Developing a resilient supply chain strategy during "boom" and "bust"

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Abstract

Supply chain resilience is often perceived as highly desirable, as it increases a firm's readiness in dealing with risks that can emerge from the customers' side, the suppliers' side, the internal processes adopted and the supply chain integration mechanisms employed. However, though practitioners responsible for the design and management of supply networks often see resilience as highly desirable, they also see the direct trade-off being cost. An in-depth qualitative single case is presented in this study, using an iterative cycle between theory and practice to delve into the experiences of the case company and various concepts from the literature. A framework for the development and implementation of a resilient supply chain strategy is proposed, which illustrates the relevance of various management paradigms (robustness, agility, leanness and flexibility) in increasing a company's ability to deal with disturbances emerging from its supply chain. The paper advances theory and closes some of the gaps existent in the literature with regards to the ways certain management paradigms could be combined in practice in order to develop a supply chain resilience strategy.

Keywords*:* Lean, agile, flexibility, robustness, redundancy, food and drink sector.

Introduction

Today's supply chain leaders are responsible for providing reliably high levels of order fulfillment and sophisticated customer service in the midst of increasingly volatile trading conditions. At the same time, they are tasked with offsetting rising costs through improvements to operational efficiency. However, both academics and practitioners contend that the cost reductions achieved by applying lean concepts during the "boom" years leading up to the economic pains of 2007 and onwards have left supply chains lacking resilience and in too fragile a state to cope with the challenges of both demand and supply volatility.

When disentangling the relevant academic debates, many practical questions need to be addressed: Should buffers of inventory, capacity and / or time (redundancy) be built into networks to ensure resilience and provide protection against the unknown? Is doing so compatible with a lean philosophy, or should this redundancy be seen as waste? How does organizational and supply chain flexibility change the relationship between these concepts? Does flexibility equate to agility?

In addition, modern supply chains are becoming increasingly complex. They are also becoming leaner, longer as a result of globalization, and more vulnerable (Christopher and Peck, 2004). In recent years, managers have reportedly enhanced supply chain efficiency through reducing inventory holdings, outsourcing noncore activities, cutting the number of suppliers and sourcing globally and this has been done based on the assumption that the world market is a relatively stable and predictable place (Kearney, 2003). The resulting business environment has increased the importance of resilience and dealing with the risks that can emerge from the customers' side, the suppliers' side, the internal manufacturing processes and the supply chain integration mechanisms employed (Mason-Jones, 1998; Colicchia et al., 2010; Juttner and Maklan, 2011).

Following the terrorist attacks of 9/11 in 2001, the Asian tsunamis in 2004 and the hurricanes in North and Central America in 2005, closer attention started being paid to the topic of supply chain resilience (Christopher and Peck, 2004; Sheffi, 2005; Tang, 2006; Datta et al., 2007). The more recent global financial crisis (Alsop and Armstrong, 2010; Juttner, 2011) has sparked further interest in the subject. In particular, resilience is increasingly used to examine companies' responses to such major shocks. However, recent trends in the dynamics of marketplaces (Mangan et al., 2008) and complex supply chain procedures have also amplified the importance of handling the "everyday risks" that emerge, especially at the operational level (Pettit et al., 2010).

In the academic literature, there is still no consensus on the definition of resilience. For instance, several other terms—such as agility, flexibility, risk, responsiveness, adaptability, alignment, robustness and redundancy—are linked with resilience (Goranson, 1999; Lummus et al., 2003; Rice and Caniato, 2003; Christopher and Peck, 2004; Christopher and Rutherford, 2004; Tang, 2006; McManus et al., 2007; Asbjørnslett, 2008). In addition, the evidence that highlights the approaches used by companies to translate these management theories into practical tools for the design, development and implementation of a supply chain resilience strategy is limited and lacks specific and important practitioners' insights (Juttner, 2005; Scholten et al., 2014). For example, although the literature acknowledges that there is a danger that supply chain resilience and flexibility are often only achieved with an increase in operational costs, there is a lack of understanding with regard to how companies overcome these trade-offs and the strategic decisions that result.

The main purpose of this paper is to explore one company's approach to translating management theories into a practical tool for the design, development and implementation of a supply chain resilience strategy. The strategy adopted by the company builds on and advances various streams of supply chain management literature. Such theories informed "what" needed to be done, while the "how" was developed by the company itself, independent of theory. Through grounding the empirical evidence presented into the current body of literature, this study aims to combine theory and practice in order to develop a supply chain resilience framework. An in-depth, qualitative case study is presented. The findings extend current knowledge on supply chain resilience by, first, illustrating how practitioners can integrate various capabilities associated with robust, agile, lean and flexible practices in order to develop a resilience strategy and, second, by proposing a supply chain resilience framework that integrates various management paradigms.

The article is organized as follows. We begin by introducing the concept of resilience, which spans several branches of knowledge. We then present our case study and introduce the resilience strategy adopted by the focal organization. Their approach is then retro-fitted in the

current body of knowledge related to the relevance of lean, agile, flexible and robust practices in the context of resilience. Finally, we propose a supply chain resilience framework that integrates the empirical evidence presented with the relevant theory identified.

