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Investigation of Disruption Management Practices and Environmental Impact on Malaysian Automotive Supply Chains: A Case Study Approach

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ABSTRACT

Much focus on managing a supply chain in the event of disruption has been on the financial consequences and the service level impact on the customers. The negative impact caused by the disruption could influence a company's profit and market share. Nonetheless, the importance of the environmental impact consideration in the supply chain disruption management has not been emphasised in the existing literature despite research findings that highlight the impact of some resilient supply chain practices on its environmental sustainability. This paper aims to assess the relationship between supply chain mitigation and recovery practices and its environmental impact. To achieve this objective, a case study was employed where semi-structured interviews were conducted at selected automotive companies in Malaysia. The results show that most disruption mitigation and recovery practices of a supply chain have a medium impact on its environmental performance. In particular, the production process during supply disruption recovery has the highest influence on environmental performance in the form of waste generation and use of energy. The results of this study can be used by supply chain managers to focus their efforts in the right direction in order to achieve cost objectives, service levels and environmental goals during the management of disruptions.

Keywords: *Supply Chain Disruption Management; Mitigation and Recovery Practices; Environmental Impact; Case Study*

INTRODUCTION

Supply chain (SC) disruptions could reportedly cause a negative market perception and long-term devastating effects on shareholder value; thus an effective and efficient strategy is essential (Hendricks & Singhal, 2012). According to Vakharia and Yenipazarli (2009), effective management of SC disruption can be achieved through a structured approach using an SC risk management framework. The implementation of mitigation tactics is undertaken after the earlier process of risk identification, risk measurement, risk mitigation prioritisation and risk mitigation evaluation (Bradley, 2014). Various mitigation and recovery strategies have been discussed in the literature. One case is Chang et al. (2015), who classified building redundancy and flexibility as broad categories for mitigating disruption risk in SC. Similarly, Sodhi and Tang (2012) proposed building flexibility and redundancies in the SC. According to the authors, an extra inventory, extra back-up production capacity, and extra back-up suppliers can help to minimise the impact of delays and disruptions in the supply chain. A framework of prevention, response, protection, and recovery policies was proposed by Hopp et al. (2013). Backup inventories and/or backup capacity count among the protection plans that could allow downstream nodes to continue working during the disruption. Snyder et al. (2016) proposed a mitigation strategy in the form of inventory, sourcing and demand flexibility, facility location and interaction with external stakeholders. In addition to the inventory and supplier strategy, Kamalahmadi and Parast (2017) emphasised that regionalising a supply chain is also an effective mitigation approach. Meanwhile, Shao (2013) proposed that firms improve mitigation capabilities by reconsidering sourcing decisions, improving their supply chain agility, making contingency plans, and concentrating on operational and supply chain policies and initiatives that promote cooperation, integration and timely information-sharing. Oke and

Gopalakrishnan (2009) proposed a mitigation plan which involved working with suppliers to find alternative raw materials for global consumption risk. Besides that, Marley et al. (2014) proposed that an alternative strategy for supply chain disruption mitigation can be achieved by designing a simple process.

In addition to disruption management strategy, SC operations also need a plan to become more environmentally friendly since the processes in SC consume a lot of energy and water, generate waste, and produce carbon emissions. A wide array of possible damage to the environment caused by SC has been stated in the literature. Tang and Zhou (2012) listed electronic waste, waste water, and greenhouse gas emissions as some of the environmental effects. Chin et al. (2015) listed environmental impact in terms of carbon monoxide emissions, discarded packaging materials, scrapped toxic materials, traffic congestion and other forms of industrial pollution. Eskandarpour et al. (2015) highlighted the following environmental impacts: climate change, biochemical oxygen demand, damage to human health and water footprint. Moreover, the environmental performance considered were the generation of waste, use of energy, and material recovery. Water and land pollution were also commonly included as environmental impacts that can originate from SC operation. In research by Esfahbodi (2016), the environmental performance considered from the adoption of green SC management practices are linked to the amount of environmental pollutants. Hence, several approaches have been introduced such as green supply chain management where green practices or environmental considerations are integrated throughout the supply chain, such as in the purchasing process, product design and logistics activities (Azevedo et al., 2011).

