Supply Chain Resilience in the New Zealand FMCG Sector: A Study of the 2021 Canterbury Flooding

Aidan Hamilton
University of Waikato, Hamilton, NZ
aidan.hamilton@waikato.ac.nz

Cécile L'Hermitte
University of Waikato, Hamilton, NZ
cecile.lhermitte@waikato.ac.nz

ABSTRACT

Disasters can severely disrupt the flow of Fast-Moving Consumer Goods (FMCGs) in New Zealand (NZ), preventing the replenishment of essential products and causing shortages on retailers' shelves. This paper presents work-in-process research that aims to better understand how the NZ FMCG retailers build resilience into their replenishment operations to mitigate disruptions in the wake of a disaster. The two key components of supply chain resilience (redundancy and flexibility) are investigated in the context of the 2021 Canterbury flooding. A survey was used to collect data on retailers' routine replenishment operations, the impacts of the flooding, and practices mitigating disruptions. The preliminary findings suggest that redundant inventory is used to compensate for insufficient flexibility in the NZ freight system (due to not only the lack of adequate secondary roads and alternative modes of transport, but also the centralised distribution system limiting the sources of supply). This study contributes a better understanding of the FMCG distribution and replenishment operations in NZ and highlights the need for public and private investments (e.g. redundant transport infrastructure and distribution facilities). Additional research investigating the most influential investments to improve the ability of the FMCG sector to manage post-disaster freight disruptions would benefit the literature.

Keywords

Freight Disruptions; Supply Chain Resilience; Redundancy; Flexibility; Fast-Moving Consumer Goods

INTRODUCTION

The COVID-19 outbreak and other recent events have brought supply chain resilience to the forefront of business decisions and academic discussions. Supply chain resilience is defined as "the adaptive capability of the supply chain to prepare for unexpected events, respond to disruptions, and recover from them by maintaining continuity of operations" (Ponomarov and Holcomb, 2009, p. 131). Building resilience into freight systems is critical to mitigate the impacts of major disruptive events such as disasters (Sheffi, 2019). By causing infrastructure damage and disrupting deliveries, disasters expose the fragility of supply chain systems that have been designed to achieve a high level of efficiency and cost control in normal circumstances (Sáenz and Revilla, 2014). In particular, the continuous implementation of efficiencies and cost reduction strategies in the distribution of Fast-Moving Consumer Goods (FMCGs, namely low-cost, non-durable household products quickly sold and replenished) has left retailers vulnerable to supply chain disturbances and, ultimately, to shortages of goods on store shelves (Agigi et al., 2016; Simba et al., 2017). Resilient supply chain operations are critical for FMCG retailers that cater for essential everyday needs by making large volumes of consumer goods (including food, drinks, and personal care) widely available (Bala and Kumar, 2011). Despite the FMCG sector's essential economic and societal role (Sable, 2019), academic studies investigating the resilience of FMCG distribution systems and the strategies implemented to ensure supply chain continuity and product availability scarcely focuses on post-disaster response and recovery.

To fill this gap, this paper presents work-in-process research focusing on the May/June 2021 Canterbury flooding that damaged major transport links and disrupted FMCG distribution operations in the lower South Island of New Zealand (NZ). The following research question guided the investigations: *how can the NZ FMCG retailers build resilience into their replenishment operations to mitigate disruptions in the wake of a disaster?*

To address this question, data was collected through an online survey of the FMCG retailers affected by the 2021 Canterbury flooding. The analysis of the responses collected so far indicates that participants build buffer stock

to enhance resilience and ensure that goods are available on shelves. However, the lack of flexibility in the NZ freight system (few adequate secondary roads, lack of alternative modes of transport, and limited backup sources of supply) leaves them vulnerable and limits their ability to re-arrange replenishment operations in the wake of a disaster. Although this research project is still in the early stages, the preliminary results contribute a better understanding of the FMCG distribution and replenishment operations in the NZ context.

The remainder of this paper is structured as follows: the next section reviews the literature on supply chain resilience and distribution practices. The research context and the methodological approach are subsequently presented, before the findings of the research are reported, and then discussed. The limitations of this study, its contribution, and concluding comments are provided in the final section.

LITERATURE REVIEW

Supply Chain Resilience: Redundancy and Flexibility

For almost two decades, the supply chain literature has highlighted the critical role of two key components of supply chain resilience (redundancy and flexibility) and the importance of building them into supply chain systems (Christopher and Peck, 2004). Redundancies are additional resources and excess capacity kept as a buffer to manage fluctuations and mitigate disruptions. Commonly used in supply chain management, this capacity-adding strategy includes buffer inventory, backup suppliers, additional facilities, and low capacity utilisation rates (Tomlin, 2006; Knemeyer et al., 2009; Stecke and Kumar, 2009). As discussed by Sheffi (2019), redundancy provides an immediate (but short-term) solution to deal with disruptive events by quickly smoothing fluctuations in the demand and/or supply of goods. Since the building of redundancy is a strategy incurring a high level of upfront costs without providing benefits until the disruption occurs (Rice and Caniato, 2003; Kamalahmadi and Parast, 2017), it is often described as an insurance policy or a just-in-case approach (Sheffi and Rice Jr., 2005).

Flexibility is the ability to rapidly reconfigure operations in order to mitigate disruptions in the flow of goods and to ensure that they are delivered when and where they are needed (Sheffi and Rice Jr., 2005; Sreedevi and Saranga, 2017; Sheffi, 2019). Common aspects of flexibility include the ability to swiftly re-route freight movements across alternative routes/modes when a route/mode is unavailable and/or to use alternative sources of supply, including alternative suppliers or alternative distribution centres (Tang, 2006; Agigi et al., 2016). Compared to redundancy, flexibility requires some initial reconfiguration time but provides a longer-term solution (Sheffi, 2019).

Redundancy and flexibility are commonly presented as contrasting strategies in the literature. While the building of redundancy is viewed as a passive strategy incurring a high level of cost (e.g. capital investment and depreciation), flexibility is often considered a more dynamic and cost-avoidance approach (Kamalahmadi et al., 2021). However, as explained by Sheffi (2019), flexibility requires a level of redundancy built into the supply chain system. For example, building a flexible distribution network with geographical dispersion (e.g. two or three distribution centres serving retail stores in specific service areas) calls for a lower level of capacity utilisation at the distribution centres (to enable them to serve different service areas when handling disruptions).

