

Corporation' s Adaptation to Climate Change Related Natural Disasters : Embedding Resiliency in Supply Chain*

- A Study on Climate Change Related Natural
Disaster Adaptation for Corporations -

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I. Introduction

In 2011 Japan was hit hard by earthquakes and tsunamis leaving major damages. The earthquake left Japan's infrastructure (building, roads, homes, factories) in the ruins. At least 46,027 buildings were destroyed and Fukushima nuclear power plant was among one of them. Damages to the nuclear power plant led to additional damages which will haunt Japan for decades to come. 15,828 deaths were officially confirmed while 3,760 people are still missing. 2011 Japan earthquake is recorded as the biggest natural disaster catastrophe in the world with an economic loss of \$300 billion.

Global corporations with production or manufacturing facilities in Japan were severely affected. Leading automobile makers such as Toyota, Honda, Nissan, Mitsubishi, Mazda, Subaru and Suzuki experienced economic loss due to disruptions in production and damages in inventory. The world largest automobile maker Toyota was hit the hardest and lost its world leader position. It took 6 months to fully recover to its normal operations and the delay of two models resulted in over 140,000 vehicle production loss and 30% fall in profits. Even within a decade, many other natural disasters which caused major social problems, economic loss, and disruptions to corporations easily come to mind: tropical cyclone in Myanmar in 2008, flood in the UK in 2007 which destroyed \$8 billion in economic value, US Hurricane Katrina in 2005 which resulted in over 1,000 death and \$125 billion economic loss, European heat wave of 2003 with more than 35,000 fatalities and 2011 Thailand flood with 815 fatalities and \$45.7 billion in damages.

Numerous literature shows natural disasters due to climate change have increased in frequency and severity. According to ECA (2009), the number of natural disasters increased over the past decades and weather related natural disasters resulted in some 800,000 fatalities and over trillion dollars in economic loss over the past 50 years. World's economic loss due to weather disasters, just counting insured loss, is recorded to be about

\$10–50 billion a year.¹⁾

Due to globalization, supply chains are becoming more complicated and wider linking different regions and players around the world. Even the smallest disruptions and complications will lead to a ripple effect. Problems will amplify and rapidly spread throughout the supply chain with major consequences effecting suppliers, producers, manufacturers, distributors and even customers. The pattern of increase in frequency and severity of natural disasters caused by climate change and the fact of increasing interconnectedness of supply chains are well acknowledged by leading global corporations.

Leading global corporations' awareness towards the importance of managing climate change risks is supported by Global Risk Survey 2012 conducted by World Economic Forum. Global Risk Survey 2012 identified 50 global risks across five categories; economic, environmental, geopolitical, societal, and technological risks. 469 experts in business, government and academic fields were asked to assess the likelihood and potential impact of each risk over the next decade.²⁾

Global risks experts identified risk in 5 different categories; environmental risk, economic risk, geopolitical risk, societal risk, and technological risk. Severe income disparity, chronic fiscal imbalances, rising greenhouse gas emissions, cyber-attacks, and water supply risk were identified as the top 5 risks likely to occur.

Environmental risk category includes risks from natural disasters to man-made disasters. Rising greenhouse gas emissions and failure of climate change adaptation, both closely related to climate change, were identified as risks with severe impact and a high likelihood of occurrence in the

1) Economics of Climate Adaptation, "Shaping Climate-Resilient Development: a Framework for Decision Making, Economics of Climate Adaptation", Climate Works Foundation, Global Environment Facility, European Commission, McKinsey & Company, The Rockefeller Foundation, Standard Chartered Bank, SwissRe, 2009. p. 3.

2) World Economic Forum, "Global Risks 2012", Insight report, 2012.

environmental risk category. Failure of adapting to climate change is high in rank even among total risks and can be interpreted as being considered as one of the major concerns for corporations, government and academic experts.