Integration of environmental considerations into various parts of the SC processes has been motivated by the goal of creating a sustainable and resilient supply SC. Even though the importance of cost and service level impact on the supply disruption recovery has been recognised, the need for environmental consideration in the supply disruption decision-making process has yet to be established. Findings from the study by Govindan et al. (2014) showed that resilient supply chain management practices such as supply chain risk management do have a significant impact on a supply chain's environmental sustainability.

In the Malaysian automotive industry, government policy, legislation and stakeholder awareness have created a demand for companies to integrate environmental impact management into every aspect of supply chain operations. Use of international standards like ISO 14001 is an approach that can be undertaken by an organisation to have an effective environmental management system. In connection with this scenario, the aim of this study is to assess the relationship between supply chain disruption management practices and their environmental impact, particularly in the Malaysian automotive company setting. The expected outcome from this study is a better overview and understanding of the influence of disruption mitigation and recovery practices on SC environmental sustainability performance. In addition, the results can be an indication of how environmental criteria can be incorporated into operational decision-making during supply disruption management.

METHODOLOGY

A case study method was conducted to achieve the objective of the study. According to Baxter & Jack, (2008), a case study approach is a valuable method to study individuals or organisations in complex phenomena within their contexts. For this study, the data concerning the personal judgment of the participants was obtained through semi-structured interviews. The same methodology can be found in Govindan et al. (2014), in which the authors studied the impact of lean, green, and resilient supply chain management practices on sustainability. Other relevant studies included Zailani et al. (2012), who used a questionnaire method to study the practices of environmental purchasing and sustainable packaging, and the performance of a sustainable supply chain.

Company background

Three companies that were selected were automotive companies in Malaysia, where this study was conducted. The samples included one original equipment manufacturer (OEM) company while the other two are first tier and second tier suppliers. The representatives from the companies were senior executives or managers experienced in supply chain management. Table 1 lists the details of the company profiles and the position of the five respondents of the case study.

TABLE 1. Company profiles

	Core product	Position in the supply chain	Respondents
Company A	Cars	Original equipment maker	Senior executive – Procurement
Company B	Roll-formed metal automotive door sash	First- tier Second- tier	Deputy General Manager Manager - Production/Production planning/control Engineer - Quality management
Company C	Plastic injection mouldings automotive part	First-tier Second-tier	Senior Manager – Vendor and business development

Data collection and analysis

Based on the literature review of SC disruption management, green SC management and sustainable SC management, the semi-structured interview was built into a questionnaire-type form to ease and guide the interview, and to assist in the analysis of the answers. Based on their experience and opinion, the respondents were asked to rate the impact level of ten different mitigation and recovery practices on six types of environmental performance. A score range from 1 (No Impact) to 5 (Very High Impact) was used to measure the responses of the participants.

RESULTS AND DISCUSSIONS

Case study results

There were two components of the case study: the responses obtained from the list of semi-structured interview questions, and also the findings from the open-ended questions. Table 2 summarises the results from the semi-structured interview questions followed by the results analysis. Additional inputs from the respondents are discussed in the next section.

TABLE 2. Mean score results

	Mean Value					
Supply Chain Disruption Mitigation and Recovery Practices	Impact on waste generation	Impact on use of energy	Impact on carbon emission	Impact on water pollution	Impact on production of hazardous materials	Impact on soil/land
Selection of facility location	3	3.2	2.8	2.6	2.8	2.8
Selection of infrastructure	3.2	3.2	3.2	2.4	3	3
Selection of supplier	2.8	3	3	2.2	2.6	2.4
Use of alternative materials	2.2	3.2	2.4	2	2.8	2
Use of inventory reserve/safety stocks	2.4	2.8	2.2	2.4	2.6	2.2
Use of alternative sourcing/backup supplier	2.6	2.8	2.8	2.4	2	2.2
Use of capacity reserve	3.2	3.2	2.4	2.4	2.6	2.2
Use of alternative machine	2.8	3.4	2.6	2.4	2.6	2.4
Use of alternative transportation	3	3	3.4	1.8	2.6	2.6
Production process during supply disruption recovery	4	3.4	2.8	2.4	3.6	3

Table 2 above lists the mean values of sixty result items as scored by the respondents. These values represent the impact level and the relationship between ten mitigation/recovery practices and six environmental impact criteria.

