the assembly plants of automobiles were shut down, leading to bankruptcy of some of the companies. Among Korean parts makers, 45% of all parts makers had transactions with only one automaker. Only 8.3% of the parts makers dealt with more than five companies. On the other hand, in case of Japan, more than half (52.6%) of parts manufacturers do business with multiple companies. So even though Japanese companies also had some difficulty in receiving wiring harnesses from China in the early days, thanks to the diversification of their supply lines to Southeast Asia, they were able to bring their production plants back to capacity relatively quickly. In fact, for Korean companies the dependence of wires and cables to China was 75.3%, whereas for Japan, it was only 35.2% due to diversification of their parts suppliers (Lee, 2020).

The Southeast Asian region is the production base for Japanese automakers. It serves to buffer volatility in major markets such as the US and Europe. As of 2018, Japanese automakers operate 104 factories in the region and employ 150,000 people. The industry produces 3.88 million units a year and sells 3.02 million units to the Asian market.

The main reason the Japanese automobile industry fared better in its response to COVID-19, as compared to the Korean automobile companies, was the improvement in supply network visibility and supply chain diversification that the industry had implemented following the earlier major disruption (the 2011 Great East Japan Earthquake). Japanese automobile companies had in place a diversified supply chain with a regional network of part suppliers and parts manufacturers that were supplying parts to multiple companies rather than relying on specific companies. As a result, the industry was better able to respond to challenges and risks that COVID pandemic brought in its wake.

3.8 COVID-19 and Samsung Electronics

In the electronics industry, the effects of COVID-19 depended on the part or the product. The smartphone market in the second quarter of 2020 decreased by 16.0% compared to the previous year (IDC, 2020). On the other hand, the semiconductor market enjoyed the advantage of an increase in prices due to the expansion of the server and PC markets even as other market segments (such as smartphones and automobiles) declined. This was the result of increased emphasis on online education and work from home (WFH) measures various governments initiated. In this case, the product line with decreasing demand needs to adjust the production volume so that inventory does not increase, and the product line with increasing demand needs to manage risk so that the supply network of parts can operate smoothly. Here, we will look at the case of Samsung Electronics, which produces smartphones, semiconductors, home appliances, and displays.

Samsung Electronics adopts a regional distribution strategy in its supply chain design. It has 37 production facilities in countries around the world, with 10-15% of production being done in China. Samsung Electronics introduced “One-day SCM decision system” in 2017, which is based on big data and measures and determines, every hour, global raw materials and parts supply, product demand, etc. Supply chain decisions can be made within one day, allowing immediate response to market changes, enabling adequate supply chain management even in crisis situations (Rho, 2018). For example, if a factory in China goes down, the system decides which of the five smartphone factories in Korea, India, Vietnam, or Brazil should increase production and from where they should procure parts. Core parts, such as camera modules for smartphones, have also been generalized, allowing the production site to be flexibly changed. Samsung Electronics has long maintained a system capable of responding to unpredictable catastrophic crises by distributing parts suppliers and production facilities even at the expense of increased cost. As a result, at the outbreak of COVID-19 Samsung Electronics did not need to stop operation of its smartphone factories unlike its competitors, whose production was stopped and procurement of key parts blocked.

According to the 2017 “Samsung Electronics Sustainability Report”, Samsung Electronics established in May 2014 G-SRM (Global Supplier Relationship Management), an integrated system for purchasing, which is being used by all global business operators and partners. 100% of the parts purchased through G-SRM are analyzed for

detailed costs, cost efficiency, and purchase status of regional partners. In addition, SCM information required for transactions with suppliers, who are members of the supply chain, is shared bi-directionally through the system; G-SRM is also used for operations related to overall supplier operation management and supply chain risk management (SAMSUNG, 2017).

Samsung Electronics categorizes possible risk factors in the supply chain for external partners and internal purchasing processes. The risk of natural disasters related to business continuity is additionally managed. Vulnerabilities related to supply chain risk are continuously monitored and managed through the G-SRM system and on-site inspection. Among them, the risk of partner companies is managed through the registration evaluation of new companies and the annual comprehensive evaluation of existing companies.

Since 2016, Samsung Electronics has established and maintained an emergency response process which can be activated whenever business continuity is threatened by natural disasters such as earthquakes, volcanic activity, typhoons, or floods. The company can quickly detect natural disasters using major global disaster information agency systems and send emails or text messages to the person in charge about parts/products located in the disaster area, based on the analyzed information of business partners in the G-SRM system. In 2016, more than 20 earthquakes and typhoons affected Samsung Electronics' supply chain, but the company was able to minimize losses due to cuts in material supply through rapid detection and response (SAMSUNG, 2017).