Efficient (and Fragile) Distribution Practices

Due to the growing use of information technology enhancing supply chain visibility (DeGroote and Marx, 2013), to the prevalence of lean practices, and to the constant quest for costs savings (Womack and Jones, 1994; Holweg, 2007), freight operations have been streamlined and spare resources and capacity systematically eliminated from supply chain systems. In other words, supply chains have been designed to operate like clockwork, with a high level of efficiency and little latent capacity (Hendricks and Singhal, 2012). From the late 1980s, these highly efficient practices have been applied to downstream supply chain operations (i.e. distribution operations) in order to squeeze distribution costs and, in turn, increase profit (Zylstra, 2006; Reichhart and Holweg, 2007). More specifically, inventory has been taken out of the distribution systems by promoting just-in-time deliveries, single sourcing has been implemented to reduce purchasing prices and the costs of managing the supplier base, and distribution operations have been concentrated to achieve economies of scale and lower transaction costs (Hendricks and Singhal, 2012). Concentration has been carried out, for example, by centralising distribution and arranging replenishment from a small number of large distribution centres (Agigi et al., 2016).

Although transitionally efficient, these practices have increased the fragility of distribution systems by leaving little or no capacity to absorb and mitigate shocks, namely little or no redundancy and flexibility. This, in turn, has increased the chance of disruptions in distribution operations and the risk of delays and stock-outs (Hendricks and Singhal, 2012). These concerns are particularly apparent in FMCG distribution systems that are characterised by a high level of concentration and typically consist of large retail players with central, strategically located distribution centres that continuously replenish a vast number of stores operating under their banners. In addition, trucks are predominantly used for moving FMCGs between distribution centres and the retail stores, limiting the

opportunity for flexible transport when roads are inaccessible (Kellner et al., 2013; Rodrigues and Potter, 2013; Manders et al., 2016).

RESEARCH CONTEXT AND METHODOLOGY

2021 Canterbury Flooding

NZ is prone to natural hazards such as floods, earthquakes, tsunamis, and volcanic eruptions. Due to the country's over-reliance on road transport, natural hazards and the subsequent road infrastructure damage frequently disrupt freight operations (Davies et al., 2017). This study focuses on the May/June 2021 Canterbury flooding that made major transport links inaccessible and disrupted transport in the lower South Island of NZ. From 29th to 31st May, severe rainfalls affected the Canterbury region, with the largest accumulation of rain (526 millimetres in 48 hours) recorded in Mt Somers (Environment Canterbury, 2021). The National Institute of Water and Atmospheric Research (NIWA) estimates that the probability of such an extreme weather event is once every 200 years (NIWA, 2021). As a consequence, the Canterbury region experienced widespread flooding and declared a state of emergency on 30th May (Environment Canterbury, 2021). Floodwaters caused significant infrastructure damage to bridges, railways, and state highways in the Christchurch, Ashburton, Waimakariri, Selwyn, Timaru, Hurunui, and Mackenzie districts (McDonald, 2021; Stuff, 2021). As a result of the infrastructure damage and the subsequent road closures, trucks had to travel almost 900 additional kilometres between Christchurch and Timaru, increasing the travel time from 2 hours to 13 hours (Newstalk ZB, 2021). Figure 1 shows the road closures in the aftermath of the flooding as well as the alternative route used.

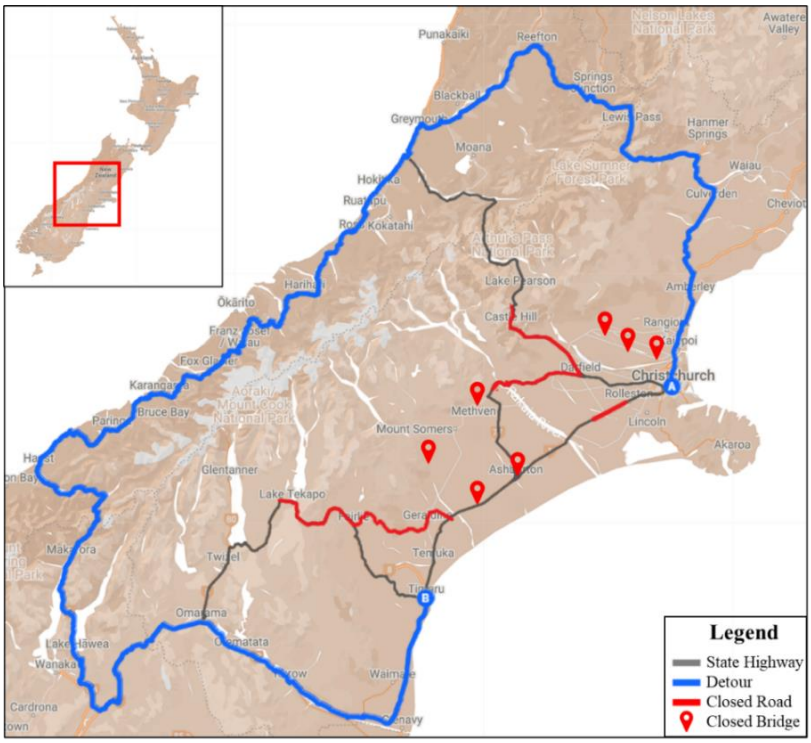

Figure 1. Transport Adjustments in the Wake of the 2021 Canterbury flooding

The 2021 Canterbury flooding was selected for this study because it severely affected the deliveries of consumer goods to the lower South Island (including Ashburton, Timaru, Oamaru, Dunedin, Mosgiel, Gore, and Invercargill) and resulted in shortages on the shelves of supermarkets and other retailers (Harding, 2021; McDonald, 2021). It was, therefore, expected to provide relevant insight into the resilience of the NZ FMCG sector. In addition, this event was sufficiently recent to reflect the current state of practice in this sector.

Data Collection and Analysis

A survey was used to collect data from the grocery retailers located in the three lower South Island regions impacted by the 2021 Canterbury flooding (Canterbury, Otago, and Southland). While Otago and Southland experienced relatively little flooding, the FMCG distribution operations within these regions were disrupted by

the road closures in Canterbury (Harding, 2021; McDonald, 2021). The survey participants included supply chain professionals and store managers of grocery retail outlets in the above regions. Questions focused on their routine replenishment operations, the impacts of the Canterbury flooding, and the practices used/recommended to mitigate disruptions. The data was collected anonymously.