From the results, the production process during supply disruption recovery has the highest mean score with regard to impact level on waste generation. A high mean score was also obtained for impact on production of hazardous materials and use of energy. This result can be considered as consistent with the established fact that the manufacturing process is energy intensive and also a large source of carbon emissions. Thus, it has been suggested in the literature that the reduction of three aspects - waste, consumption of raw materials, and toxicity in the manufacturing material - are essential in achieving environmental sustainability (Chakravarty, 2014].

Among the other SC practices, the 'selection of infrastructure' scores second highest in impacting environmental performance of a SC, with equal mean scores of 3.2 for these three criteria: impact on waste, use of energy and carbon emission. In the automotive industry context, the term 'infrastructure' refers to the basic requirements for the operation of the SC such as buildings, roads, and power supplies. In view of this, the selection of infrastructure not only influences economic growth and development, but also the sustainability of an organisation (Luger et al., 2013). The same rationale can be applied for the result of 'facility location selection' which scores a mean value of 3 for impact on waste generation, 3.2 for impact on use of energy, and 2.8 for impact on carbon emissions. Since a SC will select a suitable facility location based on the available infrastructure, among other factors, the results for these two practices are consistent with each other.

The result also shows that the environmental performance most impacted by the use of alternative transportation is carbon emissions. This finding is an expected outcome since logistics activity is one the primary sources of carbon emissions, mainly due to the engine combustion process. Meanwhile, the use of capacity reserve scores an equal mean value of 3.2 for impact on the generation of waste and use of energy. This result could be justified by the need for a longer setup process when a different machine or equipment was used. There might be more consumption of raw materials and electricity usage before the actual production run. Similarly, for 'use of alternative materials', the mean score 3.2 for the use of energy could be caused by the longer setup process required to configure the parameter settings for the production machine to run smoothly.

Other findings show that the selection of supplier scores a mean value of 3.0, representing a medium impact on the environmental performance in terms of energy usage and carbon emissions. The justification for this result would be linked to the supplier's machine technology, since a different machine could require a different amount of energy during the production process. In addition, the selection of a supplier's location would determine the transportation distance which would directly influence carbon emissions.

The results also show that the lowest mean score is obtained by the use of alternative transportation with impact on water pollution. This finding is reasonable since water pollution is usually caused by the discharge of industrial waste or pollutants to the river. Another item worth mentioning is that a low impact score was obtained for the use of alternative sourcing/backup supplier and the use of inventory reserve/safety stock.

With an overall mean value of 2.7, it can be emphasised that most supply chain disruption mitigation and recovery practices have a medium impact on environmental performance. Figure 1 and Figure 2 below illustrate graphical representations of the results. Figure 1 shows the total impact score for SC disruption mitigation and recovery practices and their impacts on carbon emission, use of energy, and waste generation. Meanwhile, Figure 2 shows the total scores for impact on water, soil/land, and the production of hazardous material.