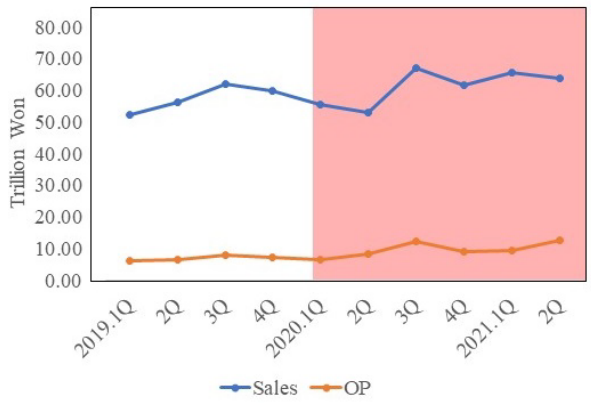

Fig.4 Samsung Electronics' quarterly performance from 2019.1Q-2021.2Q

Figure 4 shows Samsung Electronics' quarterly sales and profits, starting Q1 of 2019. Starting with second quarter of 2020, when the global economy was affected by the impact of COVID-19, Samsung Electronics' sales performance declined for three consecutive quarters, but operating profit rose. Now after more than a year since the outbreak of COVID-19, the Samsung's sales and operating profit are already showing a modest upward trend compared to the previous year.

Samsung Electronics is continuing to emphasize risk management in supply chains. According to the 2020 Sustainability Report, Samsung Electronics operates a separate organization that monitors risks in the entire supply chain in real time since the beginning of the COVID-19 outbreak. The unit uses various transportation routes such as land, sea, and multimodal transportation for smooth flow of all logistics from procurement of raw materials in the value chain to sales of finished products. In addition, it continuously supports the diversification of logistics and production bases, customs clearance, and manpower transfer to corporations and suppliers (SAMSUNG, 2020).

4. Prescription Framework for Risk Management

In an earlier section, we presented the risk diagnosis matrix as a framework for classifying supply chain risk

types. Looking at the cases of Asian global companies and their response to supply chain risks, it becomes obvious that an appropriate response strategy for each type of risk is very important and required for successfully mitigating the risk.

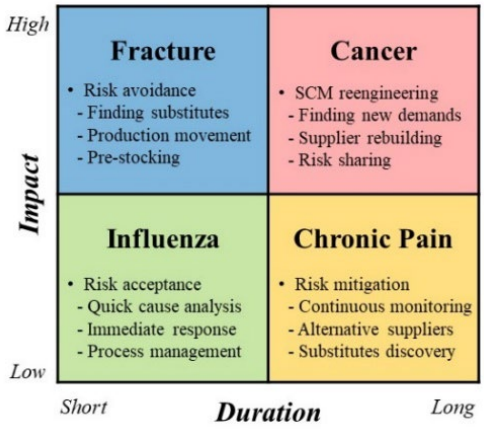

Fig.5: Risk Prescription Matrix

Figure 5 shows the response strategies as a 2x2 matrix, strategies adopted by companies depending on the type of risk faced. Risk diagnosis matrix is transformed to risk prescription matrix by overlaying the response strategies that should be deployed according to the type of risk faced. We next discuss the risk prescription matrix as per the type of risk and the associated prescription.

Influenza This is the area of risk (short duration, low impact) where the cause of the problem is most likely within the company, perhaps due to technical factors or quality issues, as in the case of Recall of Galaxy Note 7 and sudden acceleration problem of Lexus. As a response strategy, the most important thing is to acknowledge that the cause of the problem is due to internal deficiency/negligence. In other words, it is important in the early stages to respond quickly to such a risk, and for this an attitude to actively accept risk is a pre-requisite. This type of risk can occur frequently. In the event of a risk from within the organization, companies expand their initial response manual to strengthen the technical capabilities, to enable quick analysis of the cause of the problem. In addition, a quick response system should be established. Since the occurrence of risk due to quality factors can be prevented through better management of the internal operating processes, management and supervision of the process can be considered an effective countermeasure to prevent future occurrences, just as we do with strengthening of our immunity to prevent future occurrences of flu.

Chronic Pain Unlike Influenza, this is an area of risk created by external factors (political, economic, historical, etc.) and the impact, even though low, may last a long time. Examples of rare earth materials and semiconductor parts export restrictions fall into this category. Obviously one key characteristic of this type of risk is that it takes a long time to mitigate the impact. Therefore, it is important to not take a short-term view of mitigation (such as procuring substitutes) but rather adopt a long-term perspective, for example, by finding alternative suppliers. As a fundamental risk management measure, it is important to secure investment and technology that can completely replace existing materials, for example. In other words, it is necessary to diversify the supply base that provides raw materials and parts, and to establish a strategic cooperative system with companies that possess key technologies, along with direct investment in core technologies absent in the supply chain. Lastly, when receiving important raw materials, parts, and technologies from companies in countries with political and historical problems, continuous monitoring of frictions with the country concerned and relations with foreign companies (trust, relationship norms, relationship commitment, conflict, etc.) must be continuously managed. This is like the prescription of pain management for human body.