The survey was administered in a challenging time for the FMCG retailers since data collection started in December 2021, namely during the busy Christmas season (which was followed by the NZ Omicron outbreak in January 2022). In this context, retailers were overworked, making it difficult to achieve an adequate level of survey participation. At the time of writing, only 14 usable responses have been received, and the data collection is currently suspended. The responses were analysed by using exploratory data analysis, a statistical analysis method that conveys information through visual representation of the data. Given the limited number of responses and the fact that no definitive findings can be presented at this stage, exploratory data analysis is deemed appropriate to preliminarily address the objectives of this research, namely to perform an initial assessment of the impacts of natural hazards on FMCG distribution operations in NZ and to identify the mitigation practices used.

FINDINGS

The findings are reported in the same order as respondents answered the survey questions.

Sources of Supply

All participating retailers reported using a combination of distribution centres and direct suppliers for replenishment. However, 57% of the participants have access to only one distribution centre, limiting their alternative sources of supply and, therefore, their flexibility when roads are closed in the wake of a disaster.

Replenishment Intervals

Respondents were asked to indicate their replenishment intervals for a range of product categories. As shown in Figure 2, retailers appear to have uniform intervals across the various categories. 86% of the participants have replenishment intervals of 3 days or less in place. 50% of the respondents replenish every day, 36% every 2-3 days, 14% every 4-7 days, and no respondents have restocking intervals longer than seven days. These results indicate that retailers place regular orders with their distribution centres and direct suppliers, and that small, frequent quantities are replenished, most likely to decrease inventory levels.

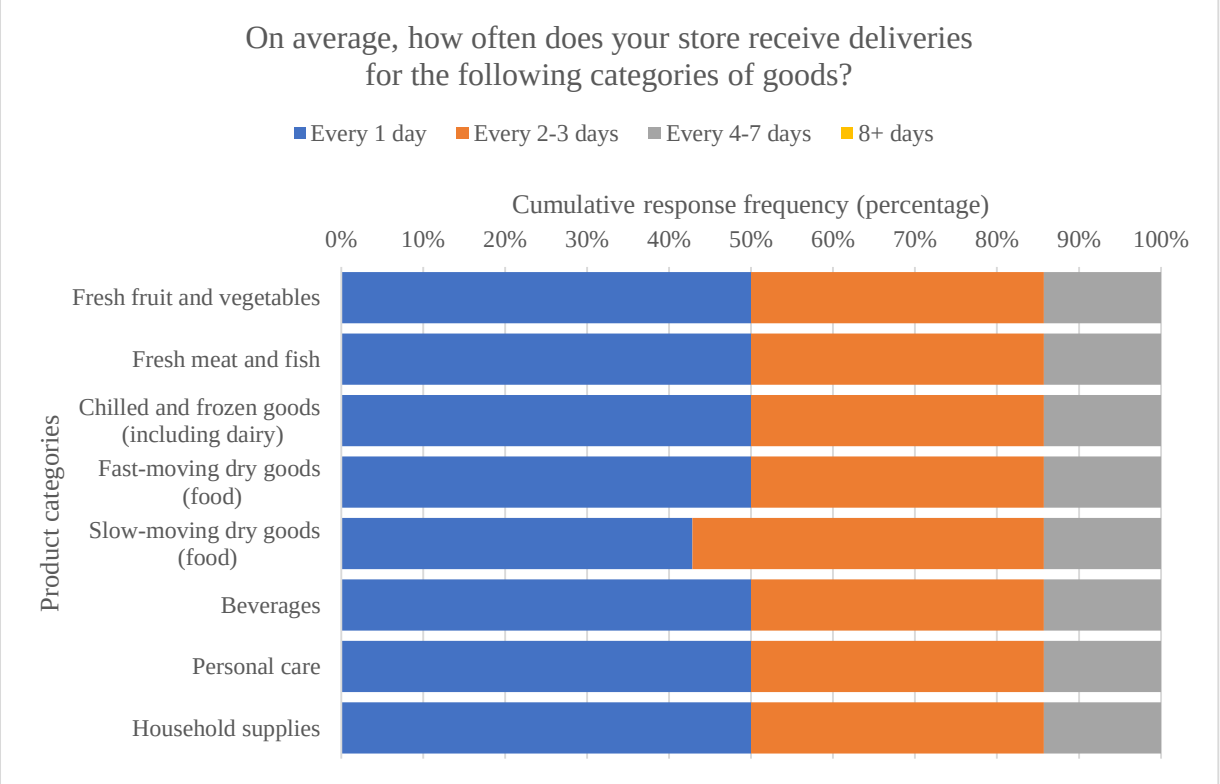

Figure 2. Restocking Interval by Product Category

Buffer Stock

As mentioned in the literature review, the carrying of buffer stock is a redundancy practice commonly used in supply chain operations. Respondents were asked to indicate their buffer stock levels for a range of product categories. The data indicates that buffer stock levels vary with product category and perishability. In particular, Figure 3 shows that at least 79% of the respondents maintain seven or fewer days of buffer stock for perishable items such as fresh fruit and vegetables, fresh meat and fish, and frozen goods. 71% of the respondents carry eight or more days of buffer stock for non-perishable items, including slow-moving dry goods, personal care items, and household supplies. Reduced buffer stock levels for perishable goods relative to non-perishable goods is a common retail practice designed to limit spoilage that would result in financial losses and customer dissatisfaction.