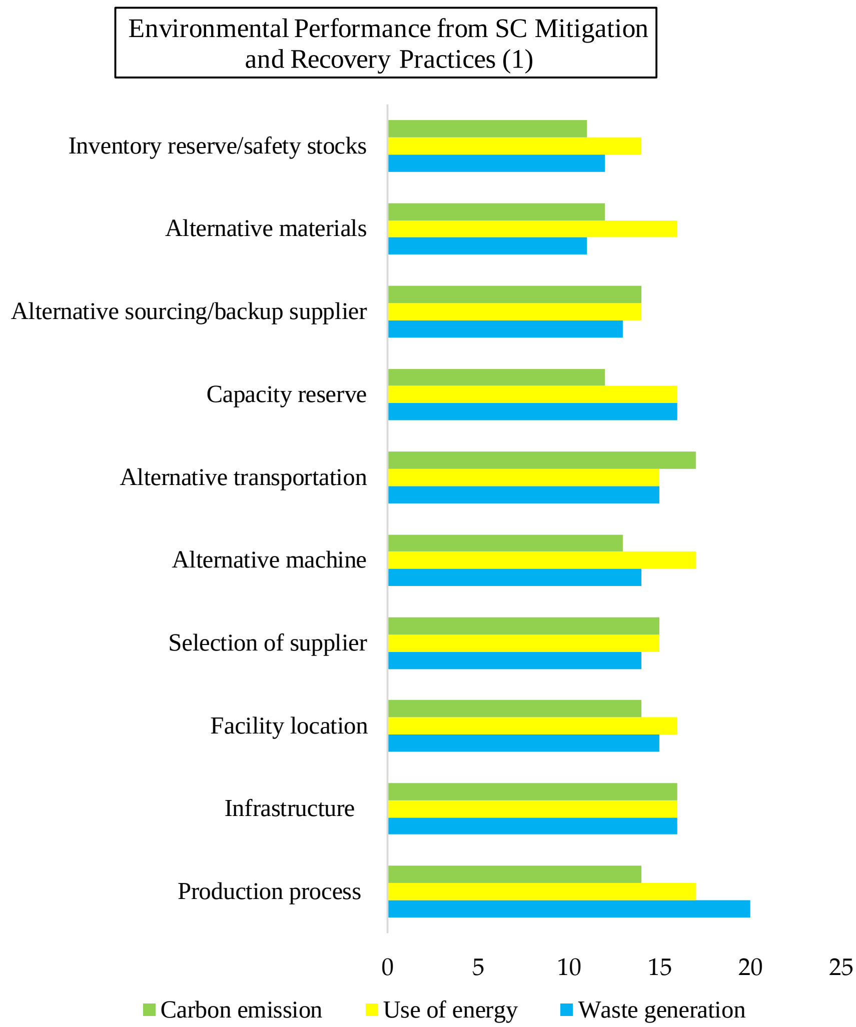

FIGURE 1. Total score for impact on carbon emissions, use of energy and generation of waste from the mitigation and recovery practices

Figure 1 shows the top three environmental performances most impacted by SC disruption mitigation and recovery practices. As discussed, the high impact on waste generation and use of energy is mainly due to the manufacturing process and the recovery process which require high electricity usage and consumption of raw materials. Meanwhile, the impact to carbon emissions is primarily from the transportation activity which will be influenced by the mode of transport and the location of the facility and the suppliers.