Resilience: From the physical sciences to management theory

In general terms, resilience is perceived as "the ability to recover from or adjust easily to misfortune or change" (Merriam-Webster Dictionary, 2014). The existing academic literature on resilience spans several branches of knowledge. In physics and engineering, resilience is seen as the ability of a material to return to its original form after being bent, compressed or stretched. In other words, it is the ability to exhibit an elastic behavior as a result of disturbance (Pytel and Kiusalaas, 2003). In the analysis of ecological dynamic systems, early studies made connections between resilience and stability (Holling, 1973). Without stability, there is no return to the pre-disturbance state; hence, there is an assumption of a steady ecological state in the system when evaluating its resilience. In the social sciences, the study of resilience seems to have originated in development theories of social psychology and psychiatry. Resilience is seen as the individual's capability to cope successfully in the face of significant change and stress; it is a dynamic process because successful coping strengthens the individual's competence to deal with adversity in the future (Stewart et al., 1997). In the field of economics, resilience is an important concept because of the gigantic asset and business losses that can be incurred due to shocks in the economic sector (Rose, 2004).

From an organizational perspective, resilience has been described as a dynamic capacity of adaptability, which grows and develops over time (Wildavsky, 1988). It reflects any organization's capacity to adjust and maintain desirable functions under challenging conditions (Weick et al., 1999). Thus, resilience within organization studies recognizes both the ability to absorb shocks in the form of extreme events and an adaptive capability to adjust to new circumstances (Johnson et al., 2013). Firms that have enhanced resilience are more likely to deal with day-to-day problems, as well as those arising from a crisis. Therefore, resilience is a source of competitive advantage (McManus et al., 2007).

Resilience has been studied extensively from ecological, social and organizational perspectives (Bhamra et al., 2011), but it is still an emerging topic in the supply chain management literature. In this field of study, resilience is essentially defined as "the ability of a [supply chain] system to return to its original state or move to a new, more desirable state *after being disturbed*" (Christopher and Peck, 2004) or "the adaptive capability of the supply chain to *prepare* for unexpected events, *respond* to disruptions and *recover* from them by maintaining continuity of operations at desired levels of connectedness and control over structure and function" (Ponomarov and Holcomb, 2009).

Greater interest in issues of security and risk management in supply chains appears to have emerged following the terrorist attack of 9/11, prompting academics and practitioners to call for more research into supply chain resilience (Sheffi, 2001; Rice and Caniato, 2003; Barry, 2004; Spekman and Davis, 2004). Supply chain disruptions, in this case, were perceived as not being caused by the attack itself but by the government's response to it: closing borders, shutting down air traffic and evacuating buildings (Sheffi, 2001). This event was a wake-up call to the uncertainty that exists in the global environment (Barry, 2004). Similarly, humanitarian logistics research emerged even more forcefully following the Asian tsunamis in 2004 (Thomas and Fritz, 2006; Kovacs and Spens, 2007) and the hurricanes in North and Central America in 2005 (Craighead et al., 2007). In addition, studies on warfare and

peacekeeping mission logistics (Kovacs and Tatham, 2009) are on the rise and more recently, the horse meat scandal that affected European food supply chains has further reinforced the importance of resilience. All these events have emphasized the importance of the strategic planning and positioning of supply chain resources.

At the same time, the link between effectively managing operational risks and achieving improved financial performance has attracted further attention. For example, in global supply chains, the longer the transport distances and the more resources involved, the greater the likelihood of operational disruptions and financial penalties (Sheffi, 2005). In this context, resilient supply chains should be capable of creating and sustaining competitive advantage (Christopher and Peck, 2004). Nevertheless, to date, there has been little empirical evidence available that highlights the approaches companies use to translate management theories into practical tools for the design, development and implementation of supply chain resilience strategies. Although the literature acknowledges that there is a danger that supply chain resilience is, for example, often only achieved with an increase in operational costs, there is a lack of understanding with regard to how companies overcome these trade-offs and the strategic decisions that result. Given the foregoing gap in the literature, the main purpose of this paper is to explore one company's approach to translating relevant management theories into a supply chain resilience strategy, which it named RALF **(R**obust, **A**gile, **L**ean and **F**lexible).

The case company

An exploratory, single, qualitative case study is presented, aimed at developing a holistic and in-depth understanding of a complex and unique phenomena in a real life context (Yin, 2008). Due to the currently limited empirical evidence related to the relevance of robust, agile, lean and flexible management paradigms in the development of a supply chain resilience strategy, the case study approach is deemed as useful in such theory building contexts, enabling a holistic investigation (Eisenhardt, 1989; Meredith, 1998; Voss et al., 2002). In terms of using a singular case study approach, Yin (2008) argues that this is particularly applicable to revelatory cases, where the investigators have the opportunity to observe and analyses a phenomenon that previously attracted limited scientific investigation. The subject of our study, exploring how various management paradigms are combined by firms in order to develop a resilient supply chain strategy, is emergent in nature and there is very little empirical evidence available. Therefore, this study, through the consideration of a single case, is believed to lead to the development of new theories and ideas (Adebanjo, 2010).

Data was collected using unstructured interviews and verbal narratives on the company's supply chain resilience strategy. To corroborate the information derived from the interviews, secondary data was analyzed including multiple company documents: email correspondence, company reports and performance data, promotional material (Hanna and Jackson, 2015). The case study findings are presented via a written narrative, leading to a post hoc rationalization of the development process for the supply chain resilience strategy. An iterative cycle between theory and practice was used to delve into the experiences of the case company and various concepts from the literature (Liedtka, 2014).

