Int. J. Production Economics 135 (2012) 870–881

Contents lists available at SciVerse ScienceDirect

Int. J. Production Economics

journal homepage: www.elsevier.com/locate/ijpe

How should you stabilise your supply chains?

Alex Hill[a,*], Des Doran[b], Roy Stratton[c]

[a] Kingston Business School, Kingston University, Kingston Hill, Kingston upon Thames, Surrey KT2 7LB, UK
[b] Brunel Business School, Brunel University, West London, UK
[c] Nottingham Business School, Nottingham Trent University, Nottingham, UK

ARTICLE INFO

Article history:
Received 10 December 2009
Accepted 26 October 2011
Available online 12 November 2011

Keywords:
Stabilising strategy
Cushioning strategy
Supply chains
Operations strategy

ABSTRACT

This case based research paper examines the stabilisation strategies used within seven supply chains and presents a framework to help practitioners stabilise their chains. The findings show that organisations should first select a cushioning strategy and then reduce demand uncertainty to lower the level of cushion held. However, they need to recognise that other organisations within the supply chain are making similar decisions and the whole supply chain needs to be stabilised. Despite this, businesses seem to only share information about their demand uncertainty-reducing mechanisms and not their cushioning strategies. This means that companies often make decisions in isolation of each other, which can then destabilise the chain.

1. Introduction

To compete in increasingly uncertain and competitive markets, many companies choose to focus on their area of core competence and outsource other goods and services (Lowson et al., 2000), which often results in organisations managing ever more complex and varied supply chains (Preiss et al., 1996). A key strategic decision for businesses is how best to stabilise their supply chains and cushion them from market instability. Authors such as Newman et al. (1993) and Hopp and Spearman (1995) suggest using a combination of mechanisms such as inventory, order backlog and capacity. However, others believe there is a gap between theory and practice in supply chain management (Storey et al., 2006) and further management tools are required to help businesses develop strategies (Mills et al., 1998) and become more competitive (Menda and Dilts, 1997).

This research seeks to examine the practical implications of stabilising supply chains to examine the gap between theory and practice. The paper explores the mechanisms for stabilising delivery systems, choosing between alternative mechanisms and current research on stabilising supply chains. The case study research methodology is then outlined explaining how companies were selected and how data was collected and analysed. The findings from each case study are described and the various cushioning strategies reviewed. This discussion leads to the development of the stability managerial framework and theoretical propositions about where alternative mechanisms are most appropriate and how supply chains can be stabilised.

1.1. Stabilisation strategies

Reducing delivery system variation and uncertainty helps organisations maximise their profit and cash flow (Deming, 1982; Ohno, 1988; Womack and Jones, 1996; Adler et al., 1999; Dyer, 2000). There are a number of different strategies to cope with variability that make sense in different business conditions (Hopp and Spearman, 1995). Authors such as Newman et al. (1993) and Caputo (1996) suggest using inventory, order backlog and capacity to cushion an operation from variability in its markets. Rather than cushioning the delivery system, other authors suggest methods for reducing demand uncertainty (e.g. Lee, 1998; Van Hoek, 1998; Disney, 2008; Germain et al., 2008). Equally, other authors suggest companies make their delivery systems more responsive by postponing product differentiation by separating the 'efficiency' and 'market mediation' phases of their delivery systems (e.g. Olhager, 1994; Gattorna and Walters, 1996; Feitzinger and Lee, 1997; Fisher et al., 1997; Lee, 1998). This approach is often referred to as 'postponement', 'demand chains', 'lean supply' or 'agile supply' (e.g. Naylor et al., 1999; Mason-Jones et al., 2000; Christopher and Towill, 2001; Lee, 2002; Hsu and Wang, 2004; de Treville et al., 2004; Yang et al., 2004; Swafford et al., 2008).

Although a number of stabilising mechanisms are identified in the literature, few authors consider how they should be used together. Lovejoy (1998) proposes the 'operations management triangle' where capacity, inventory and uncertainty[1] (or

* Corresponding author. Tel.: +44 20 8547 2000.
E-mail addresses: a.hill@kingston.ac.uk (A. Hill), des.doran@brunel.ac.uk (D. Doran), roy.stratton@ntu.ac.uk (R. Stratton).

[1] Lovejoy (1998) refers to this as 'variability'. However, he then suggests that having more information will make demand less variable. However, this may not always be the case as demand may still be variable, but the organisation will be have able to advanced knowledge or this variations and be able to predict them

0925-5273/$ - see front matter © 2011 Elsevier B.V. All rights reserved.
doi:10.1016/j.ijpe.2011.10.027

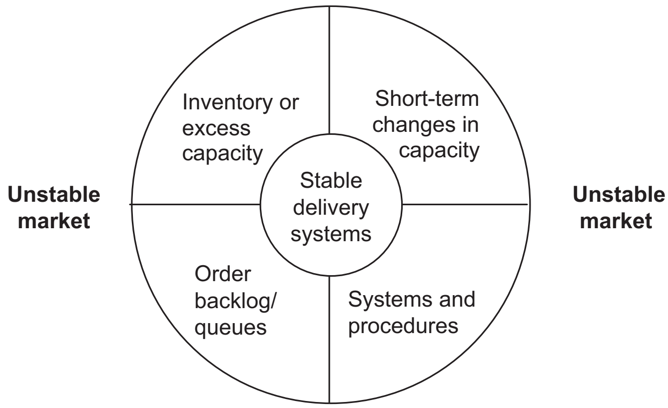

Fig. 1. Mechanisms for cushioning the delivery system from market instability proposed by Hill (2005).

information) are substituted for one another to maintain supply lead-time, which Lovejoy (1998) refers to as customer service. For example, holding excess capacity allows variable demand to be met with lower levels of inventory or reduced lead-time. If there is no excess capacity then inventory must be held to meet uncertain demand or supply lead-time will increase. Equally, reducing both excess capacity and inventory will increase supply lead-time. However, if demand is more certain then inventory or excess capacity can be reduced without supply lead-time increasing. Hill (2005) develops this further by suggesting organisations cushion using one or a combination of inventory/excess capacity, short-term changes in capacity, order-backlog/queues and systems/procedures as shown in Fig. 1. However, the frameworks suggested by Lovejoy (1998) and Hill (2005) both only include mechanisms to cushion the delivery system and do not consider how organisations could reduce demand uncertainty.