Although climate change risks are less frequent than costs containment risk or most risks encountered by corporations, the severity and impact of a natural disaster caused by climate change risk are detrimental. Corporations can no longer afford to treat climate change related natural disasters as ‘black swan’ events that have negligible chance of happening and dismissible concerns that only affect ‘other’ corporations.³⁾ Faced with increasing climate change risk, a framework for corporations to assess, manage, and adapt to climate change is in dire need. This paper explores best practices of adaptations to climate change related natural disasters and attempts to offer a comprehensive checklist of existing climate change related natural disaster adaptation strategies. It starts by providing effects of climate change and how it impacts global corporation’s operations and supply chain. Followed by how to manage climate change related natural disaster risks and building resiliency in the supply chain by implementing both mitigation and adaptation strategies is described. Adaptation process to climate change related natural disaster and building ‘climate change disruption proof’ supply chain is offered.

II. Effects and Impacts of Climate Change

Opponents of global warming argue any one natural disaster cannot be blamed on global warming (climate change) but many scientists predict that natural disasters will increase in frequency and intensity as global warming

3) Plenert, G., Makharia, M., Sambukumar, R., “Supply Chain Vulnerability in Times of Disaster”, WIPRO Consulting Services, 2012, pp. 1~5.

proceeds. There is a proportionate increase in natural disasters to rising global mean temperature.

There is no doubt of the existence of climate change and climate variation has been increasing in recent decades. In 2007, Intergovernmental Panel on Climate Change (IPCC) officially published that climate change will lead to adverse physical effects such as rise of sea level, temperature pattern variation, extreme weather events, etc.⁴⁾

Adverse effects of climate change include:

<Table 1> Climate change effects

<p>Temperature increase</p> <ul style="list-style-type: none"> • Average global warming is approximately 0.2° C per decade and expected to continue for the next two decades • Long term global warming is projected to be between 2° C to 4.5° C • Temperatures is expected to increase by 1.8—reaching 4 8C by the end of the century • Warming will result in fewer cold days and nights, and warmer and more frequent hot days and nights • Heat waves with increased frequency, intensity and duration will occur in the central European, western United States, East Asia, and South Korea region
<p>Sea level rise</p> <ul style="list-style-type: none"> • Due to thermal expansion and loss of land ice, sea levels will rise during the continuing decades • Sea level rise is estimated to rise 18 to 59 centimeters until the 21st century • Sea level rise will continue for many centuries even after greenhouse gas concentration are stabilized

4) Parry, M.L., Canziani, O.F., Palutikof, J.P., Linden, van der., Hanson, C.E., "Climate Change 2007b: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change", Intergovernmental Panel on Climate Change (IPCC), Cambridge University Press, 2007.

<p>Precipitation and humidity</p> <ul style="list-style-type: none">• There will be increase in wet days and precipitation in high latitudes and in subtropical areas, there will be increased dry spells• Northern Europe, Canada, northeast United States and Arctic will experience increased annual precipitation• Northern Asia and Tibetan Plateau is expecting increased winter precipitation
<p>Extreme wind and rain storms and other events</p> <ul style="list-style-type: none">• Increase in intense tropical cyclone• Increased frequency of flash floods and large-area floods in many regions• Risk of drought in Australia, eastern New Zealand, and the Mediterranean will increase and central Europe and Central America will experience increased seasonal droughts• Increased wildfires in arid and semi-arid areas
<p>Other related effects</p> <ul style="list-style-type: none">• Snow season length and snow depth will decrease for Europe and North America• Fewer cold days and nights

Source : IPCC, 2007.

Additional to effects stated above in the table, the risk of species extinction will increase leading to loss of biodiversity. Catastrophic effects of climate change in longer terms, if mitigation efforts are not carried out to the fullest, include irreversible and eventual meltdown of the Greenland ice sheets, disruption of global ocean circulation system due to slowing or shutting down of Atlantic Gulf Stream and faster global warming from higher methane concentration in the atmosphere, which is caused by methane released from the ocean.

These changes will in turn affect human health, built environments, natural ecosystems, and impose tremendous stress on existing social, institutional, and legal arrangements.⁵⁾Climate change damages are global

5) Bierbaum, Rosina., Smith, Joel.B., Lee, Authur., Blair, Maria., Carter, Lynne., Chapin,

and does not discriminate where and who to affect. But poor developing countries will suffer the greatest since they lack the means to protect themselves.