The company, Innocent Ltd., is a United Kingdom-based specialist premium drink producer. Using a highly integrated supply network, Innocent produces and delivers 170 stock-keeping units (SKUs) for a European market consisting of around 200 major retail customers in 14 countries. It does so via a fully outsourced network of co-packers in the UK that produce 300 million consumer units per year; these are then distributed via seven outbound logistics warehouses based in the UK, France, Denmark, Germany, Ireland, the Netherlands and

Switzerland. Ingredients come from a worldwide supply base (including Europe, the United States (US), Central and South America, India and South-East Asia) made up of thousands of growers, ranging from large plantations to sole growers, who together supply around 120 varieties of circa 50 fruits. These are then delivered to 25 global processors that produce juices and purees, packaged aseptically or frozen in various batch sizes and then dispatched by sea or road to the Netherlands, where they are unloaded, stored and if required, blended for Innocent by a stevedoring partner. The blends are then transported by road tankers to the co-packers in the UK, where the product is offloaded, the final ingredients are added and the blend is flash-pasteurized and filled into a variety of packaging formats. From this point onward, the vast majority of the products need to be maintained within chill-chain conditions to ensure safety and sensory quality throughout their shelf life. The finished products are packed into retail packaging, palletized and sent for storage with a UK third-party logistics provider (3PL). The UK 3PL distributes customer orders via wholesaler and retailer networks within the UK and forwards stock to partner 3PLs around Europe to serve the Innocent customers within their regions.

The retailed products have high ingredient costs, are relatively low margin and have a short shelf life. High levels of service fulfillment are expected by the main customers, without Innocent incurring crippling finished goods waste. This is the foundation on which the company strives to build high levels of integration within a global network of supply partners and across time frames spanning hours (for customer orders) up to multiple years (for fruit contracts). Innocent describes itself as a "manufacturing integrator" in respect of these capabilities. Its globally dispersed network calls for high levels of process integration and visibility, which need to be achieved without actually owning any of the retail, manufacturing or distribution facilities. Innocent takes ownership of the ingredients and raw materials from an early stage of the process and specifies and controls the production processes carried out by its partners as the raw materials are transformed into finished products. It also coordinates and, where necessary, synchronizes the production plans of all the partners to ensure the minimization of waste. Although this model is increasingly adopted by companies operating in a wide range of sectors, such as the automotive, fashion and construction industries, it is relatively unusual in food manufacturing. Its success is highly dependent on the ability of the focal firm to coordinate all players in order to achieve a level of performance and resilience that is greater than the sum of its parts.

Findings

How RALF happened

Innocent was founded in 1998 on very limited capital, which meant that the only viable approach for production was to outsource. The founders selected a partner that was capable of sourcing all the necessary ingredients and raw materials and manufacturing its prototype products. However, when faced with accelerating demand, certain constraints emerged: shelf life was limited to 14 days, which ruled out many potential stockists; the partner had limited blending capacity, which constrained overall volumes; the partner had no access to the suitable packaging formats that were required to gain access to retail multiples in the UK; and its sourcing skills were not adequate to conform to tight specifications. Innocent's supply chain began to evolve as solutions were sought to overcome these limitations. It, therefore, did the following:

- Invested in a small team of highly skilled agronomists and developed the knowledge to source ingredients directly, thereby improving consistency of quality and taste;

- Found a partner in the Netherlands that was able to blend ingredients and transport them to the UK;
- Worked with a co-packing partner to invest in "super-clean" extended-shelf-life filling technologies; and
- Found a second co-packer that was able to fill take-home formats.

The above combination of capabilities gave Innocent a competitive advantage with regard to product design and taste. By 2006, the company was growing fast, expanding its product range and setting up sales and marketing operations in seven European countries. The main challenges for its supply chain were keeping up with increasing demand and maintaining consistent quality. However, the rapid growth in retail points in the UK led to a reduction in the rate of sale in each store as the product started to lose its novelty appeal. Moreover, the changing economic environment of 2008 accelerated this effect.

In 2008, an internal review of the strengths and weaknesses of Innocent's supply chain was carried out to define a strategy for the years ahead. Several challenges emerged:
- Dramatically falling demand for core products and uncertain future demand in the face of an expected upcoming recession;
- Demand from marketing to launch supplementary products in new categories to increase sales (e.g., vegetable pots and not-from-concentrate [NFC] orange juice);
- Long contracts and commitments for raw materials and services based on expectations of continued growth, leading to potential write-offs, relationship issues and quality problems;
- Pressure to reduce production and logistics costs to offset increased commodity prices and forecast adverse currency movements, as well as the need to fund deeper promotions;
- A scale of operations at which low-cost sourcing of "fill-in" demand at a marginal cost from larger suppliers (which Innocent had enjoyed when it was smaller) was no longer possible;
- Increased risk of insolvency or other failure for key suppliers or customers;
- Changing and uncertain customer and consumer priorities and demands;
- Potential for increased competition arising from competitors seeking to offset losses in other categories by entering Innocent's core smoothie sector;
- Growth opportunities in subscale new geographies; and
- How best to protect the brand, built on a reputation for premium quality and corporate responsibility, including enhanced levels of environmentally and socially sustainable operations.

A set of assessment criteria designed to gauge the resilience of Innocent's supply chain in light of the above challenges emerged as a result. Innocent categorized its operations into 16 distinct groups of activities (see Figure 1). Each activity was then internally rated (against what was perceived as industry norm) from 1 (worst=red) to 5 (best=green) on what they perceived as resilience-related characteristics—robustness, agility, leanness and flexibility. Innocent referred to the resulting resilience framework as the "RALF criteria." The definitions that Innocent adopted for the RALF criteria were as follows:

- **Robust**: *able to withstand disruptions to components within the network,* normally by having an alternative source readily available or a plan to implement one quickly, if needed.
- **Agile**: *quick and well coordinated*, able to respond quickly to relatively small-scale market opportunities, normally by having a partner able to handle unexpected and/or volatile demand and small batch sizes.

- **Lean**: *containing little or no excess/waste*, able to fulfill predictable demand very efficiently.
- **Flexible**: *capable of modification or adaptation*, able to respond easily to disturbances in the supply base without excessive cost, write-offs or long lead time.