1.2. Choosing between alternative stabilisation strategies

Alternative stabilisation mechanisms have been used to meet varying market and business conditions during the last century. During the two decades after World War II, global demand exceeded capacity and businesses used inventory to help maximise utilisation and output. In the 1960s, an alternative approach emerged from Japan where high material costs and limited physical space created pressure to reduce inventory. Smaller order quantities started to be made through reduced process set-up times (Ohno, 1988), reduced process variation and holding excess process capacity (Shingo, 1981). Lowering inventory exposed problems, leading to process refinement and waste reduction (Ohno, 1988) that, in many instances, led to higher quality conformance, shorter lead times and lower costs. The benefits of the 'lean' approach, as it became known, were widely reported by authors such as Schonberger (1982, 1986) and Womack et al. (1990) and have since been widely adopted. However, the 'lean' approach is more suitable to high volume, more certain markets whereas many businesses find customers hold less inventory, outsource more processes and demand shorter lead-times (Fisher et al., 1997; Lee, 2002, Ferdows and Lewis, 2004). It is, therefore, important that companies understand the characteristics and benefits of alternative cushioning mechanisms before selecting ones that suit their market, delivery system and supply chain configurations.

(*footnote continued*)
making demand more certain. Therefore, for the purpose of this study we will refer to it as 'demand certainty', rather than 'demand variability'. This is consistent with other authors such as Krajewski et al. (2005).

1.3. Stabilising supply chains

Supply chain management is an emergent field of practice and an emerging academic domain (Storey et al., 2006, Burgess et al., 2006). Although case studies such as BMW, Compaq, Dell and Zara (Ferdows and Lewis, 2004; Gunasekaran and Ngai, 2005) challenge existing management practice, there is little empirical research into supply chain stabilisation. Research to-date has examined the impact on supply chain stabilisation of factors such as

- **Pricing**—Hamister and Suresh (2008)
- **Demand forecasting**—Chen et al. (2000) and Saeed (2008)
- **Scheduling**—Kadipasaoglu and Sridharan (1995), Harrison (1996), Zhao et al. (2001), Bogataj et al. (2005), Meixell (2005), Sahin et al. (2008), and Childerhouse et al. (2009)
- **Production techniques**—Bivin (2008)
- **Order review intervals**—Waller et al. (2008)
- **Inventory management**—Ganeshan et al. (2001), Irvine and Schuh (2005), Bertsimas and Thiele (2006), Villegas and Smith (2006), Olsen and Parker (2008), and Sipahi and Ilker Delice (2010)
- **Replenishment policy**—Son and Sheu (2008)
- **Relationships**—Lai et al. (2005) and Kehoe et al. (2007)
- **Information sharing**—Lee et al. (1997), van Donselaar et al. (2000), Sahin and Robinson (2005), Geary et al. (2006), Hartland et al. (2007), Chu and Leon (2008), Kin Chan et al. (2008), Chan and Chan (2009), and Jain et al. (2009).

Some authors have looked at supply chain stabilisation within the context of 'inventory theory' or 'supply chain dynamics'. However, most of the extant research examines only one of these factors in isolation, without considering the overall stabilisation strategy. Only Fisher et al. (1997) and Krajewski et al. (2005) have started to compare alternative supply chain stability strategies. Fisher et al. (1997) argued 'functional products' require 'efficient supply chains', whereas 'innovative products' require 'responsive supply chains'. Each type of chain requires a different mix of inventory, order backlog and capacity to hedge against demand uncertainty. However, it is not clear how these mechanisms should be used or where they should be placed within the chain. Krajewski et al. (2005) conclude that firms can either 'reduce uncertainty' by using restrictive supply contracts, infrequent schedule revisions and high form postponement; or 'cope with uncertainty' by having flexible supply contracts, frequent schedule revisions and low form postponement. The perspectives of these two sets of authors provide a useful starting point for investigating the alternative strategies for managing supply chain instability.

2. Methodology

The empirical research presented here builds on the work of Fisher et al. (1997) and Krajewski et al. (2005) and is guided by the Lovejoy (1998) and Hill (2005) cushioning frameworks. It explores the practical implications of managing supply chain stability by investigating four questions:

1. How do companies select supply chains stabilisation mechanisms?
2. How are these mechanisms used to support alternative market and business conditions?
3. How do companies work together to stabilise the whole supply chain?
4. Why do supply chains become destabilised?