III. Risks Stemming from Climate Change

How does climate change effect business and its operations? Impacts of climate change for corporations include; limited availability of raw material and natural resources, supply chain and logistics system interruptions,⁶⁾ higher maintenance cost, O&M cost, and product price, reduced production efficiency,⁷⁾ varying asset values and property loss, market change,⁸⁾ insurance premium increase, infrastructure damage, increased investment, and declining financial returns and growth.⁹⁾ Also Current systems that business and governments rely on were built on past climate conditions before climate change and global warming became an issue. But now climate conditions have changed due to human generated adverse effects such as frequent natural disasters. Existing systems are not suitable to cope and manage the risk arising from frequent and intense natural disasters. Negative climate change impacts in the form of natural disasters in turn, become

F. Stuard., Fleming, Paul., Ruffo, Susan., Missy., McNeeley, Shannon., Wasley, Emily., Verduzco, Laura., "A Comprehensive Review of Climate Adaptation in the United States: More than Before, but Less than Needed", *Mitig Adapt Strateg Glob Change, Vol. 18*, 2013, pp. 361~406.

6) Firth, J., Colley, M., "The adaptation tipping point: Are UK businesses climate-proof?", *Acclimatise and UKCIP*, Oxford, 2006.

7) Sussman, F. G., Freed, R., "Adapting to Climate Change: A Business Approach", Pew Center on Global Climate Change, 2008.

8) Schwartz, P., "Investing in Global Security", *Harvard Business Review, Vol. 85, No. 10*, 2007, pp. 26~28.

9) Van Bergen, B., "Climate Changes Your Business", KPMG, 2008.

motivation and driving factors to adaptation to climate change.

Driving factors for climate change related natural disaster adaptation may be anything that persuades business or governments to act. It can be any pressure, compelling information, key triggering external event, economic costs of inaction, and realizing opportunities or any other reasons. Adaptation is not caused by a single factor; instead it is a culmination of different factors that drive adaptation. It is true that driving factor is a combination of several reasons but adaptation only occurs when these reasons are perceived as risks.¹⁰⁾ Climate change effects stated above (limited availability of raw material and natural resources, supply chain and logistics system interruptions, etc) all have the potential to become a risk factor to organizations, thus this risk is mitigated by adapting to climate change related natural disasters.

Organizations are in general, able to reduce their exposure to these disruptions by acquiring knowledge about them and implementing adequate adaptation measures.¹¹⁾ Also managing climate change related natural disaster risks can generate a competitive advantage. By proactively managing climate change related natural disaster risks, businesses can mitigate negative effects and at the same time turn potentially damaging uncertainties, risks, into advantages.

Sussman and Freed classifies physical risk of climate change that can damage business in to three categories.¹²⁾ The concept of 'risk disk', figure 1, illustrates 3 types of physical climate change risk that business can

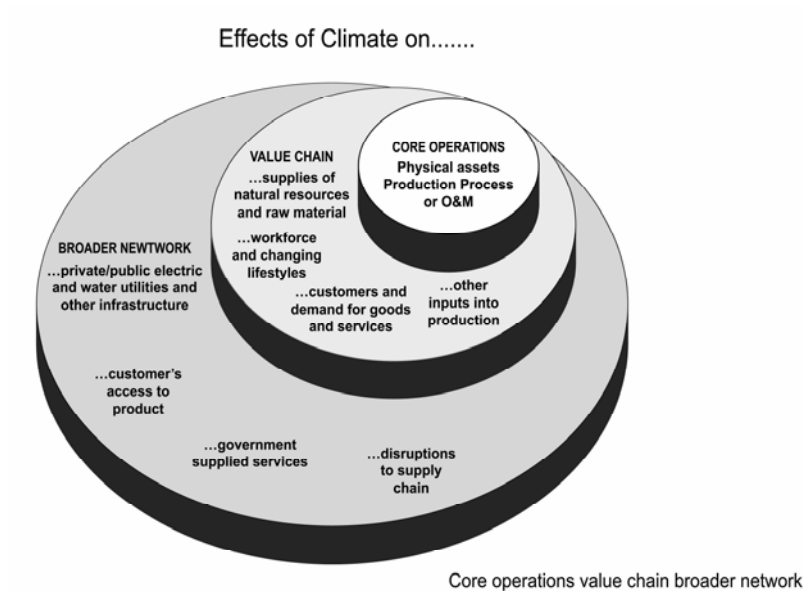
10) Biesbroek, G. Robbert., Swart, Rob.J., Carter, Timothy.R., Cowan, Caroline., Henrichs, Thomas., Mela, Hanna., Morecroft, Michael. D., Rey, Daniela., "Europe adapts to climate change: Comparing National Adaptation Strategies", *Global Environmental Change*, Vol. 20, 2010, pp. 440~450.