[Figure 1 near here]

The rating for each of the 16 activities was based on benchmarking against industry norms. A visual "traffic light" representation of the results was used, with dark green representing a score of 5 and red a score of 1, as shown in Figure 1.

Using a "process + systems + people + infrastructure" framework, a new strategy was then conceived and change initiatives/projects were defined, prioritized and implemented. The overall strategy development process, targeting the 2008–2012 time frame, is shown in Figure 2.

[Figure 2 near here]

Two illustrations of how RALF was used in practice are provided below.

Example 1: Responding to supply disruptions (the "bust")
Following the RALF assessment, it became clear to Innocent that they were highly vulnerable to the potential failure of certain blending and packing partners (see Figure 1), for whom no backup was in place. For example, in early 2008, Innocent was using a single partner in the UK for co-packing smoothies into pet bottles. Bottled smoothies, sold for consumption on the go, command a price premium from consumers and were an extremely important part of Innocent's income and profit mix at the time; without them, the executive team deemed unlikely that the company could survive in its current form. The supplier was financially weak and was dependent upon the continued support of its offshore parent company. Following the RALF review, a target was set to ensure that at least two co-packers capable of filling each format were available. Discussions were started with an additional UK supplier that began planning to establish contingency capabilities for filling smoothie bottles for Innocent.

In January 2009, the original supplier was taken into administration. However, the administrator agreed to continue trading with Innocent whilst shutting down the rest of the operations. Meanwhile, the new supplier accelerated its contingency plans and agreed to take over the operations and team that were used to manufacture Innocent smoothies at the original supplier. Production continued at the old supplier's location for several months before the work and some key equipment were ultimately transferred to the new supplier's state-of-the-art manufacturing facility, which was also located in the UK. Another Innocent smoothie co-packing partner then developed smoothie-bottling capabilities to reestablish the targeted RALF resilience. The early step toward a RALF network to form a relationship with the alternative supplier was crucial in protecting Innocent from the failure of an essential supply partner.

Example 2: Responding to new market opportunities (the "boom")
In 2008, the demand for smoothies fell dramatically in the UK, Innocent's primary market, following the economic downturn (see Figure 3). At the same time, a main competitor entered the smoothie market in the UK and took a significant market share. Part of Innocent's response was to accelerate its planned diversification into a wider range of products, including vegetarian ready meals (Innocent Veg Pots) and 100% NFC orange juice. At the time, the market for NFC

juices in the UK was bigger than the smoothie market and even a small share of this opportunity would provide a welcome relief for Innocent.

[Figure 3 near here]

In terms of bottling the new NFC juices, Innocent secured two suppliers who were expected to take the roles of lead "agile" (fast, flexible) and "lean" (large-scale, efficient) partners. After several product packaging redesign attempts, the "agile" supplier was able to bottle the new 100% NFC orange juice in a gable-top carton, alongside smoothies, in a matter of months and these were launched by autumn 2008. However, without strong marketing support, the new juice products did not stand out alongside the more established competitor's product, which was packaged in similar cartons and Innocent made little progress in the category. A reevaluation of the 100% NFC juice market and a study of the success of a similar brand in the USA, led Innocent's marketing team to conclude that a breakthrough would only be made possible by redefining the product in the consumers' eyes. Amongst other things, this would require bottling the product in an eye-catching and ergonomically pleasing PET carafe with a large cap—something that no manufacturing facility in Europe could produce at that time.

The decision in 2010 to gear up production for such a product and support it with a heavy marketing investment at launch, in the depth of the recession, would test the flexibility of Innocent's RALF network. By upgrading a small, flexible filling line, the "agile" partner was able to produce the first carafes, which were ready to be launched in February 2011 and which had a capacity of 25 million liters per annum. The product was successful with consumers and retailers and the rollout plan was accelerated. Six months later, the "agile" manufacturer converted a second line, doubling the capacity to 50 million liters per annum. Meanwhile, Innocent's "lean" partner had been securing and implementing a faster line that was capable of meeting the demands of the new product format and this went live in February 2012, doubling the capacity to over 100 million liters per annum, improving efficiency and stabilizing supply. By the end of 2012, Innocent had developed additional business worth around $160m per annum of sales in carafes and had taken over 20% of a category of which it had owned less than 1% in 2010.

The "outsourced but in-control" partnership-based network design that Innocent adopted as part of the strategy that was developed following the RALF review enabled the rapid development of a new format using new, as well as existing partners. The clearly allocated and accepted roles of "agile" and "lean" partners meant that Innocent was able to respond to a perceived market opportunity quickly and, once it had been found to be successful, to ramp up production rapidly and efficiently to maximize the opportunity before its key competitor could react.

Discussion: Linking supply chain management paradigms

The literature review presented earlier in this article highlighted the ongoing debate surrounding the relevance of the RALF concepts—robustness, agility, leanness and flexibility—in the context of resilience. The main difficulty leading from this is figuring out how either the concurrent or sequential adoption of these paradigms in practice can contribute to, or hinder, a firm's ability to increase its resilience. With the evidence from the Innocent case highlighting the relevance of these paradigms, as seen by practitioners, in developing a resilient supply chain strategy, further grounding in the current literature was then saught.