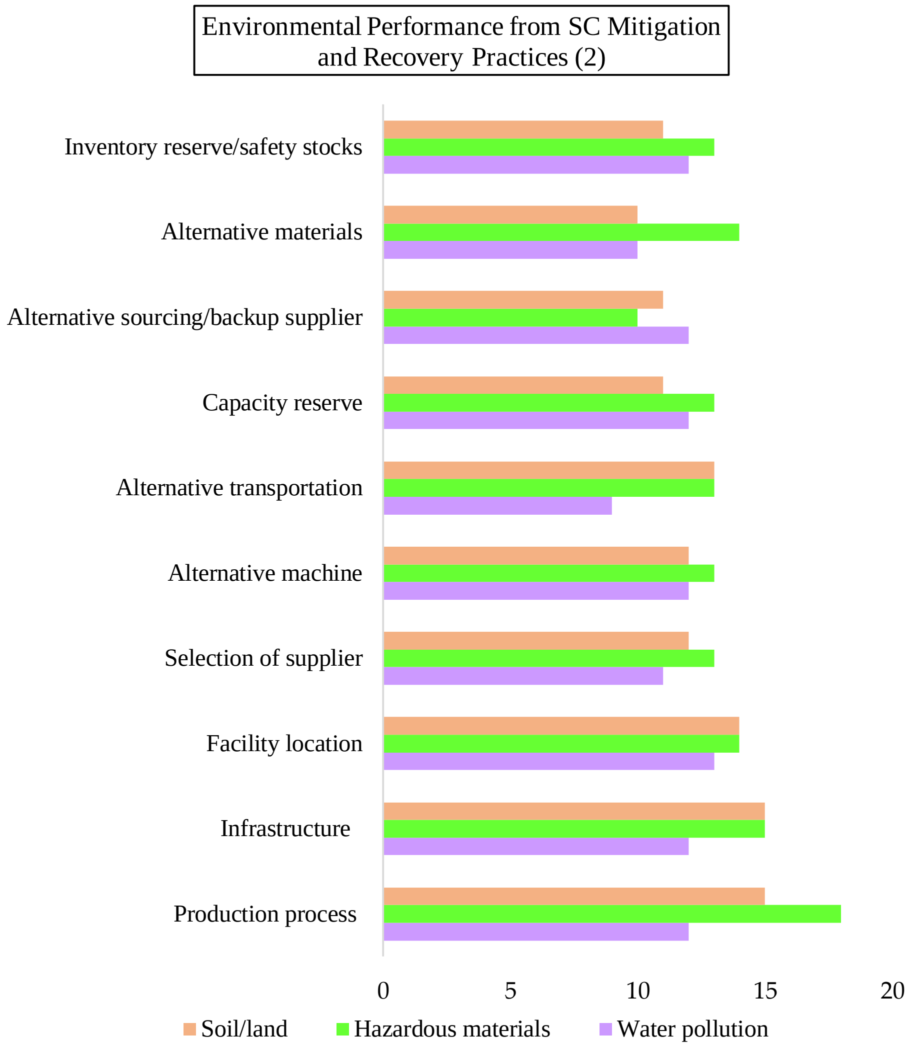

FIGURE 2. Total score for impact on soil, water, and hazardous material from the mitigation and recovery practices

Figure 2 shows the scores for the environmental performance in terms of impact on soil/land, water, and production of hazardous material. From the graph, it can be seen that the production process, the selection of infrastructure, the selection of facility location, and the use of alternative material will have a considerable impact on the production of hazardous materials. Taking the example of the automotive industry, some hazardous substances such as acids, diesels, oil, and solvents can be commonly found in the production line. Furthermore, for the facility and infrastructure, the storage and work area must be well designed to ensure that the potential hazardous fumes and hazardous dust from the production process do not harm the people or the environment. In addition, it can be seen from Figure 2 that the facility and infrastructure selection also scores more than the other practices in impacting soil and water, mostly due to the industrial waste and waste water treatment.

Open-ended questions

In addition to the questionnaire-like information, a further interview was conducted for a better understanding of the management process in managing SC disruption. Information on the disruptions that have occurred in the past was sought to ascertain if any environmental impact was being considered. Some of this feedback is listed in Table 4.

TABLE 3. Actual practices of disruption mitigation action and its environmental impact consideration

Type of disruption	Mitigation action	Environmental impact consideration (if any)
Fire incident	Part resourcing to other vendor	Appointment of vendor that complies with ISO14001
Water supply disruption	Order water tank	No direct environmental impact being considered.
Machine breakdown	Repair work	Oil spillage - generation of scheduled waste

As per the feedback by the interviewees, the environmental impact on the SC is only sometimes considered in the process of making mitigation and recovery plan decisions. According to the interviewees, in general there is already an indirect environmental consideration in supply disruption management. In the example of the generation of more waste due to machine failure, the disposal of waste would follow the scheduled waste disposal practice. Based on several managers' opinion, through compliance with international standards such as ISO14001, the environmental consideration should have been considered in the operation of the SC. For the first tier and second tier suppliers, there is more effort on to consider the environmental impact through participation in environmental improvement initiatives by the OEM such as green procurement programmes. In addition, by fulfilling customers' product requirements, like hazardous content limit, the environmental impact consideration is simultaneously being addressed.

CONCLUSIONS

In this study, the relationship between supply chain disruption mitigation and recovery practices, and their impact on environmental performance was explored to establish the importance of integrating the two entities. It can be emphasised that the production process during supply disruption recovery has the highest influence on SC environmental performance. In addition, the environmental factors that are affected most are carbon emissions, use of energy and generation of waste. Overall, the results showed that most SC disruption mitigation and recovery practices had medium or moderate impacts on environmental performance.

With this information, SC managers can focus their efforts in the right direction in order to achieve cost objectives, service levels and the environmental targets during the management of disruption. In addition, the different impact levels of different SC mitigation practices can be translated into different weightage values for SC optimisation or modelling purposes.