11) Busch, Timo., "Organizational Adaptation to Disruptions in the natural Environment: The Case of Climate Change", *Scandinavian Journal of Management*, Vol. 27, 2011, pp. 389~404.

12) Sussman, F. G., Freed, R., *op. cit.*

encounter; core operation risk, value chain risk, and broader network risk.

〈Figure 1〉 Risk Disk



Source : Sussman and Freed, 2008.

Core operation risk is illustrated in the innermost circle and includes risk related to physical structure or assets, production process, and O&M. Climate change has direct impact on core operation risk. Extreme weather may directly damage physical structures or assets affecting asset values. Climate also directly influences the effectiveness or efficiency of production, costs of O & M, and quality of product. Value chain risk is listed in the middle and risks include natural resources and raw material supply, workforce and changing lifestyle, customers and demand for goods and services, and other inputs in production process. Climate change can influence the quality and quantity of products that goes into productions and raw materials supplied. Climate change has the risk of effecting workforce and the demand pattern. Broader supply and demand network risk is the outmost ring and displays risks that arise because of broader

changes in the economy and infrastructure. Climate change (extreme weather conditions) can cause disruption to the supply chain which in turn influences customer's access to product. Publicly and privately owned utilities, services, and related infrastructure provide support to business operations and production processes, and to supply chains and distribution networks. Disruption to utilities, especially electricity generation, water supply, and sewerage can severely affect the supply chain.

The Importance of actively managing climate change risk and preparing for supply chain disruptions due to natural disasters are not only found in literature but practiced by leading global corporations as well. According to the Smarter Supply Chain of the Future by IBM in 2009, one practice that separates a 'top' global supply chain management corporation from the rest is 'managing disruption risks and disaster monitoring'. IBM asked 393 supply chain executives in 25 countries and 29 different industries to identify top 5 supply chain challenges that impact business operations. Supply chain visibility was ranked as the top challenge (70%) followed by risk management (60%), increasing customer demand (56%), cost containment (55%), and globalization (43%). Among the 393 respondents, 17 top global leaders were identified and responses from the 'top leader group' and 'remaining group' was compared. Supply chain risk management practices, ranked second in manager's challenges, include process controls in logistics and operations, compliance programs with suppliers/providers, risk management in supply chain planning, and event management to monitor disruptions. Results show 'top' global supply chain corporations actively managed disruption risks while the rest showed little to no concern. Monitoring disruptive events and acting on disaster response simulation models was what differentiated 'top' global leaders from the rest making disruption (climate change) risk management a key component of effective and resilient supply chain.¹³⁾

13) IBM, "The Smarter Supply Chain of the Future: Global Chief Supply Chain Officer

IV. Corporation's Adaptation to Climate Change Related Natural Disasters

Alpaslan (2003) suggests that only 25 percent of Fortune 500 companies can survive and are prepared for a \$50 million–\$100million loss per day when supply chain is disrupted by natural disasters. Also the time to recover period is two years in average when major supply chain failure occurs.¹⁴⁾ But this is not always the case, some corporations bounce back fast with little to no damages. 9/11 caused major distribution disruptions around the world due to temporary border shutdowns and inspections. The normal lead time for garment businesses in that period was 90 days but Zara filled shelves with clothes within 5 days due to its agile supply chain. The difference is adapting to climate change related natural disasters. The following sections provide a checklist to businesses wishing to adapt to climate change related natural disasters. It will list strategies and frameworks that implement adaptation and best practices of adaptation. It is not a comprehensive framework since strategies or best practices are not applicable for every type of business due to the different nature of businesses. Also not all elements need to be applied in order for a corporation to be adapted to climate change. A corporation can satisfy only one or several recommendation and still be 'climate change ready'

1. Mitigation vs Adaptation Strategies

In recent years, many organizations have set targets and mitigation strategies of measuring, controlling and reducing CO₂ and GHG and

Study", IBM Corporation, 2009.