Resilience and agility

Agility is perceived as the ability to focus on maintaining a good level of productivity under the pressure of uncertainty (Helo, 2004), caused by increasing competition, more sophisticated customers, changing customer requirements and/or variable demand (Walters, 2007). In this context, definitions of agility share verbs that point to the reactive ability to answer to change—that is, to "react," "respond," "adapt," or "re-configure" (Wieland and Wallenburg, 2013), which are terms that are also frequently associated with the resilience of a supply system. However, the focus of an agile firm appears to be on its capability to cope with unpredictable changes emerging primarily from market or customer demands (Wadhwa and Rao, 2003). Agile firms continually sense opportunities for competitive action in their product market spaces and marshal the necessary knowledge and assets for seizing these opportunities (Sambamurthy et al., 2003). These debates highlight that agility can lead to resilience by enabling companies to both sense and respond to the disruptions emerging from the downstream (demand side) of their supply chain. Hence, we argue that agility is a necessary, but not sufficient, prerequisite to resilience.

Lemma 1 - Supply chain resilience (to demand volatility) is a function of agility.

Agility, flexibility and leanness

The link between flexibility and agility is also widely discussed in the literature (Christopher, 2000; Prater et al., 2001; Swafford et al., 2006), with some authors suggesting that the origins of agility lie in flexible manufacturing systems (Christopher, 2000). However, in the literature, some attempts have been made to differentiate between agility and flexibility. For instance, Wadhwa and Rao (2003) contend that an agile firm should be capable of coping with unpredictable changes in market or customer demands. They argue that the major distinction between flexibility and agility is the character of the situations requiring change. Flexible changes are responses to known situations, where the procedures are already in place to manage the change and flexibility should be seen as the capability to mitigate against these changes in supply and internal processes, as well as in demand. Conversely, agility subsumes the notion of flexibility. Flexibility tends to be used at a lower, more operational level, whereas agility tends to be used at a more encompassing, business-wide level (Baker, 2006), with a focus on satisfying demand. It is the combined effect of different types of flexibilities (Swafford et al., 2006) that determines an organization's supply chain agility, with flexibility being an antecedent of agility and, hence, to resilience.

Lemma 2 – Agility is a function of flexibility.

It has also been argued that leanness should be seen as a necessary prerequisite to agility (Narasimhan et al., 2006). Leanness provides the platform for agility, by developing efficient processes that are focused on delivering customer value and eliminating waste in terms of effort, resources and time.

Lemma 3 – Agility is a function of leanness.

Resilience and robustness

The notion of robust supply chains contributes further to the need for a reconciliation of terms, as robustness appears to have been most frequently used as a substitute for resilience. For example, robustness has been previously defined as the ability of a supply chain to "carry out its functions despite some damage done to it" (Meepetchdee and Shah, 2007). It enables the supply chain to retain the same stable configuration it had before the changes occurred (Asbjørnslett, 2008), it endures rather than responds (Husdal, 2010) and it helps to "withstand

shocks" rather than to "adjust to shocks" (Wallace and Choi, 2011) As such, both robustness and resilience involve post-disturbance recovery, but robustness encompasses a proactive rather than a reactive response. Robustness should be understood as "the ability of a supply chain to resist change without adapting its initial stable configuration (Wieland and Wallenburg, 2012), in contrast to resilient systems, which have the ability to adapt but also to achieve a new stable situation following the response to various types of disturbances in the supply chain. As such, while robustness is desirable, it does not in itself equate to resilience. Moreover, since a robust system is able to respond to reasonable variations while a resilient system responds to major changes in input, a resilient supply chain will be robust, while the reverse is not always true (Christopher and Rutherford, 2004).

Lemma 4 – Supply chain resilience is a function of robustness.

Robustness also differs from resilience by having lean thinking as the central strategy (Christopher and Rutherford, 2004). For example, though both robust and resilient supply chains emphasize low inventory levels throughout, in order to minimize risk (while positioning strategic safety stocks at optimum supply chain locations), robustness calls for lean processes, with spare capacity minimized throughout in order to reduce waste.

Lemma 5 – Robustness is a function of leanness.

In contrast, resilient practices can also call for critical path spare capacity in manufacturing, storage space and process capability. In this context, Stevenson and Spring (2007) define robustness using the concept of "rigid flexibility" so that a robust supply network, or one with rigid flexibility, predetermines the range of events with which the existing supply chain structure is able to cope.

Lemma 6 – Robustness is a function of (rigid) flexibility.

This means that a robust supply chain can deal with reasonable variability in input whilst maintaining good control over output variability. However, by having risk management central to its supply chain strategy, resilience, while being certainly robust, offers much more. In addition to being responsive to predictable input variability, it is able to respond to a sudden and unexpected shift in the level and variability of input. Following this logic, a resilient supply chain would be expected to be adaptable, scalable and able to sustain a response indefinitely (Christopher and Rutherford, 2004).

Resilience and redundancy

According to systems thinking, the ability to deal with a sudden and unpredictable shift in input (supply side) or a significant increase in variability (demand side)—which, as highlighted before, is a main characteristic of resilience—can also call for redundancy (Bruneau et al., 2003; Sheffi, 2005). Redundancy could emerge, for example, through holding extra inventory, delaying the response, keeping low capacity utilization, having alternative suppliers and/or spreading business over many locations (Rice and Caniato, 2003; Christopher and Peck, 2004; Tomlin, 2006) to increase a firm's ability to deal with disruptions. This strategy leads to the creation of buffers (inventory, capacity and / or time) through the supply chain, which can enable companies to continue operating after a disruptive event (Zsidisin and Wagner, 2010). Ultimately, redundancy is a capability that can be employed to ensure resilience, regardless of the need for resilience emerging from demand volatility (Lemma 7' in Figure 4), or to ensure

resilience due to supply and/or internal disturbances (Lemma 7'' in Figure 4). Without such flexibility, redundancy has little value.

[Figure 4 near here]

Lemma 7' – Supply chain resilience (to demand volatility) is a function of redundancy.