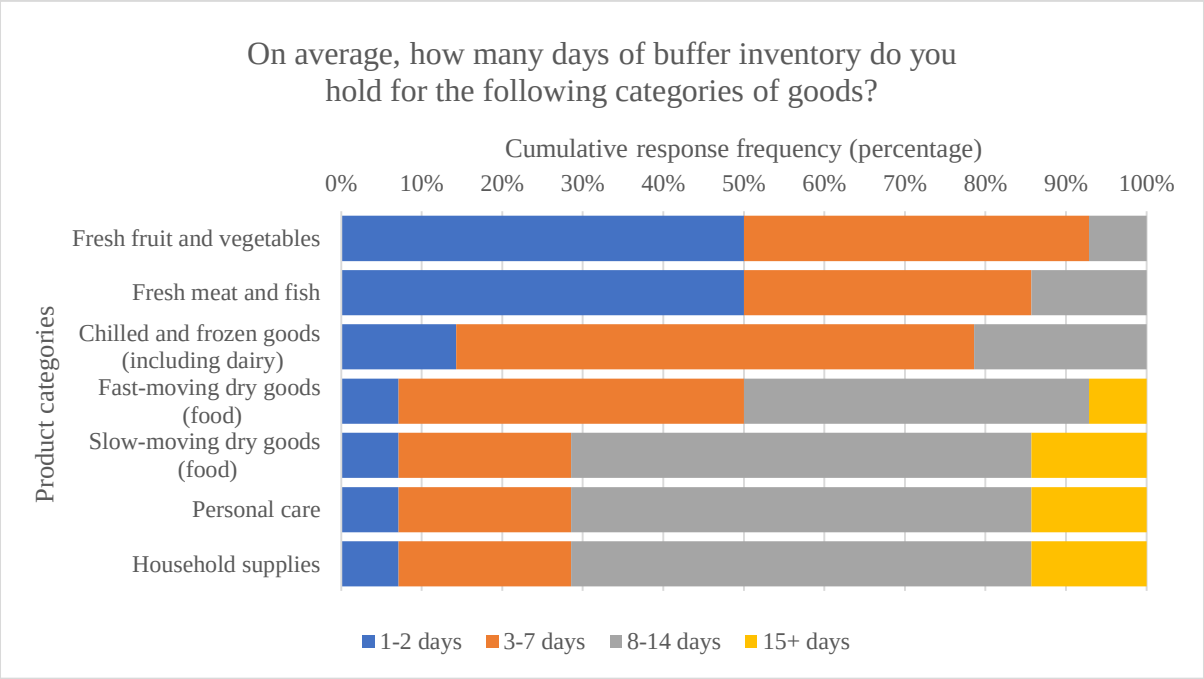

Figure 3. Days of Buffer Stock by Product Category

Nature of the Disruptions in the Wake of the Canterbury Flooding

As shown in Figure 4, the participants experienced inaccessible roads and inventory shortages. 92% of the respondents cancelled some replenishment orders and 83% experienced longer travel times. In addition, 42% of the participants dealt with consumer panic buying and implemented purchase limits.

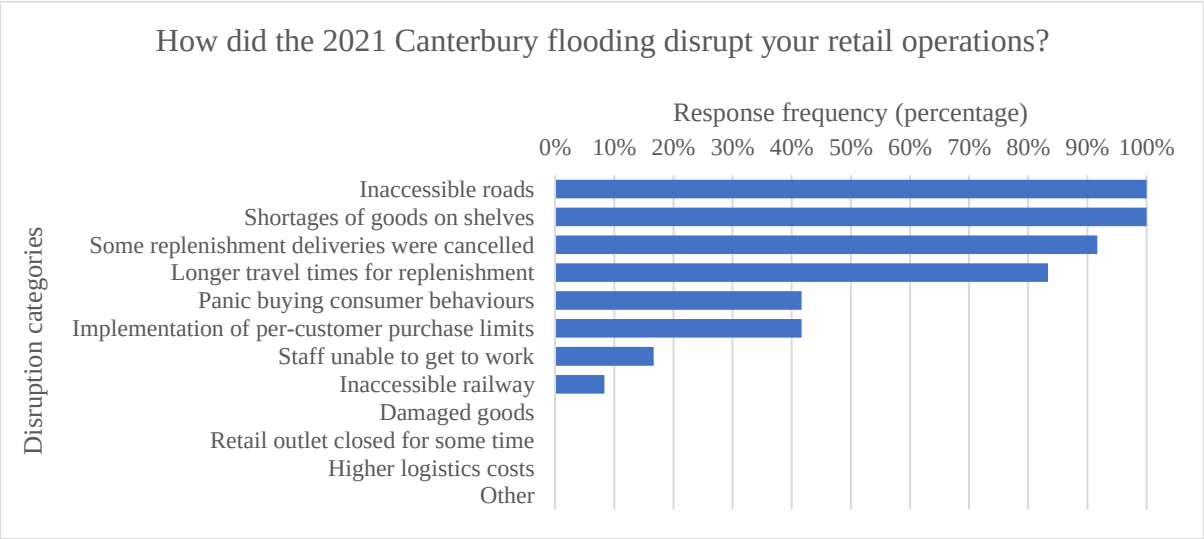

Figure 4. Nature of Disruptions

Duration of the Disruptions

Respondents were asked to indicate the length of the disruptions for a range of product categories. Figure 5 shows some variance between product categories and a clear distinction between perishable and non-perishable goods. Among the perishable goods, fresh fruit and vegetables were the least disrupted (28% of the participants reported no disruption). Across all the categories of perishable goods, up to 83% of the participants were disrupted for two days or less, and none were disrupted for longer than three days. In contrast, non-perishable categories (fast-moving dry goods, slow-moving dry goods, beverages, and personal care items) were the most disrupted.

This variance between perishable and non-perishable goods was unexpected, particularly when considering the buffer stock levels for these products (see Figure 3). Although the data does not enable us to identify any explanation at this stage of the research, one possibility is the establishment of restocking priorities. In particular, due to the urgent restocking of critical food items, the replenishment of non-perishable goods may have been rescheduled, pushing back delivery dates.