14) Hendricks, Kevin.B., Singhal, Vinod.R., "An Empirical Analysis of the Effect of Supply Chain Disruptions on Long-Run Stock Price Performance and Equity Risk of the Firm", *Production and Operation Management*, Vol. 14, issue 1, March 2005, pp. 35~52.

substantial research on green shipping has been done. These are all mitigation strategies for climate change which is inherently different from adaptation strategies. United Nations Framework Convention on Climate Change (UNFCCC), defines adaptation strategies to climate change as “the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities”. An adaptation strategy is the ability to adjust to climate change and moderate existing damages. Whereas IPCC defines mitigation strategy as “An anthropogenic intervention to reduce the source or enhance the sinks of greenhouse gases.”¹⁵⁾ Nelson defines mitigation strategies as “actions that reduce future exposure and its effect and impacts are long term, e.g. through regulation, location or technological shifts, adaptation strategies on the contrary refers to the adjustments that population takes in response to current or predicted change.”¹⁶⁾ As different definitions illustrates, mitigation and adaptation can be differentiated by incentives and resulting benefits. Benefits of implementing mitigation strategies in business include, saving energy thus costs, improving environmental performance, developing new energy saving production process and gaining market advantage, etc. Benefits of implementing adaptation strategies include establishing a risk management system, saving costs due to pro-active risk preparation and measurements, gaining technological innovation which leads to competitive advantage, etc. Much effort is being made by governments and business to reduce emission and to meet Kyoto Protocol targets. Clearly current existing literature and policy emphasizes mitigation strategies rather

15) Solomon, S., Qin, Manning, M., Chen, Z., Marquis, M., Averyt, K.B., Tignor, M., “Climate Change 2007a : The Physical Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change”, Intergovernmental Panel on Climate Change (IPCC), Cambridge University Press, 2007.

16) Nelson, D.R., Adger, W.N., Brown, K., “Adaptation to environmental change: contributions of a resilience framework”, *Annual Review of Environment and Resources*, Vol. 32, 2007, pp. 395~419.

than adaptation strategies but only implementing mitigation strategy is not sufficient since it cannot correct the damage already done and substantial climate change is unavoidable. Also it is evident that even if global emission reduction and mitigation efforts are carried out to the fullest, further climate change and its impacts will continue on for decades to come.¹⁷⁾ In order for governments and business to be less effected by climate change, mitigation strategies (greenhouse gas reduction efforts) are not enough, thus the necessity of adaptation strategy. But implementing only adaptation strategy is also insufficient since most adaptation strategies are less effective; adaptation strategies focus on avoiding the short term negative consequences rather than eliminating global warming or climate change in the long run. Mitigation efforts mainly produce public benefits as reducing GHG emissions without having a direct benefit in doing so, adaptation mainly produces private benefits for private business. Also two strategies have different degrees of uncertainty, effectiveness and efficiency. The degree of uncertainty is higher for adaptation since climate change projections are hard to forecast as well as the magnitude of impact.¹⁸⁾ Climate change continues to disrupt the supply chain (supply, production, distribution) with floods, earthquakes, hurricane, drought, tsunami, and other natural disasters. Climate related disruptions can decrease the quantity and quality of recourses, cause physical infrastructure damage, and affect the quality of products and services. Climate in the past will not be the same in the future, future climate bring extreme weather related disasters. These weather related disasters can only be managed by implementing both mitigation and adaptation strategies.

Most business acknowledges the threat of climate change but few have begun the process of building resilience in their value chain.¹⁹⁾ 90% of

17) Biesbroek, G. et al., *op.cit.*, pp. 440~450.

18) Beermann, Marina., "Linking Corporate Climate Adaptation Strategies with Resilience Thinking", *Journal of Cleaner Production*, Vol. 19, 2011, pp. 836~842.

worldwide companies admit they have experienced climate related risks but only 30% are actively responding to climate risks. Beermann(2011) identifies 5 types of adaptation to climate change:

- Reactive adaptation: measures which are taken after the fact, in response to climate change

- Anticipatory adaptation: takes place before climate change impacts are observed and is a deliberate measure in preparation of potential effects

- Autonomous adaptation: it is not a conscious response to climate change but spontaneous adaptation in the face of climate change

- Planned adaptation: this strategy requires conscious intervention. It stems from the awareness that climate has changed or about to change and human planning is necessary to return to its original state.