Lemma 7'' – Supply chain resilience (to supply volatility) is a function of redundancy.

However, an overreliance on redundancy and its buffers to achieve resilience is also perceived as an expensive strategy, which should only be used temporarily in situations in which the disruption is predictable or more likely to occur in the near future (Sheffi, 2005). Redundancy, in this context, might also conflict with some of the lean principles, such as eliminating waste, just-in-time and pull processing (Christopher and Peck, 2004). This further underlines the need for flexibility and a focus on rapid reconfiguration of resources in terms of what is required to attain resilience (Sheffi and Rice, 2005).

Thus, redundancy may be exploited via two forms of supply chain flexibility: vendor and sourcing flexibility (Purvis et al., 2014). The former requires individual companies to have in-house flexibility, which they can call upon when a disturbance arises, while the latter may be seen to be a network-wide capability, where the focal company has the ability to quickly and efficiently access capabilities within the wider supply network in order to increase its flexibility. *Lemma 8 – Redundancy is a function of flexibility.*

Taking the preceding lemmas, we determine that there is strong evidence in the literature of the antecedents of resilience. In view of the case evidence presented above, the RALF proposition made by Innocent may be expressed as follows:

Theorem 1 – Resilience (to either supply or demand volatility) is a direct function of agility (Lemma 1), robustness (Lemma 4) and redundancy (Lemmas 7' and 7'').

Incorporating lemmas 2, 3, 5, 6 and 8, this leads to Theorem 2:

Theorem 2 – Resilience is a function of robustness, agility, leanness and flexibility (based on all lemmas).

Theorem 2 highlights that robustness, agility, leanness and flexibility should all be seen as necessary capabilities in achieving supply chain resilience. These were also the elements incorporated into the RALF framework developed by Innocent.

Sense and respond – RALF in action

The case study presented above highlighted that, through the development and subsequent implementation of its RALF resilience framework, Innocent was better prepared to detect and then respond to a series of disruptive events, as illustrated in the two examples provided. The supply chain resilience literature, for example, refers to this approach through the concepts of readiness, response and recovery, reflecting the view that resilience is "the adaptive capability of the supply chain to **prepare** for unexpected events, **respond** to disruptions and **recover** from them by maintaining continuity of operations at desired levels of connectedness and control over structure and function" (Ponomarov and Holcomb, 2009). Thus, through the development

and implementation of a resilience strategy, a company (and its supply chain) should be better equipped in terms of the following:

a) **Readiness**: The supply chain is prepared for uncertainty or a disruptive event (through the development of RALF capabilities).
b) **Sensing**: Minimise the lag between the event occurring and the supply chain's recognition of the event, which ensures that the number of options available to the supply chain manager is maximized.
c) **Response**: The reaction to a specific event is given by the decision window. A RALF response implies minimizing the time to react to the disruptions, while begin the recovery phase.
d) **Recovery**: The return to normal, stable, or steady conditions.

The implications of developing RALF capabilities for resilience are captured in Figure 5, which reflects the fact that the sooner an event is sensed, the more options are available to a supply chain for corrective action and hence, the possibility of finding a better course of action in the time available increases (Bodendorf and Zimmerman, 2005). Taken to its ultimate conclusion, if an event can be sensed even before it occurs, the total cost of resilience may be minimized. This will require considerable sensing enabled via information visibility in the supply chain and communication flexibility (Naim et al., 2007). Hence, a simple action would be to ensure that such information is transferred immediately and directly to the supply chain manager(s).

[Figure 5 near here]

In terms of the Innocent case, the relevance of developing RALF capabilities to increase supply chain resilience has been summarized in Tables 1 and 2. It can be seen that RALF provides readiness for the supply chain as well as enhancing capabilities to respond and recover.

[Table 1 near here]

[Table 2 near here]

A unified theorem for supply chain resilience

The RALF resilience framework introduced previously can be seen as a means to address the interplay between the network as a whole and its individual components. For instance, a flexible network can consist of flexible or inflexible components. Reliance on the latter may, however, require a certain degree of redundancy. The "amount of resilience" created through the introduction of a certain redundancy buffer (i.e., capacity, inventory, etc.) increases with the flexibility of the supply network in terms of its ability to integrate additional nodes into the supply system at short notice. This can, in turn, affect how "efficient" resilience is. For example, Innocent's sensing capabilities enabled it to ascertain that a particular inflexible manufacturing partner was not coping with the post-2007 economic downturn. However, the network was flexible enough to quickly substitute another supplier to take up the required demand volume.

Resilience through RALF is also particularly relevant in the current, difficult financial times—that is, the bust that followed the boom. The boom helped Innocent by means of a period of extremely fast growth—even faster than Nike's growth during its start-up phase. While the bust led to a small dip in growth, RALF has subsequently supported continued growth for Innocent. It helped Innocent understand the RALF capabilities of the individual parts, as well as the

resilience of the whole supply chain. Thus, Innocent was able to respond to disturbances in supply, as well as changes in the marketplace. This meant that during the economic recovery, Innocent sustained an upward trajectory in the marketplace and was able to cope with category-leading growth in 2011 and 2012, as well as with some subsequent specific demands, such as those of the London 2012 Olympics/Paralympics, for which Innocent was the official supplier of juices and smoothies.

The RALF framework illustrates how companies may use management paradigms to develop and implement a strategy for introducing resilience into their supply chains. The framework enabled Innocent to sense, respond and recover from a series of events that affected the company over a period of eight years, including a key single-source supplier going out of business and a significant drop in demand. The latter was triggered by a series of "unknown unknowns," such as a new competitor entering Innocent's market, as well as the beginning of the financial crisis. The framework also highlights the fact that, as opposed to a traditional approach to risk management, which calls for risk identification and quantification, followed by the development of specific mitigation strategies, the RALF resilience strategy calls for a holistic *sense-respond-recover* approach which enables organisations to deal with unforeseeable disruptions and events (Pettit et al., 2010). Such a process was established over the years by Innocent through the development of various lean, agile, flexible and robust capabilities.