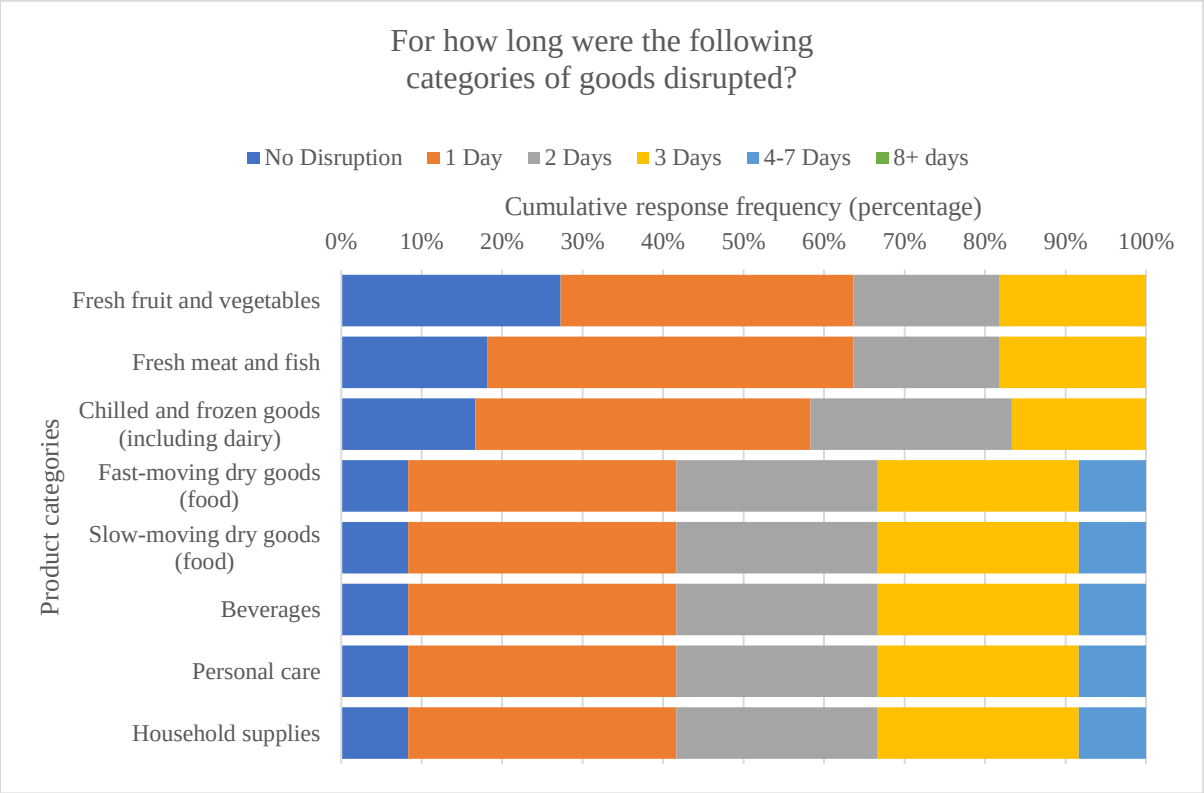

Figure 5. Duration of Disruptions by Product Category

Disruption Mitigation

The participants were asked to indicate how they mitigated disruptions in the wake of the Canterbury flooding. As illustrated in Figure 6, 58% of the participants used alternative roads. 50% increased orders with routinely used distribution centres and 42% with direct suppliers. 29% arranged deliveries from alternative sources (alternative distribution centres, alternative direct suppliers, or both). 8% of the respondents indicated that they could not adapt their replenishment operations.

Figure 6 also shows that no participants stockpiled inventory in anticipation of the disruptions caused by the Canterbury flooding. The participants' existing buffer stock levels and the expectation that the flooding would not disrupt operations for more than a couple of days may have influenced this outcome.

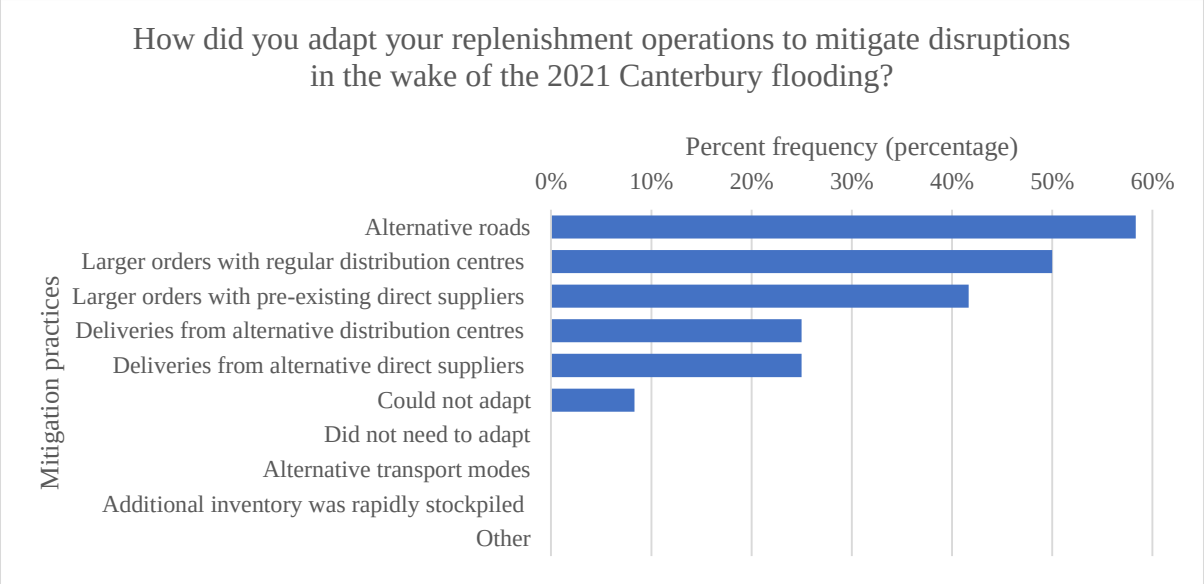

Figure 6. Mitigation Strategies Used in the Wake of the Canterbury Flooding

Impact on Resilience

Given the variety of possible mitigation options, the survey sought to understand the significance of these practices beyond the specific context of the Canterbury flooding. To this purpose, respondents were asked to indicate the extent to which various risk mitigation practices enhance resilience in the wake of a disaster (in general). As shown in Figure 7, the availability of alternative roads and alternative transport modes, as well as the ability to place larger orders with distribution centres are perceived as the factors having the strongest impact. The use of buffer stock has a strong to moderate impact, and the ability to arrange deliveries from alternative direct suppliers has a strong to little impact. Since NZ's road infrastructure has been damaged by multiple disasters in recent years and given NZ's overreliance on trucks for the movement of freight, it is not surprising that alternative roads and modes are ranked high and perceived as significantly contributing to the resilience of grocery retail operations.