- Pro-active adaptation: building resilience by implementing both climate change mitigation and adaptation strategies which in turn produces financial benefits and strategic advantages. Pro-active adaptation embeds resilience within the supply chain and copes with change not in terms of switching to alternative stable states but rather in terms of retaining essentially the same function, structure and therefore identity and gives options for new and creative responses. Pro-active adaptation is climate resilience supply chain and this can only be achieved by implementing both mitigation and adaptation strategies. Pro-active adaptation is a system wide-supply chain adaptation which addresses disruptions beyond the corporate boundaries, not limiting itself to the organization itself.²⁰⁾²¹⁾ Since supply chain resilience approach goes beyond corporate boundaries it can consider supplier's, production's, and distribution's climate risk as well. It has the ability to

19) UKTI, "Adapting to an Uncertain Climate: A World of Commercial Opportunities." UK Trade and Investment and The Economist Intelligence Unit, 2011.

20) Chegini, A., "Climate change and adaptation: Business impacts and adaptation", London: Risk Solutions, 2005.

21) Sussman, F. G., Freed, R., *op. cit.*

analyze vulnerability of climate for each link and identify hotspots for risks across the whole supply chain, assess risk for each link individually and account how different impacts can have a compound effect, identify opportunities for new markets, assess full economic benefit to costs ratio for the whole supply chain, and implement climate resilience strategies for partners as well.²²⁾

2. Process of adaptation to climate change

There are four stages in accomplishing climate change related natural disaster adaptation, screen process, climate knowledge absorption, establishing climate related operational flexibility, and strategic climate integration.

1) Risk and Impact Assessment, Screening Process

The purpose of screening process is to identify the existence of potential climate change related natural disaster risks for short and long term and if a more complete risk assessment is needed or not. During screening, it classifies risk into three categories: assess now, wait and study, and take no action. In order to determine whether climate change is potentially important in decision making, identifying sensitivities, identifying the types of decisions susceptible to climate change, and evaluation the magnitude of what is at risk must be completed.

Sussman & Freed (2008) proposes a screening process which “cannot indicate where adaptation to long-term climate change is needed, but only where further risk assessment in detail and risk management might be appropriate”. This process consists of three stages or questions. Question 1 is “is climate important to business risk?” This question leads to identifying

22) Amado, Jean-Christophe., Adams, Peter., “Value Chain Climate Resilience: A Guide to Managing Climate Impacts in Companies and Communities”, Partnership for Resilience and Environmental Preparedness (PREP), 2012.

parts of business that are sensitive to climate change and the possibility of being at risk. This stage requires gathering and projecting climate and weather information for all the location in value chain (suppliers, production, distribution, customer location). Accurately quantifying uncertainty of climate effects is not necessary in this screening process since accurate quantification is required in actual risk assessment. Applying general climate changes will be sufficient. Question 2 is “is there an immediate threat? Or are long-term assets, investments, or decisions being locked into place?” This question leads to the identification of the immediacy of potential treat. If potential risk imposes an immediate threat (e.g. deciding a long term contract with supplier which is located in climate risk hot zone) then the process continues on to question 3. Not all potential risks need immediate action and these risks can be set aside for further screening. But for risks that were determined to have immediacy in stage 2 continues on to question 3. Question 3 is “is a high value at stake if a wrong decision is made?” The last step is determining how much a wrong decision would cost. If the magnitude of costs due to wrong decision is large enough and requires additional research, this risk must be subjected to further risk assessment in detail and mitigation options. This risk would be categorized as risk 1, which is risk with potential significant climate risk that needs to be managed in the short term. It requires in-depth assessment and development of risk management strategies to adapt to climate change. Category 2 risks (risks that were set aside at the end of stage 2) have potential treats that needs to be monitored or reassessed over time. Category 3 risks (risks that are not hugely impacted by climate) are insignificant and no further action is necessary.