The RALF framework enabled the company to conduct an initial assessment of its current resilience capabilities and then further develop sensing, responding and recovering competencies that dealt effectively with serious events. The company used the RALF framework across its entire supply chain to provide a common understanding of the various elements that were perceived as relevant in dealing efficiently and effectively with potential risks. As such, the RALF framework was deemed as fit for the purpose of initiating a proactive supply chain resilience strategy, based on the assumption that not all risks can be prevented (Juttner and Maklan, 2011).

The supply chain resilience framework (Figure 4) that emerged after grounding the RALF framework in the current literature can be seen as the basis for developing an understanding of how various management paradigms can be combined in a practical context to increase the resilience of a supply chain. The mechanisms enabling a parallel and / or sequential adoption of these practices can vary from company to company and from supply chain to supply chain, as the environment in which they operate and the capabilities they have developed over time can be very different and context specific. However, the findings emerging from the case analysis highlight that any strategy to enhance supply chain resilience should make reference to each of the four paradigms (see Figure 6). These findings are also supported by the existing literature and Theorem 2 is proposed as a result. Fundamentally, both the current literature and the case study findings stress that any supply chain resilience strategy should be expected to have a unique DNA structure, but a minimum of four chromosomes (lean, agile, flexible and robust) should be expected.

[Figure 6 near here]

To conclude, the supply chain resilience framework presented in this study reinforces the fact that resilience should be seen as an emergent property of the supply system as a whole, not merely of its individual parts. However, for it to be successfully implemented, a company needs to have as much end-to-end supply chain visibility as possible. RALF was feasible for Innocent

because its supply chain, when compared to, for example, those of Airbus or Boeing, is relatively simple in terms of the number of products, SKUs, components and nodes. Nevertheless, there is an opportunity for scaling up. This is afforded by the advent of information and communication technologies that allow large organizations to collect, mine and synthesize vast quantities of data in order to increase their resilience—the subject of future research perhaps?

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TABLES

Phase	Actions	RALF capabilities			
		R	**A**	**L**	**F**
Readiness Sensing	Undertaking the RALF assessment Realization that a supplier was facing financial difficulties and hence creating a vulnerable node in the supply chain (through communication flexibility)				X
Respond (pre-event)	Increase robustness through introducing redundancy (by incorporating a second supplier) Maintain fair pricing of the product (focus on efficiency) New supplier developing its manufacturing capabilities (lean processes)	X		 X X	
Event	**Original supplier goes into receivership**				
Respond (post-event)	Transfer equipment to new supplier (network flexibility)				X
Recover	Production switched to new supplier (network flexibility)				X

Table 1: Responding to supply disruptions (Example 1 – The "Bust")

Phase	Actions	RALF capabilities			
		R	**A**	**L**	**F**
Readiness	Company A develops agility as "order winner" Company B develops leanness as "order winner" Innocent develops ability to bring new nodes into the network Ensure excess capacity for future use (through capacity redundancy)	 X	X	 X	 X
Event	**Competitor penetration – new markets identified**				
Sensing	Demand monitoring (through communication flexibility)				X
Respond (post-event)	Introduce new product line with strong proactivity from marketing Utilize capacity during new product growth stage (volume and mix flexibility at Company A)		X		 X
Recover	Utilize extra capacity during product maturity stage (efficiency and mix flexibility at Company B)			X	

Table 2: Responding to market opportunities (Example 2 – The "Boom")

Activity	Robust	Agile	Lean	Flexible
Sourcing fruit & developing the suppliers				
Fruit contract planning & mgmt				
Ingredients forecasting & inventory mgmt				
Ingredients transport / unit load mgmt				
Ingredients cost control				
Production planning				
Packaging buying & mgmt				
Blend / pack cost control				
Blend / pack network and supplier mgmt				
Forecasting and sales & ops planning				
Stock control / fulfillment				
UK 3PL mgmt				
International 3PL mgmt				
Logistics control				
Customer mgmt / service / order mgmt				
Customer supply development				