The limitation of this research was the number of participating companies and the location of the study. It is possible that observations in this paper may be relevant only to Malaysian automotive companies. However, the findings can be strengthened by more participation from other companies, and the inclusion of other manufacturing sectors.

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REFERENCES

Azevedo, S. G., Carvalho, H., & Machado, V. C. 2011. The influence of green practices on supply chain performance: A case study approach. *Transportation Research Part E: Logistics and Transportation Review*, 47(6): 850–871.

Bradley, J. R. 2014. An improved method for managing catastrophic supply chain disruptions. *Business Horizons*, 57(4): 483–495.

Chakravarty, A. K. 2014. *Supply Chain Transformation*. Springer, Berlin, Heidelberg.

Chang, W., Ellinger, A. E., & Blackhurst, J. 2015. A contextual approach to supply chain risk mitigation. *International Journal of Logistics Management*, 26(3): 642–656.

Chin, T. A., Tat, H. H., & Sulaiman, Z. 2015. Green supply chain management, environmental collaboration and sustainability performance. *Procedia CIRP*, 26: 695–699.

Esfahbodi, A., Zhang, Y., & Watson, G. 2016. Sustainable supply chain management in emerging economies: Trade-offs between

environmental and cost performance. *International Journal of Production Economics*, 181: 350–366.
Eskandarpour, M., Dejax, P., Miemczyk, J., & Peton, O. 2015. Sustainable supply chain network design: An optimization-oriented review. *Omega (United Kingdom)*, 54: 11–32.
Govindan, K., Azevedo, S. G., Carvalho, H., & Cruz-Machado, V. 2014. Impact of supply chain management practices on sustainability. *Journal of Cleaner Production*, 85: 212–225.
Hendricks, K. B., & Singhal, V. R. 2012. Supply Chain Disruptions and Corporate Performance. In H. Gurnani, A. Mehrotra, & S. Ray (Eds.), *Supply Chain Disruptions: Theory and Practice of Managing Risk* (pp. 1–19). Springer London.
Hopp, W. J., Iravani, S. M. R., & Liu, Z. 2013. Mitigating the impact of disruptions in supply chains. In *Supply Chain Disruptions: Theory and Practice of Managing Risk* (pp. 21–49).
Kamalahmadi, M., & Parast, M. M. 2017. An assessment of supply chain disruption mitigation strategies. *International Journal of Production Economics*, 184, 210–230.
Luger, M., Butler, J., & Winch, G. 2013. *Infrastructure and manufacturing: their evolving relationship*.
Marley, K. A., Ward, P. T., & Hill, J. A. 2014. Mitigating supply chain disruptions – a normal accident perspective. *Supply Chain Management: An International Journal*, 19(2): 142–152.
Oke, A., & Gopalakrishnan, M. 2009. Managing disruptions in supply chains: A case study of a retail supply chain. *International Journal of Production Economics*, 118(1): 168–174.
Shao, X. F. 2013. Supply chain characteristics and disruption mitigation capability: an empirical investigation in China. *International Journal of Logistics Research and Applications*, 16(4): 277–295.
Snyder, L. V., Atan, Z., Peng, P., Rong, Y., Schmitt, A. J., & Sinsoysal, B. 2016. OR/MS models for supply chain disruptions: A review. *IIE Transactions (Institute of Industrial Engineers)*, 48(2): 89–109.
Sodhi, M. S., & Tang, C. S. 2012. Managing Supply Chain Risk. In *International Series in Operations Research & Management Science*.
Tang, C. S., & Zhou, S. 2012. Research advances in environmentally and socially sustainable operations. *European Journal of Operational Research*, *223*(3), 585–594.
Vakharia, A. J., & Yenipazarli, A. 2009. Managing Supply Chain Disruptions. *Foundations and Trends® in Technology, Information and Operations Management*, 2(4).
Zailani, S., Jeyaraman, K., Vengadasan, G., & Premkumar, R. 2012. Sustainable supply chain management (SSCM) in Malaysia: A survey. *International Journal of Production Economics*, 140(1): 330–340.