For operations or areas that climate is a concern, further risk assessment and mitigation-adaptation strategies need to be established. This can take the form of identifying alternative suppliers who can meet the required capacity or identifying lead time in the case of natural disaster. Cisco was one of the first companies to proactively manage climate change natural

disasters by building resiliency in their supply chain. Cisco identified every “node” (suppliers, manufacturing partners, logistics centers and business partners responsible for other business operations) in the supply chain and made sure each node had alternate sourcing options, alternative production locations and risk buffers. Also Cisco went one step further by dispatching their risk management experts to each node to accurately assess its capacities and establish recovery plan in case of natural disasters. Thus, each node are responsible for reporting their “time to recover” when disaster strikes. Due to Cisco’s proactive impact assessment, Cisco was able to identify potential exposure, see which nodes were affected and the magnitude of impact for the 2008 China earthquake. The earthquake affected many other corporations while Cisco experienced no customer or revenue impact. ²³⁾

2) Information–monitoring system

Absorbing climate knowledge and establishing a free flow information–monitoring system is essential in climate change related natural disaster adaptation since without climate information, risks cannot be assessed properly. This process is internalizing information about changes of mean temperature, dynamics, intensity, sources, consequences and future developments of disruptions. Information systems have two purposes; (1) to determine the probability that existing and planned operation facilities and other areas of the supply chain will be affected; (2) to analyze the potential impacts on them.

Cisco has an excellent climate–related crisis monitoring system. Cisco has a contract with National Center for Crisis and Continuity Coordination (NC4) and this information system provides 24/7 round the clock monitoring of natural disaster disruptions in important locations in Cisco’s

23) IBM, “The Smarter Supply Chain of the Future: Global Chief Supply Chain Officer Study”, IBM Corporation, 2009.

supply chain. Utilizing NC4 program, Cisco has mapped all its critical nodes and set its own criteria for alarms. Monitoring system takes into account previous natural disaster history of the location and climate information. If climate related disruption occurs, an alert is sent to Cisco's risk management team stating for example, "earthquake occurred within 200 miles of Cisco location". Cisco's Supply Chain Risk Management Team utilizes this information and response to potential or immediate risks. Cisco's team performs an impact assessment which includes identifying which nodes are near the natural disaster region, what parts are produced in the affected region, what mitigation/adaptation strategies Cisco should engage in, how much revenue will be lost and what part of market will be affected. After Cisco's Supply Chain Risk Management Team decides on the immediate action plan, it is passed down to different cross function units to be executed. When the 2011 Japan earthquake hit, Cisco's crisis management system sent out an alarm and within 30 minutes Cisco's supply chain incident manager was notified. Within 12 hours, Supply Chain Risk Management team was consisted and business contingency plan was fully activated. The team completed a profile of every supplier sites affected which included the extensiveness of damage, future production capacity, emergency power generation capabilities, alternate sourcing options, time-to-recover, etc. Due to the information monitoring system and Cisco's proactive mitigation strategies, Cisco was able to avoid disruptions down the supply chain in spite of the fact that more than 100 of Cisco's suppliers were hit hard by the earthquake.²⁴⁾

3) Climate-related Operational Flexibility

Operational flexibility is defined as the ability of a manufacturing system to quickly cope with changing environment or unstable external environment.

24) U.S. Resilience Project, "De-risking the Supply Chain: Cisco's Risk Intelligence and Analytic Tools", U.S. Resilience Project, August 2011.

Since there are many types of environmental instabilities, different types of operational flexibility is necessary and Busch (2011) identifies three types of climate-related operational flexibility: supply flexibility, routing and process flexibility and distribution flexibility.²⁵⁾ Supply flexibility describes the ability of an organization to provide a variety of inbound resource sourcing and warehousing.²⁶⁾ This flexibility is utilized when resource supply is slowed or disrupted by climate change related disruptions. Diversifying supply channels of resources and stocking inventory is a way to strengthen supply flexibility. Routing flexibility is responsible for continuing production in case of disruption in resource supply by routing production to other production site. And process flexibility is the ability to continue producing the same products by utilizing different production system or technology. Both routing and process flexibility has the purpose of continuing production even if resources are unavailable due to climate change related disruptions. Lastly, distribution flexibility is the ability to distribute products by utilizing other distribution channels. Also building operation flexibility can include building business contingency plans, practice emergency drills and using playbooks. Playbooks are frameworks that corporations can follow in case of an emergency. It provides detailed step by step action plans which can include risk assessment methods, climate change related natural disaster impact assessment, how to implement mitigation strategies, etc.