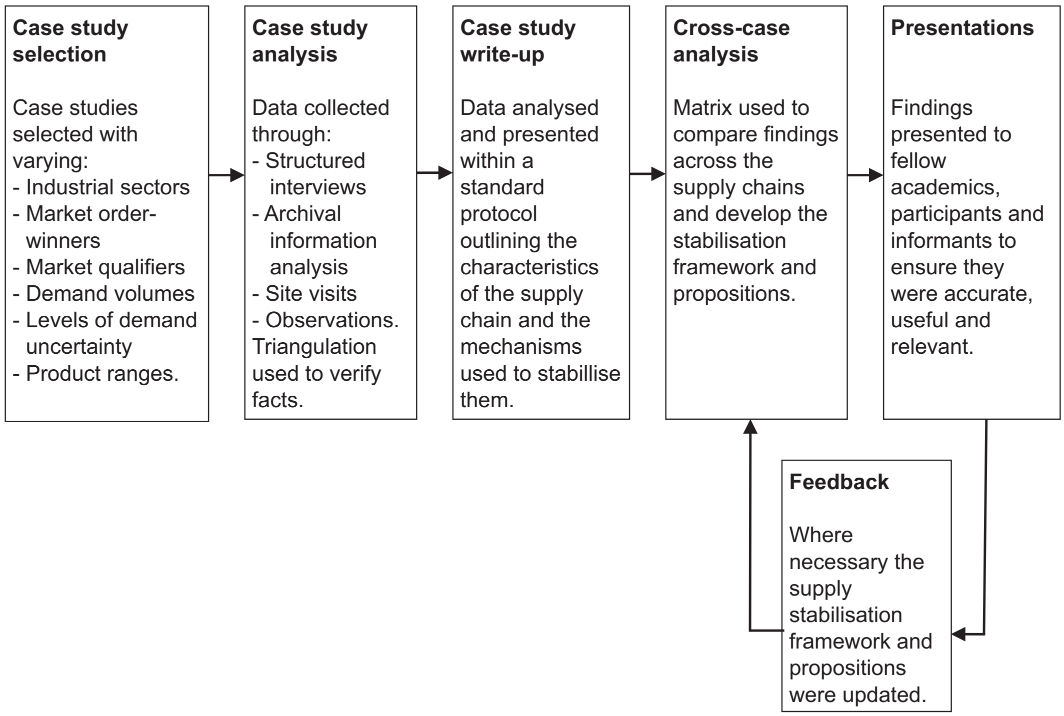

Fig. 2. Research methodology.

As these are 'how and why' questions, rather than 'who, what, where, how many and how much', a case study methodology was felt to be most appropriate (Yin, 1994). This method also suits research aiming to extend existing theory (Voss et al., 2002) and focusing on contemporary events without needing to control behavioural proceedings (Yin, 1994). Fig. 2 outlines the research methodology used to investigate each case study, compare findings across cases, develop the supply chain stabilisation framework and develop the propositions showing the suitable market and business environments for alternative cushioning strategies and demand uncertainty-reducing mechanisms.

This approach is similar to that used within other supply chain research such as the 'quick scan' methodology used by authors such as Banomyong et al. (2005) and Childerhouse et al. (2009) where intense time was spent on site to minimise disruption to organisation being 'quick scanned'. Equally, presentations after the cross-case analysis to participants within the research helped verify its findings and conclusions.

2.1. Case selection

Seven supply chains were investigated to augment external validity, guard against observer bias and ensue empirical grounding and generalisability, without reducing the depth of research within each case (Eisenhardt, 1989; Voss et al., 2002). These supply chains were within four different case studies[2] as described below:

- **Techmould**—produces and assembles moulding for a variety of customers. The research looks at the decisions made by one of its customers, a Japanese car maker, that initially helped stabilise the supply chain, but then later destabilised it and how the rest of the chain responded
- **Mechapump**—manufacturers and assembles pumps for a range of applications. It recently outsourced casting machining and split pump assembly into two business units: one for high volume products and the other for low volume products. The research looks how the decision to outsource casting machining initially destabilised both supply chains and the decisions taken to re-stabilise them afterwards
- **Pheonix**—designs and manufactures athletic clothing selling into both high volume and low volume markets. It recently destabilised both of these supply chains when it transferred its manufacturing to a low cost facility in Honduras. This research looks at how it then re-stabilised both of these supply chains
- **Hartland**—designs and assembles engineered high volume, price-sensitive products and low volume, short lead-time products for aerospace, automotive and industrial customers. However, both supply chain have recently become destabilised by some customers requesting shorter delivery lead-times. This research shows how Hartland was able to meet this requirement and re-stabilise both its high volume and low volume supply chains

The seven supply chains described above were chosen using replication logic so they either produced similar results to each other or contrary results for predictable reasons (Voss et al., 2002). For example, as Hartland had recently stabilised two supply chains, it enabled stabilisation strategies to be compared in two types of market condition within a single business. The same was true for Phoenix and Mechapump who had both recently created high volume and low volume business units. Although Techmould only supplies high volume products, it is particularly interesting because its supply chain was destabilised by its automotive customer's recent introduction of annualised hours working. Technmould, Hartland, Phoenix and Mechapump are all first tier suppliers rather than original equipment manufacturers or integrators, but they operate in different industrial

[2] Please note that the names of the companies have been changed to keep their identities confidential. This research conducted further empirical research within the Pheonix case study used by Warburton and Stratton (2005) to understand the optimal quantity of quick response manufacturing for an onshore and offshore sourcing model.

Table 1
Market order-winners/qualifiers, demand volume/certainty and product range within the cases researched.

Case study	Order winners			Qualifiers				Demand		Product range
	Price	Delivery speed	Technical capability	Price	Delivery		Quality conformance	Volume	Stability	
					Speed	Reliability				
Techmould	✓					✓	✓	High	High	Narrow
Mecha-pump										
High volume	✓				✓	✓	✓	High	High	Wide
Low volume		✓		✓		✓	✓	Low	Low	Wide
Pheonix										
High volume	✓				✓	✓	✓	High	High	Narrow
Low volume		✓		✓		✓	✓	Low	Low	Wide
Hartland										
High volume	✓		✓		✓	✓	✓	High	High	Narrow
Low volume		✓	✓	✓		✓	✓	Low	Low	Wide

sectors. A summary of the various business and market conditions for all four organisations is shown in Table 1. The similarity and difference between the seven supply chains studied creates the diversity required to answer the research questions outlined above.