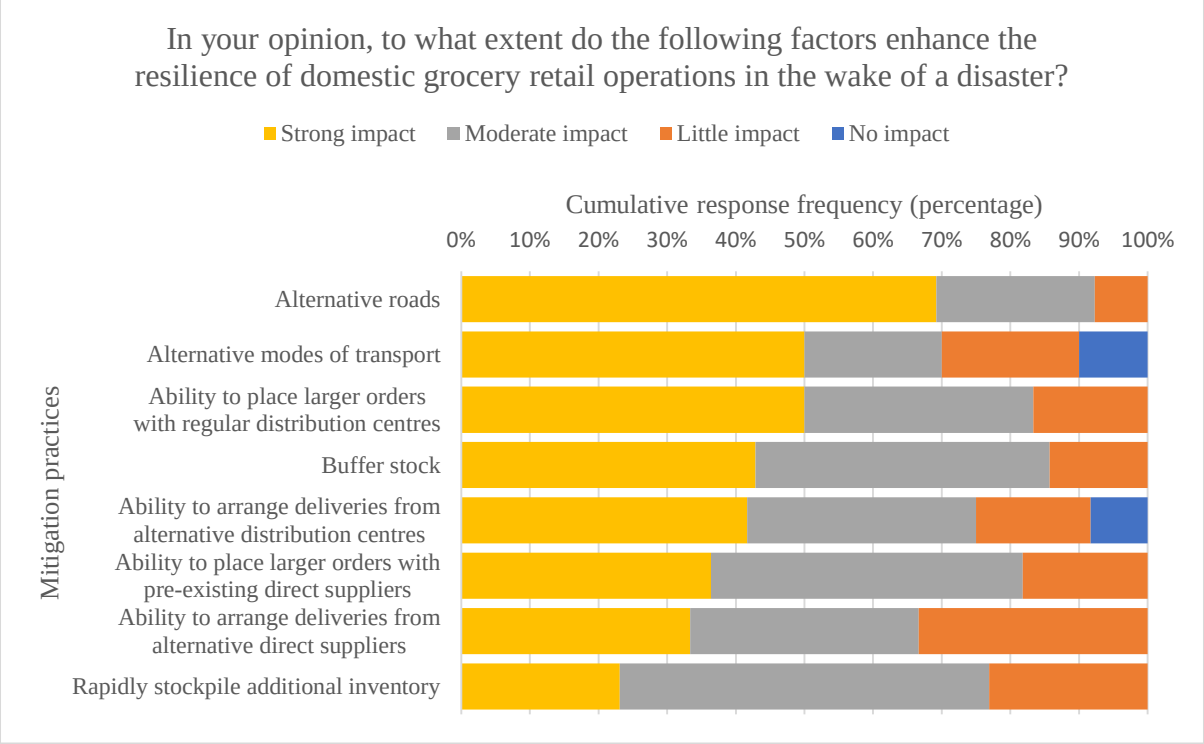

Figure 7. Perceived Impact of Mitigation Practices on Resilience

Availability of Mitigation Factors

The perceived impact of the various mitigation practices is separate from the ability of grocery retailers to use them. Therefore, respondents were asked to indicate the availability of mitigation factors in NZ. A comparison of Figure 7 and Figure 8 reveals multiple imbalances between potential impact and availability. For example, while Figure 7 showed that 69% of the respondents perceive that the availability of alternative roads strongly enhances the resilience of grocery retail operations, only 23% consider that alternative roads are actually strongly available (as illustrated in Figure 8). The imbalance is even greater for alternative modes of transport. While 50% of the respondents perceive that alternative modes of transport strongly enhance resilience (Figure 7), only 8% consider that alternative modes are strongly available (Figure 8). An imbalance between the impact and the availability of decentralised distribution centres is also reflected in the data. While 42% of the participants perceive that the ability to arrange distribution from alternative distribution centres strongly increases resilience (Figure 7), only 9% consider that this option is strongly available (Figure 8).

Figure 8 also shows that buffer stock is viewed as the most available option (it is strongly available for 36% of the respondents and strongly to moderately available for 79% of them). This seems to indicate that respondents resort to building buffer stock to compensate for the lack of flexibility in the NZ distribution system, i.e. the lack of alternative roads, transport modes, and decentralised distribution centres.

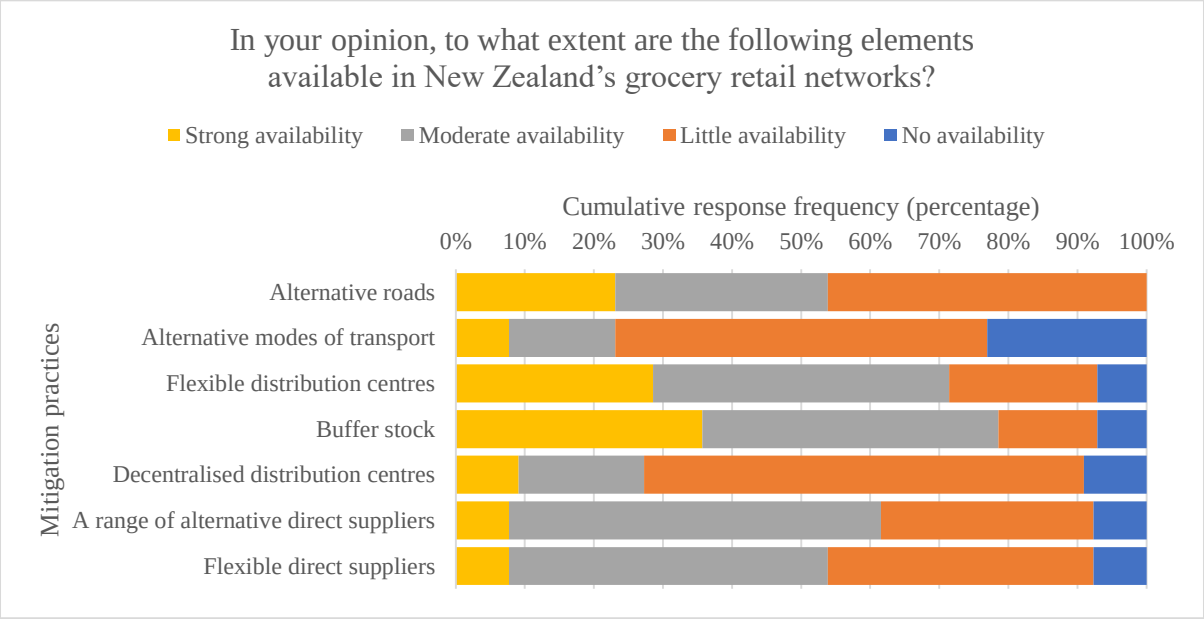

Figure 8. Perceived Availability of Mitigation Factors in NZ

DISCUSSION

This research discusses a range of redundancy and flexibility practices that enable FMCG retailers to increase their supply chain resilience and ensure that goods are available on store shelves when and where needed by consumers. It also investigates the extent to which these practices are used in the NZ context. The above findings show some aspects of redundancy and flexibility in the FMCG distribution system in NZ. For example, most participants used redundant inventory, alternative transport routes, and alternative distribution centres to mitigate the disruptive effects of the Canterbury flooding. However, the resilience of the NZ FMCG distribution system is limited as each of these elements' perceived importance far outweighs its availability.