4) Strategic Climate Integration

Strategic climate integration refers to the organizational capability to address and incorporate climate change into the continuous, long-term

25) Busch, Timo., "Organizational Adaptation to Disruptions in the natural Environment: The Case of Climate Change", *Scandinavian Journal of Management*, Vol 27, 2011, pp. 389~404.

26) Day, G. S., "The capabilities of market-driven organizations", *Journal of Marketing*, Vol. 58, No.4, 1994, pp. 37~52.

innovation process. Continuous innovation can be defined as the “changing experiential base of organizational activities, routines, and goals [targeting the long-term optimization of] technologies, processes, specifications, inputs, and products”.²⁷⁾ There are two types of strategic integrated climate change which are improvements of existing processes and the development of new process configurations. Improvements involve incremental innovation and new process requires radical innovation. Both improvement and new strategic climate integration is crucial for long-term organizational adaptation to disruptions in the environment.

V. Conclusion

Two types of responses to climate change exist. First is climate mitigation which includes efforts of reducing CO₂ and GHG emissions. Second response is climate adaptation process which is establishing climate resilience in the supply chain. The two are inherently different since mitigation strategy focus on eliminating the source of climate change and is long term in nature but adaptation strategy is moderating the impact of potential or current climate change. In order to embed climate resilience in the supply chain, mitigation strategies and adaption strategies must be implemented at the same time. Corporation’s adaptation to climate change related natural disaster can be seen as a response that includes mitigation and adaptation strategies simultaneously. A comprehensive climate change resilience supply chain approach has to be developed. This paper illustrated guidelines and adaptation process framework businesses can utilize in order to build climate resilience. Screening process before the actual assessment of risk was

27) Sharma, Sanjay., Vredenburg, Harrie., “Proactive Corporate Environmental Strategy and the Development of Competitively Valuable Organizational Capabilities”, *Strategic Management Journal*, Vol. 19, 1998, pp. 729~753.

introduced as well as the whole adaptation process of establishing information system and strengthening climate-related operational flexibility.

Climate change related natural disaster adaption is a relatively new topic which substantial research remaining. Further research can be focused on barriers to implementing climate change adaptation and building a comprehensive playbook for climate change related natural disasters that can be applied under any circumstances. There are six basic barriers in climate change adaptation. Barrier 1 relates to climate change information and decision-making. These barriers include problems such as uncertainty about future climate impact and disconnect information between information providers and information users. Barrier 2 related to lack of resources to begin and sustain adaptation efforts and example problems of lack of financial resources and limited staffing capacity. Third barrier is fragmentation of decision making and entails problems such as lack of coordination within and across agencies, private companies and nongovernmental organizations. Barrier 4 concerns institutional constraints such as lack of institutional flexibility and rigid law and regulations. Barrier 5 relates to lack of leadership when climate adaptation is traditionally spearheaded by governments. Lastly barrier 6 is divergent risk perceptions, cultures and values. Future research topics can be in relation to systematical elimination of these barriers.

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ABSTRACT

Corporation's Adaptation to Climate Change Related Natural Disasters : Embedding Resiliency in Supply Chain

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Two types of responses to climate change exist. First is climate mitigation which includes efforts of reducing CO₂ and GHG emissions. Second response is climate adaptation process which is establishing climate resilience in the supply chain. The two are inherently different since mitigation strategy focus on eliminating the source of climate change and is long term in nature but adaptation strategy is moderating the impact of potential or current climate change. In order to embed climate resilience in the supply chain, mitigation strategies and adaption strategies must be implemented simultaneously. Corporation's adaptation to climate change related natural disaster can be seen as a response that includes mitigation and adaptation strategies simultaneously. A comprehensive climate change resilience supply chain approach has to be developed. This paper illustrated guidelines and adaptation process framework businesses can utilize in order to build climate resilience. Screening process before the actual assessment of risk was introduced as well as the whole adaptation process of establishing information system and strengthening climate-related operational flexibility.

Key Words : Climate Change, Natural Disasters, Adaptation, Mitigation,
Monitoring System