2.2. Data collection

Quantitative and qualitative data was systematically collected in each case study using site visits, interviews with executives, in-depth analysis of company archival records, documents and observation (Eisenhardt, 1989; Yin, 1994; Gill and Johnson, 1997; Meredith, 1998; Voss et al., 2002). Formal collection procedures ensured data quality and perceptual triangulation assured data validity. A case study database was developed to facilitate cross-case analysis and explicit links were made between the questions asked, data collected and the conclusions drawn to increase information reliability (Miles and Huberman, 1984; Yin, 1994; Voss et al., 2002). The main data sources were interviews with key executives in organisations across each supply chain that then led to extensive analysis of archival records and documents. Interviews were semi-structured and explored the market conditions and stabilisation strategies used within each supply chain. Archival records and documents were then used to test these opinions with quantitative and qualitative data. As the research progressed it was necessary to revisit some of the case companies to provide supporting evidence for the emerging propositions.

For example, Hartland's high and low volume supply chains were researched by first interviewing the operations manager, supply chain manager and key customer account managers within each business unit. These interviews were held at Hartland's production facilities so that actual practice could also be observed. Management reports and performance data were then analysed to test executive opinion and understand current and historical inventory levels, staff working hours, weekly order receipts and production figures. This data collection process was then repeated at Hartland's high and low volume customers and suppliers. Data collection only stopped when the stability strategy and market conditions for each supply chain were fully understood. A similar process was used in the other case studies, although it varied slightly depending on the number and size of the organisations within each supply chain.

2.3. Data analysis

A detailed write-up was completed for each case. Tables then categorised the data, analysed how stabilising mechanisms were used and compared alternative approaches across different supply chains. This allowed the research team to become intimately familiar with each case as a stand-alone entity before looking for patterns across cases (Eisenhardt, 1989). Once each case had been analysed, cross-case patterns were searched for by investigating within-group similarities and inter-group differences. Pairs of cases were selected, the similarities and differences between them listed and a matrix developed comparing how and why companies used different stabilising mechanisms. To test the reliability and validity of the research data, findings were presented to relevant executives from each participating firm. Participants verified that the findings captured the critical issues involved in stabilising supply chains and ensured the conclusions were meaningful and relevant for their industries and markets. The research results could then be considered reliable, valid, and generalisable.

3. Findings

The analysis focused on finding patterns of management practice within and between forms (Adler, 1995) to identify and understand differences in practice and business performance between firms (Poole and Van de Ven, 1989). The research found companies used inventory, order-backlog and capacity to cushion their delivery system from market instability together with a number of mechanisms to reduce demand uncertainty. These findings have been summarised in Table 2 and are now discussed in more detail for each supply chain.

3.1. Case A: Techmould

Techmould makes and assembles moulding for a variety of customers. One customer is a Japanese car company to whom it supplies products that are fitted to a range of cars at different points in their assembly process. To help cushion Techmould's delivery system from the market, the Japanese car company provides an annual forecast, a 3 monthly rolling forecast, a rolling monthly forecast and a weekly forecast of demand. This forecast reflects the overall volume and approximate mix, although the exact sequence may vary. As a car enters the assembly cycle, typically 80 min prior to line build requirements, the relevant data are transferred electronically to Techmould, which it then uses to schedule its own assembly process. In this way Techmould has moved from 'synchronised delivery' to 'synchronised manufacturing'. As a result, it has reduced inventory by 75 per cent to two days of components and two hours of off-line assembled parts. It has also

Table 2
Case summaries illustrating the position of inventory, order backlog, capacity, forecasting, scheduling and process improvement cushioning mechanisms.

Case study	Cushioning mechanisms used in the supply chain					
	Suppliers		Case study company		Customers	
Techmould			△	Finished goods inventory	△ □ ◇	Finished goods inventory Annualised working hours Demand forecasts show 1 month firm and 3 months tentative
Mecha-pump						
High volume			△ ○	Raw material inventory Products made-to-order		
Low volume	△ □	Raw material inventory Capacity assigned to Mechapump				
Pheonix						
High volume			○	Products made-to-order	△ ×	Finished goods inventory Production schedules fixed for a rolling 12 months
Low volume			△ □	Raw material inventory Capacity assigned to certain customers		
Hartland						
High volume	△	Raw material inventory held for Hartland	◇ ○	Demand forecasts show 1 month firm and 2 months tentative Products made-to-order	◇	Demand forecasts show 1 month firm and 2 months tentative
Low volume	△ □	Raw material inventory held for Hartland Capacity assigned to Hartland	□	Excess capacity		

Key: △; Inventory, ○; Order backlog, □; Capacity, ◇ Forecasting, ×; Scheduling.

reduced multi-handling in the process as the customer's car assembly sequencing now drives Techmould's manufacturing. To secure these benefits, Techmould introduced a range of process improvements to ensure zero breakdowns and high quality conformance levels with rejects currently running at 22 ppm.

These arrangements provide an example of how Japanese car companies have worked with suppliers to create mutual benefits. By stabilising demand, refining demand forecasts and making to stock, Techmould's customer has stabilised its own internal processes and provided an opportunity for Techmould to do the same. The process improvements made by Techmould enabled it to further lower inventory and further exploit the advantages of its high volume markets.

However, Techmould's customer's market demand has recently become less stable and it has needed to release cash to use in other parts of its business. In response to these changes, it has introduced annualised hours for its employees to allow it to increase or decrease capacity in line with demand without incurring overtime, excess capacity or inventory costs. While this has allowed Techmould's customer to release cash and reduce cost, it has destabilised its supply chain. As neither Techmould nor its other suppliers have annualised hours as part of their working arrangements then it is more difficult for them to increase or decrease capacity. They are, therefore, having to use increased inventory and overtime working to meet this less stable demand, which has increased cost and tied up cash.