Figure 1: Traffic light representation of the resilience assessment results

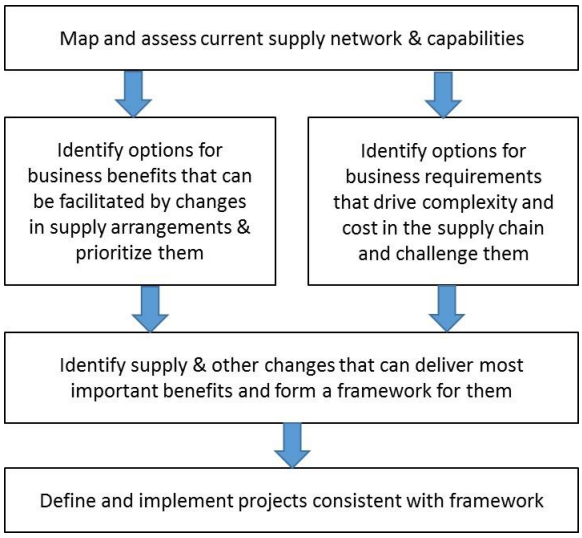
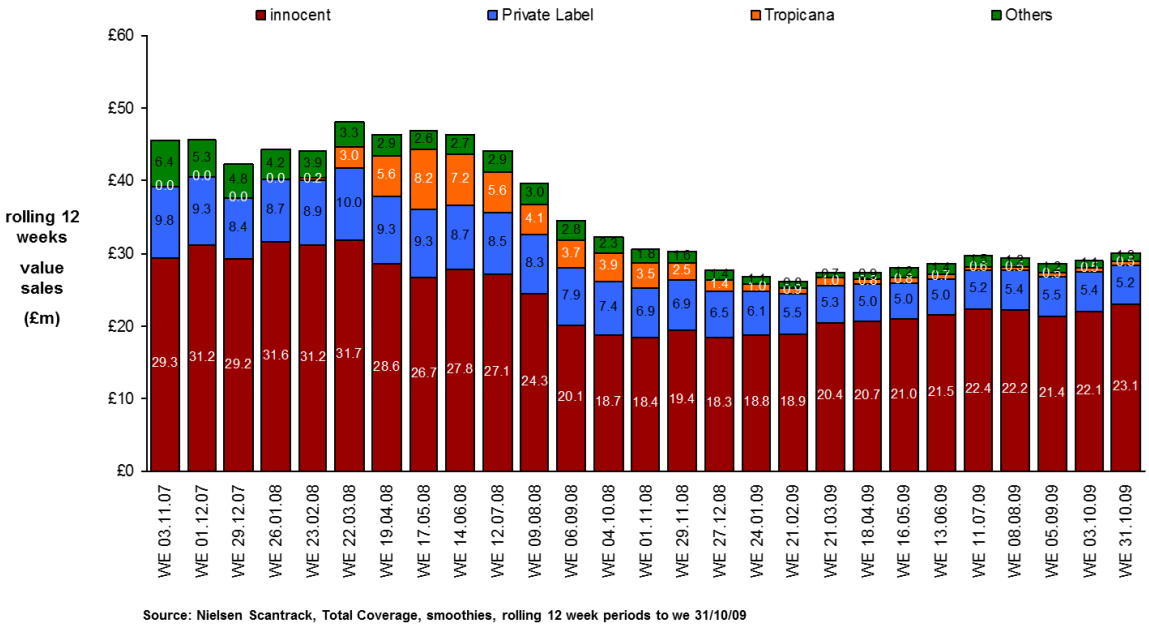


Figure 2: Innocent's five-part supply chain strategy process



Source: Nielsen Scantrack, Total Coverage, smoothies, rolling 12 week periods to we 31/10/09

Figure 3: UK smoothie sales, November 2007 to October 2009

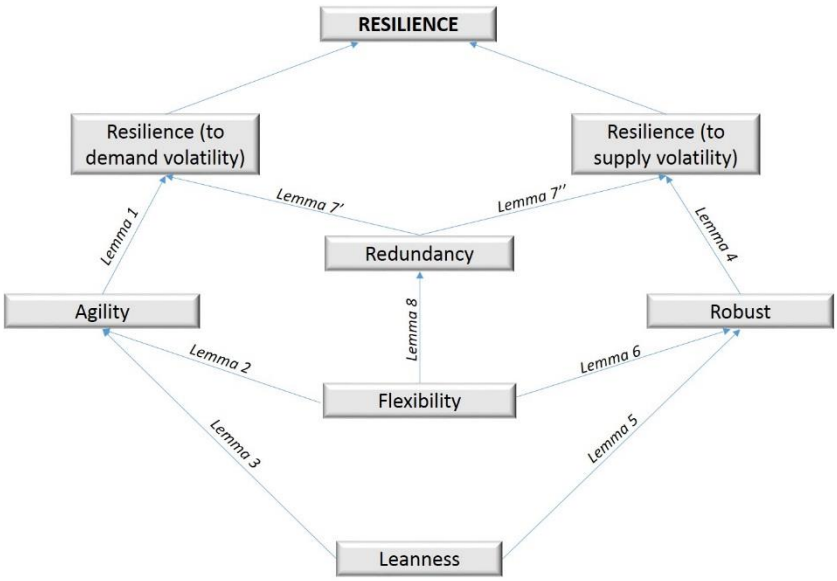


Figure 4: A unified framework for SC resilience

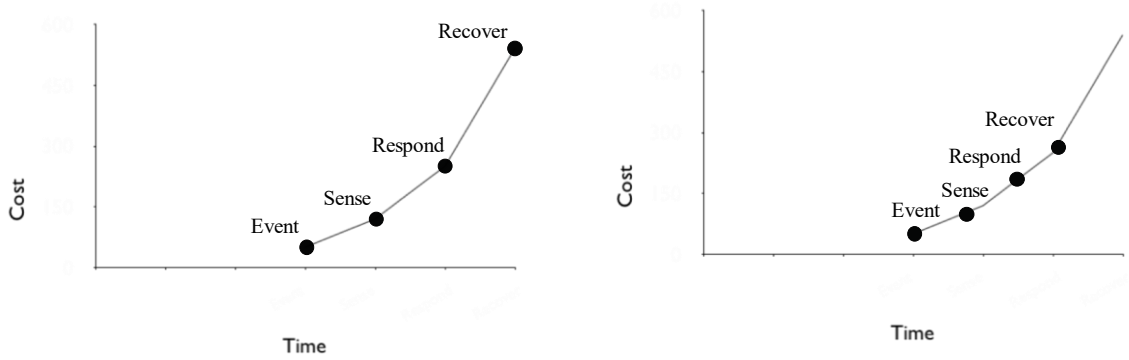


Figure 5: The benefits of resilience: (a) system without resilience, (b) system with resilience (based on Bodendorf and Zimmerman, 2005) [42]

Figure 6 – The DNA of a supply chain resilience strategy

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