Flexible Replenishment: Decentralised Distribution Centres

As indicated in the literature, the ability to place larger orders with distribution centres (volume flexibility) and the access to alternative, decentralised distribution centres increase resilience (Agigi et al., 2016; Sheffi, 2019). The findings of this study match the literature. And yet, more than half of the participants have access to only one distribution centre. NZ's relatively small population and lower density in the South Island may explain this disparity (a small market financially inhibits extensive distribution networks). Even so, centralised distribution negatively affects the resilience of FMCG retail operations in NZ.

Flexible Freight Movements: Alternative Roads and Modes

This research illustrates the disruptive impacts of losing access to key transport roads in the aftermath of a disaster. Without these roads, trucks cannot replenish retail stores, travel times are extended, and ultimately, retailers experience shortages of goods. Therefore, a robust road network with adequate secondary options is critical to ensure supply chain continuity in the wake of a disaster. This argument is supported by empirical research (e.g. Sreedevi and Saranga, 2017) showing that resilient road infrastructure contributes significantly to good delivery performance.

Going one step further, this research highlights the vulnerability of the NZ freight system that primarily relies on roads and trucks and is, therefore, prone to disruptions. Resilient transport operations call for alternative modes of transport that increase the number of route options available, a well-documented aspect of flexibility (Tang, 2006; Chen and Miller-Hooks, 2012). The above results indicate that participants are aware of their lack of modal options. In a country with long coastlines like NZ, the development of coastal shipping (that offers unencumbered sea access bypassing inaccessible roads) would significantly increase transport resilience.

Inventory: The First Line of Defence

As discussed in the literature, buffer stock is a form of redundancy commonly used to increase resilience. Buffer stock is often described as the first line of defence against disruptions (Sheffi, 2020). The above results confirm this point and suggest that redundant inventory is used in FMCG retail operations to compensate for the lack of flexibility in the NZ transport system (e.g. the lack of adequate secondary roads, alternative modes of transport, and decentralised distribution centres).

While redundant inventory increases resilience, the benefits are relatively short-lived (Sheffi, 2019) as holding sufficient stock to manage prolonged disruptions in the wake of a severe disaster event would be too costly. Even though the benefit of high buffer stock levels is a poor substitute for adequate transport infrastructure and the flexibility it enables, carrying redundant inventory seems to be the primary option that NZ FMCG retailers currently have to build resilience.

Overall, we argue that the NZ FMCG distribution system needs to be more actively designed to absorb supply variability not only by building redundancy (buffer stock), but also by enabling flexibility with secondary roads, alternative modes of transport, and decentralised distribution centres. While some of these elements are within the control of grocery retailers (e.g. building stock and decentralising distribution), the role of the government agencies in charge of infrastructure development through long-term public investments should not be underestimated. Creating a resilient freight system calls for a holistic and integrated approach involving both public and private stakeholders, which in turn would require public funding and generate extra operational costs for grocery retailers. Although investments can be seen as an insurance policy (as discussed earlier), the question of whether they are realistic in a country with low-population density (as is the case of NZ) is critical and can only be addressed with robust cost-benefit analyses identifying the most influential investments.

LIMITATIONS, CONTRIBUTION AND CONCLUDING COMMENTS

As previously mentioned, the survey was administered when retailers had a seasonally high workload, which reduced the number of responses received. Due to the low level of participation, the collected data is not statistically representative of the whole NZ grocery retailer population. Additional data needs to be collected in order to increase the sample size and, ultimately, improve the reliability of the results.

In addition, this study's focus on NZ and the 2021 Canterbury flooding generates contextual findings that are not generalisable. Similarly, the focus on a specific retail sector (FMCGs) and on a specific supply chain segment (the replenishment of retail stores) limits the applicability of the findings beyond the setting of this study. As a consequence, additional investigations should expand the research to other retail sectors (e.g. durable consumer goods) and take a more comprehensive supply chain approach (e.g. from manufacturers to retailers).

Despite the above limitations, this study contributes a better understanding of the FMCG replenishment operations in NZ and provides an initial assessment of the impacts of natural hazards on NZ's domestic freight operations. It also highlights that the lack of flexibility in the NZ freight network increases the vulnerability of replenishment operations. In particular, the lack of an adequate secondary road network and of alternative modes of transport, as well as the centralised distribution practices in place and the limited sources of supply are discussed.

This work-in-progress research is part of a broader project investigating the concepts of redundancy and flexibility and their contribution to supply chain resilience in the wake of a disaster. It is expected that, ultimately, this project will highlight the importance of a holistic approach to the building of freight resilience in NZ. In particular, freight resilience not only requires supply chain practitioners to reconsider the way they operate and manage their supply

chain operations, it also calls for the development of a robust national infrastructure that includes alternative modes of transport. In the context of the increased exposure to highly disruptive events and their negative impacts on supply chain operations, discussing inherent fragilities in freight operations and raising risk awareness have become more critical than ever.

REFERENCES

Agigi, A.F.A., Niemann, W. and Kotze, T.G. (2016) Supply chain design approaches for supply chain resilience: a qualitative study of South African fast-moving consumer goods grocery manufacturers, *Journal of Transport and Supply Chain Management*, 10, 1.

Bala, M. and Kumar, D. (2011) Supply chain performance attributes for the Fast Moving Consumer Goods industry, 5, 1, 23-38.

Chen, L. and Miller-Hooks, E. (2012) Resilience: an indicator of recovery capability in intermodal freight transport, *Transportation Science*, 46, 1, 109-123.