Fracture Risks in this area of the matrix inflict enormous damage in a short period of time, so a company level response is required. Since it is impossible to prevent such a risk in advance, it is necessary to develop a

response strategy that minimizes the impact through proactive management of the crisis. As shown in the Great East Japan Earthquake and the Great Flood in Thailand, the risk avoidance strategy may include specifically finding substitutes or temporarily moving production sites to nearby areas. In addition, since the causes of risks such as natural disasters are geographical and climate related, measures to secure the necessary inventory in advance through observation can be an appropriate countermeasure as well. As forecasting the occurrence of such a risk is nearly impossible, focus should be on quickly managing and minimizing the impact, just as a fracture of any part of human body requires immediate correction (surgery, cast) to minimize the long-term impact.

Cancer Among the four areas on the matrix this is the most difficult area to establish a response strategy for, as it takes a long time to diagnose the risk while the impact on business is deep and prolonged. As treatment of cancer in human body requires long-term therapy and lifestyle changes, to resolve such risks in supply chains, a strategy to redesign the entire supply network may be required. This is best illustrated with the example of CIVID-19. It is impossible to prevent a crisis like CIVID-19 in advance, and the time to overcome the crisis is also long. Since the prolonged pandemic acts to increase the demand volatility, even if the supply network is restored, the overall performance of the company is still adversely affected. In this case, as a specific countermeasure, it is necessary to discover new sources of demand from the point of view of demand risk management. and it is necessary to diversify the suppliers of parts and production bases to spread the risk from the point of view of supply risk management. These long-duration and high-impact risks require reengineering of supply chains across both supply and demand networks and processes.

Next, to validate the risk prescription matrix we discuss the various events that have impacted Toyota's performance and show how, in the wake of each event, the strategies recommended by the prescription matrix have been the appropriate strategy to follow. Figure 6 shows Toyota's financial performance over the last 13 years, and various events that have had an impact.

Toyota, which experienced a general market down-turn after the global financial crisis in 2008, showed a recovery in sales from the end of the first quarter of 2009. Then, after the third quarter, when the Lexus sudden acceleration problem happened, Toyota's sales performance declined again. In addition, the earthquake in Tohoku in March 2011 saw their performance sink to its lowest. However, since then and until the end of 2014, Toyota's earnings gradually recovered, until the sudden and unintended acceleration issue cropped up, and the rare-earth dispute with China was settled. However, when the Kumamoto earthquake occurred in 2016, sales plummeted again, which continue to fall in the aftermath of the COVID-19 pandemic, starting early 2020. It has been over a year since the outbreak of COVID-19, and as the risk continues to prolong, unlike in the past, the sales and operating profit have not rebounded, but continue their up and down journey.

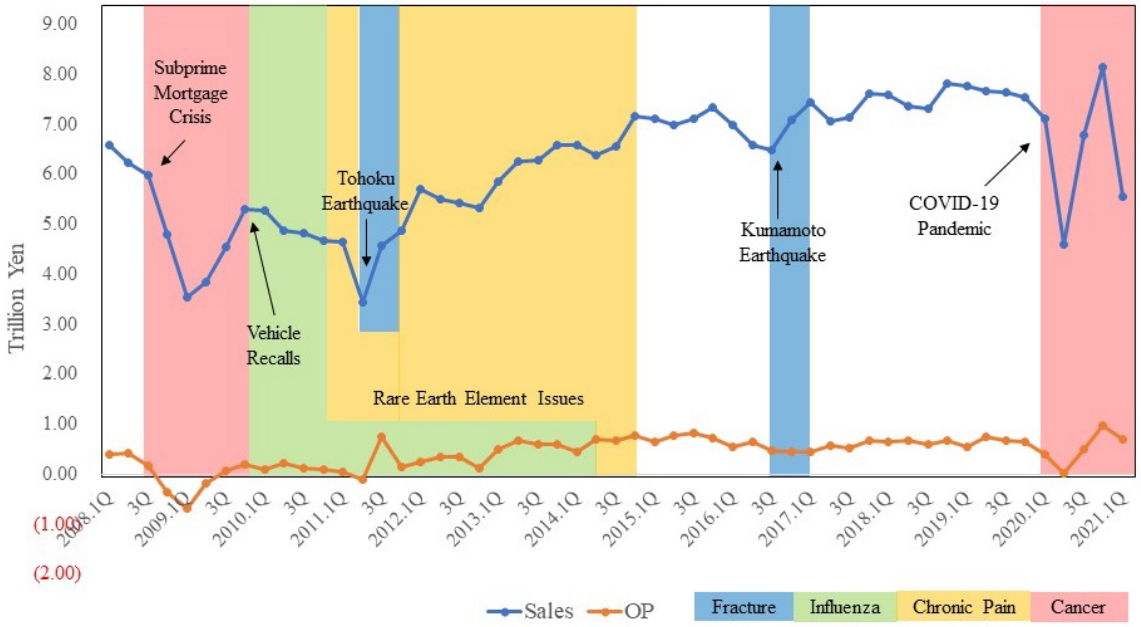

Figure 6: Toyota's Sales & Operating Profits from 2008-2021.1Q.