3.2. Case B: Mechapump

Part of an international group, Mechapump is a European-based manufacturer of original equipment (OE) pumps and spares for a range of applications. To meet the increasingly competitive nature of its markets Mechapump made two significant decisions. Firstly, it closed its own on-site foundry and casting machining capability, while keeping pump assembly in-house. Secondly, it split the Company into business units, four making OE pumps and one handling spares demand. Products were allocated to OE business units based on their technical specification that, in turn, reflects the customers' own process requirements. For example, the needs of a chemical plant pump compared to a water plant pump. Mechapump found this allowed it to focus better on the particular needs of its four high volume OE markets while managing low volume spares for all products in a separate business unit.

The details here relate to the OE Business Unit (BU2) that makes pumps for the chemical industry. Prior to the restructuring described above, BU2 manufactured both its low and high volume products to a six-week lead-time consisting of four weeks to manufacture castings and two weeks to assemble the pump. All casting manufacture, some component purchasing and all pump assembly are conducted on a make-to-order basis. As you might expect, the nature of the high and low volume markets was different. In the former, price was an order-winner and market pressure on already low margins was increasing, while in the low-volume markets price was a qualifier with correspondingly high margins. Prior to the restructure Mechapump manufactured castings internally, purchased other pump components (for example, motors, seals and shafts) against known or forecast sales and assembled pumps to order. Under the new arrangements, each business unit is responsible for all aspects of the supply chain including machined castings. BU2 has both a high-volume and low-volume casting requirement and its approach to cushioning the two supply chains from their respective markets is now discussed.

BU2 decided to source all its high-volume castings from the Group's Asian operation. There was a reduction in unit cost allowing it to better support its price sensitive markets. However, casting supply lead-times increased from 4 to between 16 and 24 weeks as the Asian plant used fixed production schedules as part of its approach to reduce manufacturing costs. The decision to outsource casting manufacture, therefore, meant the delivery lead-time requirements of Mechapump's high volume customers could no longer be met. The minimum lead-time of 18 weeks (16 weeks at best for machined castings delivery plus 2 weeks for assembly) would result in a significant loss of market share. Consequently, BU2 decided to hold casting inventory to eliminate this element of lead-time. As before, the other parts (for example, motors, seals and shafts) were purchased in line with known orders or forecasts. By holding casting inventory BU2 was able to make-to-order and meet the six-week lead-time required by its customers (four weeks for bought-in parts plus two weeks for assembly). In BU2's high volume market, outsourcing casting production helped meet its need for lower unit costs, but it had to hold inventory to overcome the longer lead-times involved. However, there is now growing pressure from the Group for BU2 to reduce inventory levels to reduce costs and increase cash flow. The dilemma now facing BU2 is how to manage the casting supply chain to retain the demand stability required by its Asian supplier while reducing lead-times and inventory holding. A by-product of the Group's decision to close the casting foundry has been an exchange of cushioning mechanism from in-house capacity to decoupling inventory. Any future outcome has to recognise the different cushioning needs of the internal and external parts of Mechapump's supply chain and the interdependence that exists.

By constrast, BU2 outsourced its low volume casting manufacture to local suppliers. Again this reduced cost, but to achieve this the local suppliers used order backlog to cushion their delivery system from the instability of their customers' markets, which includes Mechapumps. As a consequence, supply lead-time increased from 4 to between 6 and 10 weeks. The increased and less reliable lead-time meant that Mechapumps is no longer able to support its low volume market and there has been a loss of sales. Although this market only accounts for 13 per cent of BU2's sales, it contributes more than 30 per cent of its profits. To overcome this problem, BU2 decided to reserve capacity at its suppliers by committing to buy a number of castings per week. This allowed local suppliers to eliminate the use of order backlog to cushion their delivery systems from BU2's unstable low volume demand and shorten its lead-time to 4 weeks. As a result, BU2 is now able to meet its low volume customer delivery speed requirements without holding castings inventory, which is typically 4 to 5 times more expensive than the cost of high volume castings. The downside to this arrangement for BU2 is that it must provide sufficient orders for castings to meet the allocated level of capacity even when its own pump sales are lower than forecast. Occasionally this means that BU2 has to order high volume castings to make up the difference in demand and so incurs higher unit costs than if it sourced them from Asia.

3.3. Case C: Phoenix

Phoenix is a successful US subcontract designer and manufacturer of athletic clothing. Some years ago Jennings, a large multinational corporation with several clothing businesses, acquired one of Phoenix's major customers. An early outcome of this takeover was Jennings' decision to change supplier arrangements. While the material requisition and cloth-cutting processes remain at Phoenix, all other activities such as machining and packing were moved to Jennings' own low-cost manufacturing unit in Honduras.

Jennings competes in several market segments in the clothing industry and all its businesses use the Honduras manufacturing facility to meet part of their demand. Honduras production schedules are agreed well ahead to ensure products are manufactured in time for each sales season. To keep costs low, capacity within the Honduras plant is committed throughout the year. The high utilisation of the facility leaves little spare capacity to accommodate any additional sales and it is not practical to change agreed schedules given the seasonal nature of the markets it serves. As a consequence, in the two years following these changes Phoenix was increasingly asked by Jennings to manufacture those sports garments where sales exceeded forecasts. The relatively short selling season (typically 16 weeks) and the delay before it was known that actual sales exceeded forecasts meant that delivery speed was an order-winner in this part of the market.

Phoenix was subsequently reinstated as a supplier with the specific role of meeting short lead-time, post-launch requirements that comprise about 20 per cent of the demand in a typical fashion market. Under these arrangements, Honduras is allocated the base load of a launch (typically some 80 per cent of forecast total sales) with Phoenix put on standby to meet the variable demand element for designer sportswear that may range from 0 to 50 per cent of the base load. To ensure that Phoenix is able to respond quickly Jennings guarantees to place orders corresponding to an agreed level of reserved capacity.