Christopher, M.G. and Peck, H. (2004) Building the resilient supply chain, *The International Journal of Logistics Management*, 15, 2, 1-14.

Davies, A.J., Sadashiva, V., Aghababaei, M., Barnhill, D., Costello, S.B., Fanslow, B., Headifen, D., Hughes, M., Kotze, R., Mackie, J., Ranjitkar, P., Thompson, J., Troitino, D.R., Wilson, T., Woods, S. and Wotherspoon, L.M. (2017) Transport infrastructure performance and management in the South Island of New Zealand, during the first 100 days following the 2016 Mw 7.8 "Kaikōura" Earthquake, *Bulletin of the New Zealand Society for Earthquake Engineering*, 50, 2, 271-299.

DeGroote, S.E. and Marx, T.G. (2013) The impact of IT on supply chain agility and firm performance: an empirical investigation, *International Journal of Information Management*, 33, 6, 909-916.

Environment Canterbury (2021), *Canterbury floods May/June 2021*, Canterbury Regional Council, Retrieved from https://www.ecan.govt.nz/your-region/your-environment/river-and-drain-management/canterbury-flood-recovery/flooding-events/.

Harding, E. (2021), *Canterbury flooding impacts on Invercargill stores*, Stuff, Retrieved from https://www.stuff.co.nz/national/125320749/canterbury-flooding-impacts-on-invercargill-stores.

Hendricks, K.B. and Singhal, V.R. (2012) Supply chain disruptions and corporate performance, In H. Gurnani, A. Mehrotra and S. Ray (Eds.), *Supply chain disruptions: theory and practice of managing risk* (pp. 1-19), Springer, London.

Holweg, M. (2007) The genealogy of lean production, *Journal of Operations Management*, 25, 2, 420-437.

Kamalahmadi, M. and Parast, M.M. (2017) An assessment of supply chain disruption mitigation strategies, *International Journal of Production Economics*, 184, 210-230.

Kamalahmadi, M., Shekarian, M. and Mellat Parast, M. (2021) The impact of flexibility and redundancy on improving supply chain resilience to disruptions, *International Journal of Production Research*, 1-29.

Kellner, F., Otto, A. and Busch, A. (2013) Understanding the robustness of optimal FMCG distribution networks, *Logistics Research*, 6, 4, 173-185.

Knemeyer, A.M., Zinn, W. and Eroglu, C. (2009) Proactive planning for catastrophic events in supply chains, 27, 2, 141-153.

Manders, J.H.M., Caniëls, M.C.J. and Ghijsen, P.W.T. (2016) Exploring supply chain flexibility in a FMCG food supply chain, *Journal of Purchasing and Supply Management*, 22, 3, 181-195.

McDonald, L. (2021), *Flood damage splits South Island as transport links remain severed*, Stuff, Retrieved from https://www.stuff.co.nz/the-press/news/125311285/flood-damage-splits-south-island-as-transport-links-remain-severed.

Newstalk ZB (2021), *Canterbury floods causing delays, adding to supply delays*, Retrieved from https://www.newstalkzb.co.nz/on-air/heather-du-plessis-allan-drive/audio/brad-olsen-floods-and-13-hour-detours-leading-to-economic-concerns-in-south-island/.

NIWA (2021), *NIWA calculates 1:200 year flood for parts of Canterbury*, Retrieved from https://niwa.co.nz/news/niwa-calculates-1200-year-flood-for-parts-of-canterbury.

Ponomarov, S.Y. and Holcomb, M.C. (2009) Understanding the concept of supply chain resilience, *International Journal of Logistics Management*, 20, 1, 124-143.

Reichhart, A. and Holweg, M. (2007) Lean distribution: concepts, contributions, conflicts, *International Journal of Production Research*, 45, 16, 3699-3722.

Rice, J.B. and Caniato, F. (2003) Building a secure and resilient supply chain, *Supply Chain Management Review*, September/October, 22-30.

Rodrigues, V.S. and Potter, A. (2013) A comparison of FMCG logistics operations in the UK and South Africa, *European Business Review*, 25, 4, 351-364.

Sable, K. (2019), *FMCG market by type and distribution channel: global opportunity analysis and industry forecast, 2018 - 2025*, Allied Market Research, Retrieved from https://www.alliedmarketresearch.com/fmcg-market.

Sáenz, M.J. and Revilla, E. (2014) Creating more resilient supply chains, *MIT Sloan Management Review*, 55, 4, 22-24.

Sheffi, Y. (2019) Preparing for the worst, In G.A. Zsidisin and M. Henke (Eds.), *Revisiting supply chain risk* (pp. 155-168), Springer, Cham.

Sheffi, Y. (2020) *The new (ab)normal: reshaping business and supply chain strategy beyond Covid-19*, MIT CTL Media, Cambridge, MA.

Sheffi, Y. and Rice Jr., J.B. (2005) A supply chain view of the resilient enterprise, *MIT Sloan Management Review*, 47, 1, 41-48.

Simba, S., Niemann, W., Kotze, T.G. and Agigi, A. (2017) Supply chain risk management processes for resilience: a study of South African grocery manufacturers, *Journal of Transport and Supply Chain Management*, 11.

Sreedevi, R. and Saranga, H. (2017) Uncertainty and supply chain risk: the moderating role of supply chain flexibility in risk mitigation, *International Journal of Production Economics*, 193, 332-342.

Stecke, K.E. and Kumar, S. (2009) Sources of supply chain disruptions, factors that breed vulnerability, and mitigating strategies, *Journal of Marketing Channels*, 16, 3, 193-226.

Stuff (2021), *Canterbury floods: what you need to know about road closures*, Retrieved from https://www.stuff.co.nz/national/weather-news/300320108/canterbury-floods-what-you-need-to-know-about-road-closures.

Tang, C.S. (2006) Robust strategies for mitigating supply chain disruptions, *International Journal of Logistics Research and Applications*, 9, 1, 33-45.

Tomlin, B. (2006) On the value of mitigation and contingency strategies for managing supply chain disruption risks, *Management Science*, 52, 5, 639-657.

Womack, J.P. and Jones, D.T. (1994) From lean production to the lean enterprise, *Harvard Business Review*, 72, 2, 90-103.

Zylstra, K.D. (2006) *Lean distribution: applying lean manufacturing to distribution, logistics, and supply chain*, John Wiley & Sons, Hoboken, New Jersey.