Depending on the impact and duration of risk, the growth and decline in Toyota's financial performance has the following characteristics. The decline in financial performance was relatively mild in the recall of Lexus, an event like Influenza, with its low-risk impact and short duration. The Tohoku and Kumamoto earthquakes, which are events that fall in the fracture area with high impact and short duration, led to a big decline in financial performance, but sales rebounded immediately in the following quarter. In these cases, as suggested in the Risk Prescription Matrix, an immediate and short-term response strategy through risk avoidance or acceptance strategies is judged to be effective. On the other hand, rare earth element issue, which is event in the chronic pain area with its low impact and long duration, needs to be dealt with risk mitigation strategies. Finally, in events such as the 2008 global financial crisis and the COVID-19 pandemic, events which have high- impact and long duration, fundamental countermeasures such as a reengineering of the supply chain are necessary.

5. Concluding remarks

In this research, we classify supply chain risks in terms of their impact and duration and develop a risk prescription matrix, distilling the experiences of multi-national companies originating from Asia.

The Great East Japan Earthquake of 2011 and the Great Floods in Thailand the same year had a short duration but had a fatal impact on the supply chain. In this case, a strategic response that can avoid the risk in a short period of time was necessary because the time to respond to the risk is short and the impact large. In response, Japanese companies took measures such as relocating production bases or changing the source of raw materials to avoid risk in the short term and to restore the disrupted supply chain.

Risks due to technology and quality problems are usually caused by internal factors. In this case, if the company proactively accepts the risk and responds by establishing an improvement plan, it can relatively easily manage and control the risk. Toyota's response related to the sudden acceleration issue was a case of increasing the risk by not proactively responding to risk control and management. On the other hand, Samsung Electronics, which actively responded to the battery fire of the Galaxy Note 7, is a case of reducing the impact of risk in a short period of time through early response.

When a problem occurs in a company's supply chain due to political and diplomatic conflicts between countries, the company only has a narrow range of control over the risk. As can be seen from the examples, these

risks take at least three to four years to play out and affect the company over the long-term as it takes time for the governments of the countries involved to change their policy. However, the impact of the risk may not be deep, especially when supply chains of the companies are closely connected. In other words, since companies have economic interests that are independent of political interests, they make efforts to develop routes that are different from the existing cooperative routes in the context of the current conflict, thereby gradually lowering the risk. The rare earth dispute between China and Japan and the semiconductor raw material issue between Japan and Korea are examples of stakeholder companies in each country implementing risk reduction strategies such as finding short-term alternatives and diversifying long-term suppliers.

Finally, the disruption of supply chains caused by ecological factors such as COVID-19 represents a long-term risk with uncertainties as to their duration. While natural disasters, technology and quality problems, and political and diplomatic issues also aggravate supply network risks, pandemics such as COVID-19 impact the entire supply chain, both the demand network and the supply network. COVID-19 caused a sharp reduction in demand, making it hard for companies to mitigate the risk. In this case, companies should consider strategies for reengineering supply chains for the long term, including supply networks as well as demand networks.

In summary, the major contribution of this work is the development of Risk Diagnosis Matrix as a framework to assess and classify the characteristics of risk, and Risk Prescription Matrix which prescribes management strategies companies can take when faced with events of different duration and different associated impact. In previous studies, risk assessment and analysis frames have been discussed from the perspective of risk prevention only. A key differentiating aspect of this study is that the duration of risk is used as an evaluation criterion in risk diagnosis. In addition, this study has practical significance as it connects and discusses the risk diagnosis/prescription matrix with cases of global Asian companies such as Toyota, Nissan, Honda, Sony, Canon, Nikon, SK Hynix, LG Display, and Samsung Electronics.

However, the study does have its limitations, the key one being that the diversity of companies studied is limited to MNC originating from Asia, with key focus on Toyota and Samsung Electronics. Nevertheless, we strongly believe that Toyota and Samsung Electronics are not only representatives of Asian companies, but also being global leaders in the automobile and electronics industries, represent all companies in their respective industry.

In future, to further enhance the relevance of the Risk Diagnosis/Prescription Matrix, which is the basis for supply chain risk classification and diagnosis, we plan to focus on more diverse group of companies to improve the quantitative level of research and delve deeper into the financial performance of companies with the objective of improving the qualitative level of research.

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