In this way Jennings has used Phoenix as one element of a dual sourced supply-chain. It cuts cloth for its high volume, long lead-time demand in line with forecasts and supplies finished garments for its low volume, short lead-time requirements that are identified post-launch and based on Jennings' revised forecasts. Eighty per cent of demand is high volume, stable and scheduled while the other 20 per cent is lower volume and unpredictable with short lead-times. The result is that both supply chains are balanced and stable within their own markets. Jennings is now able to meet the uncertainties of high margin, designer athletic clothing by responding to additional sales within a season while avoiding the costly impact of discounted items that are a growing problem in fashion markets.

3.4. Case D: Hartland

Part of a large, US-based international company, Hartland provides make-to-order engineered products that go to form processing systems used by its aerospace, automotive and industrial customers. Its technical capability has always been a key order-winner in its markets while delivery-on-time and quality conformance are both qualifiers. However, some customers are starting to reduce lead-times and delivery speed is becoming a factor in both retaining share and an order-winner for growing share of these customers' sales. While it takes Hartland no more than 2–3 day to assemble and test its products, the lead time for sourcing parts from suppliers can be as much as 45 day and is typically around 12–18 day. Its products are highly profitable and there is Group pressure on Hartland to grow sales. To do this Hartland needs to reduce its lead-times and that means working with its suppliers to reduce their lead-times.

On review Hartland found that up to two-thirds of a typical supplier's lead-time was made up of material or order-backlog. Subsequent discussions identified suppliers were doing this to cushion their delivery systems from the unstable demand of customers such as Hartland. Order backlog ensured that work would always be available and they were not prepared to hold material stock against uncertain future orders. These insights now gave Hartland the opportunity to quickly and significantly shorten its own operations lead-time by changing the mechanisms used by its suppliers to cushion their delivery systems. For its high volume more stable demand Hartland gave suppliers a 3 month rolling forecast that showed a firm requirement for the next month and a tentative requirement for the following 2 months. It also introduced guarantees to purchase agreed raw material holdings even if they were not used. For its low volume demand, it introduced the same raw material guarantees and also reserved capacity by agreeing to place a certain number of orders each week. These actions reduced suppliers' demand uncertainty and eliminated their material and order-backlog lead-times. As a result suppliers' delivery lead-time was reduced and Hartland was able to better compete in its markets and thereby grow sales revenue.

3.5. Cross-case summary

Table 3 summarises the approaches used within each of the seven supply chains showing the sequence of steps taken within the chain to stabilise it and the impact of these decisions on the performance of the supply chain. Companies were found to first select a cushioning strategy using inventory, order-backlog or excess capacity and then use demand uncertainty-reducing mechanisms to reduce the level of cushion held. Each of these decisions changed the level and type of cushion held and the performance of each step in the chain. For example, Hartland encouraged its high volume suppliers to hold raw material inventory by agreeing to purchase it even if it was not used. This meant its suppliers started to use inventory rather than order-backlog to cushion their delivery system. As a result, supplier delivery lead-times reduced and so did Hartland's which meant it was more competitive and its sales increased. However, not all changes had a positive performance impact. For example, the decision by Techmould's customer to introduce annualised working hours actually increased demand uncertainty for Techmould who then increased inventory and overtime costs to cushion against this.

4. Discussion

After analysing the data within each supply chain, the findings were then searched for within-group similarities and inter-group differences (Eisenhardt, 1989). Based on this review, eight propositions are made about how companies stabilise their supply chains, the suitable market and business conditions for alternative mechanisms, how companies need to work together to stabilise the whole supply chain and why supply chains become destabilised. A supply chain stabilisation managerial framework is proposed that classifies the stabilisation mechanisms and shows how they need to be used across the supply chain. Companies initially select a cushioning strategy and then reduce demand uncertainty to decrease the level of cushion held. Different cushioning strategies were used in different business and market conditions. To stabilise the whole supply chain, cushioning strategies need to be aligned across all the organisations within the supply chain. However, the evidence

Table 3
Summary of approaches used within each case study to stabilise their supply chains and the impact of each of these decisions.

Case study	Steps taken to stabilise supply chain	Key impact of each step
Techmould	1. Techmould introduced raw material and finished goods inventory to cushion against demand uncertainty	Techmould increased inventory Techmould reduced delivery lead-time
	2. Customer provided demand forecast	Techmould reduced inventory
	3. Techmould scheduled production using customer forecast	Techmould reduced handling costs
	4. Customer introduced annualised working hours to create flexible capacity	Customer reduced inventory Customer reduced overtime costs
	5. Techmould introduced raw material and finished goods inventory to cushion against demand uncertainty	Techmould increased inventory Techmould increased overtime costs
Mecha-pump		
High volume	1. Mechapump outsourced manufacturing to reduce production costs	Mechapump reduced production costs Mechapump increased delivery lead-time
	2. Mechapump introduced raw material inventory to cushion against demand uncertainty	Mechapump increased inventory Mechapump reduced delivery lead-time
Low volume	1. Mechapump outsourced manufacturing to reduce production costs	Mechapump reduced production costs
	2. Suppliers introduced order-backlog to cushion against demand uncertainty	Supplier increased delivery lead-time Mechapump lost sales
	3. Mechapump reduced demand uncertainty at its suppliers by committing to buy enough products per week to fill its capacity	Mechapump increased production costs for high volume products (when has to order them from its low volume supplier)
	4. Supplier reduced order-backlog cushion	Supplier reduced delivery lead-time Mechapump increased sales
Pheonix		
High volume	1. Pheonix transferred manufacturing to Jennings, its low cost production facility to reduce production costs	Phoenix reduced production costs
	2. Jennings fixed production schedules to reduce demand uncertainty	Jennings reduced production costs
Low volume	1. Jennings transferred manufacturing of low volume, short lead-time orders to the Pheonix production facility	Jennings reduced production costs
	2. Jennings reduced demand uncertainty for Pheonix by committing to buy a number of products per week	Phoenix reduced order-backlog Pheonix increased sales
Hartland		
High volume	1. Hartland agreed to purchase supplier raw material inventory even if not used	Suppliers increased inventory Suppliers reduced order-backlog
	2. Hartland provided demand forecast to its suppliers	Suppliers reduced order-backlog
	3. Supplier reduced order-backlog cushion	Supplier reduced delivery lead-time Hartland increased sales
Low volume	1. Hartland agreed to purchase supplier raw material inventory even if not used	Suppliers increased inventory
	2. Harland agreed to place a certain number of orders per week	Suppliers reduced order-backlog cushion
	3. Supplier reduced order-backlog cushion	Supplier reduced delivery lead-time Hartland increased sales

presented above suggests that organisations only share information on mechanisms reducing demand uncertainty and not their cushioning strategies. This situation may cause supply chain instability as companies make decisions in isolation of one another.

4.1. Supply chain stabilisation managerial framework

Observation of case practice has demonstrated that mechanisms were used to either cushion the delivery system from market instability or reduce demand variation. These decisions occurred in two distinct phases. First, a cushioning strategy was chosen using some combination of inventory, excess capacity or order-backlog. Secondly, demand uncertainty was reduced using forecasting, scheduling, demand management or some combination of all three. For example, Techmould initially decided to hold component and finished goods inventory to ensure that it reliably supplied its automotive customer. It has since used forecasting techniques to reduce demand uncertainty and that has helped it to reduce component and finished goods inventory by 75 per cent. However, although reducing demand uncertainty led to a decreased level of cushioning, it did not alter the cushioning strategy used. In other words, forecasting helped reduce inventory, but Techmould still used inventory to cushion its delivery system from market instability. The same was true for Hartland where its high volume suppliers used inventory as a cushion. When Hartland provided them with a three month rolling demand forecast, they were able to reduce raw material stock, but they still used inventory to cushion their delivery systems. However, this was pattern was not only true for companies initially using an inventory cushioning mechanism. In the Mechapumps low volume supply chain, suppliers first decided to use order-backlog cushion against demand uncertainty, but then reduced the size of this cushion when Mechapump committed to buying enough products per week to fill its capacity. The same was true for the Pheonix low volume supply chain. In accordance with these findings, we forward our first proposition:

P1. *Companies first decide on a cushioning strategy and then use demand uncertainty-reducing mechanisms to lower the level of cushion(s) being used.*

The supply chain stability managerial framework shown in Fig. 3 was developed to show these two decision levels and the interaction between alternative mechanisms, with a description of each mechanism given in Table 4. Subsequent discussion with practitioners showed this framework as a useful tool for stabilising supply chains. In particular, it shows how decisions made at one stage of the supply chain affect other organisations across the chain and, therefore, facilitates discussion about how to stabilise the whole chain.

4.2. Application of alternative cushioning strategies

Cushioning mechanism selection depends on the business and market conditions of that point within the supply chain. The mechanisms used within each supply chains were shown earlier in Table 2 and the market and business conditions of each chain in Table 1. These two analyses are now combined and summarised in Table 5.

Table 5 shows that an inventory cushioning strategy is used within supply chains with price sensitive products having a narrow range and high volume stable demand profile. For example, Techmould, and the Japanese car company it supplies, both hold finished goods inventory to cushion their delivery systems from high volume stable demand. This enables them to increase capacity utilisation which, in turn, reduces operating costs and supports market price sensitivity. Equally, Phoenix's customer holds finished goods inventory for its high volume price sensitive markets, however this strategy is not appropriate for their short lead-time products with a wide range and low volume unstable demand. Hartland's suppliers also hold raw material inventory for its high volume products. In many ways, it would make sense for Mechapump to use an inventory cushioning strategy for its high volume products. However, its product range is too wide and, therefore, this strategy would tie up too much cash so it chooses to use order-backlog instead. Therefore, we present our second proposition:

P2. *Inventory is an appropriate cushioning mechanism where there is a narrow product range with high volume stable demand and where price is a market order-winner.*

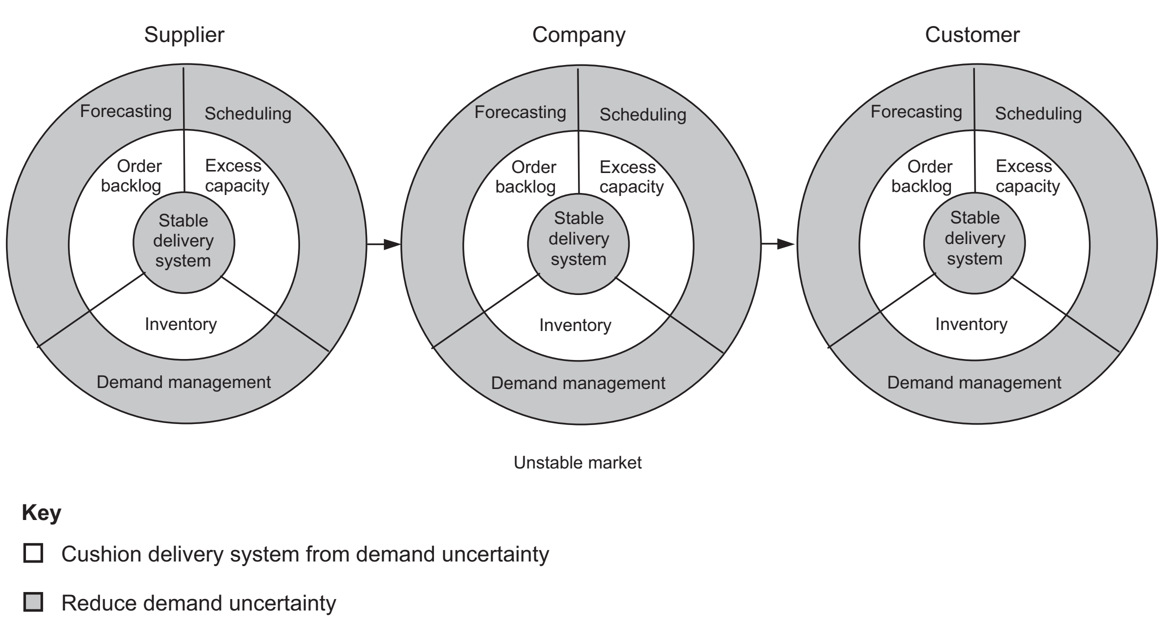

Fig. 3. Supply chain stability managerial framework showing the levels and types of mechanism available across the supply chain.

Table 4
Description of alternative mechanisms proposed in the Supply Chain Stability framework shown in Fig. 3.

Category	Mechanism	Description
Cushion delivery system from demand uncertainty	Inventory	Allows capacity in one time period to meet demand at a future date, reduces supply lead-times and decouples process steps so they can work independently
	Order backlog	Demand waits until capacity is available, often described as forward load or time
	Capacity	Create temporary increases in capacity through methods such as overtime working, subcontracting and eliminating planned non-productive time such as maintenance and continuous improvement
Reduce demand uncertainty	Forecasting	Highlight future demand/capacity imbalances to give time to plan how to overcome them
	Scheduling	Smooth demand by choosing to meet it within a different time period
	Demand management	Smooth demand by moving sales from one period to another through methods such as price reductions or discounts

Table 5
Business characteristics in which mechanisms are most appropriately used to cushion the delivery systems from the market.

Mechanism	Order winners		Qualifiers				Demand				Product range	
	Price	Delivery speed	Price	Delivery		Quality conformance	Volume		Certainty		Narrow	Wide
				Speed	Reliability		High	Low	High	Low		
Cushion												
Inventory	✓			✓	✓	✓	✓		✓		✓	
Order backlog	✓			✓	✓	✓		✓		✓		✓
Excess capacity		✓	✓		✓	✓		✓		✓		✓
Reduce demand uncertainty												
Forecasting	✓			✓	✓	✓	✓		✓		✓	
Scheduling	✓			✓	✓	✓	✓		✓		✓	
Demand management	✓			✓	✓	✓	✓		✓		✓	

In its low volume market, Pheonix uses excess capacity to cushion its delivery system. This offers the flexibility required for its short lead-time products comprising a wide range and exhibiting low volume unstable demand. Although holding excess capacity helps it meet changing patterns, it also increases Phoenix's operating costs. As this results in higher prices for these products, customers only use Pheonix's low volume business units to meet their short lead-time, post-launch requirements. All other requirements are met by its high volume business where an inventory cushioning strategy is used. We also find that an excess capacity cushioning strategy is used by Mechapump's and Hartland's low volume suppliers to meet short lead-time, non-price sensitive requirements. Again, excess capacity cushions the uncertain low volume demand, but increases operating costs. Based on these findings, we forward our third proposition:

P3. *Excess capacity is an appropriate cushioning mechanism for non-price sensitive, wide-ranging products where delivery speed is an order-winner and there is low volume uncertain demand.*

Order-backlog was used for long lead-time, price sensitive products. For example, Pheonix's high volume customers fixed their production schedules for a rolling 12 month period to stabilise production and maximise capacity utilisation. This, in turn, made delivery speed a qualifier and, therefore, meant Phoenix could use order-backlog rather than having to hold excess capacity or finished goods inventory. The same is true for Hartland's high volume products. Since reducing supplier lead-times it is now able to manufacture products within customer requested lead-times and can, therefore, use order-backlog to cushion its delivery system from market fluctuations. We see a similar strategy for Mechapump's high volume products where raw material inventory is held to eliminate supplier lead-times and then products are made-to-order using an order-backlog cushioning strategy. Therefore, we now forward our fourth proposition:

P4. *Order-backlog is an appropriate cushioning mechanism for price sensitive markets where delivery speed is not an order-winner.*

4.3. Application of demand uncertainty-reducing mechanisms

Having deciding upon a cushioning strategy, organisations can reduce demand uncertainty in order to decrease the level of cushion that needs to be held. For example, the demand forecasts provided to Techmould by its high volume automotive customer enabled it to reduce finished goods inventory by 75 per cent. Equally, the demand forecasts developed by Hartland's high volume customers and then passed onto its high volume suppliers meant that their raw material inventory could be reduced by 50 per cent. Both of these chains supply a narrow range of price-sensitive products with stable high volume demand.

By contrast, although Phoenix's high volume supply chain had a narrow product range, demand was unstable and very difficult to forecast. It therefore chose to fix its production schedules for a rolling 12 months. This meant Pheonix could use an order-backlog cushioning strategy but, in reality, the level of cushion held was very small because its demand was fixed for a rolling 12 months. However, to use this mechanism, Phoenix's customer had to hold finished goods inventory to cushion against its own variable demand.

For the low volume supply chains of Mechapump, Pheonix and Hartland, it was very difficult to reduce demand uncertainty due to the wide product range and low demand stability. Therefore, the companies in these supply chains only used cushioning strategies. Based on these findings, we forward our fifth and sixth propositions:

P5. *Forecasting is a suitable approach for reducing demand uncertainty for a narrow product range with high volume stable demand where price is an order-winner.*

P6. *Scheduling is a suitable approach for reducing demand uncertainty when an inventory cushioning strategy is used for a narrow range of products with high volume stable demand.*

4.4. Stabilising the whole supply chain

The previous two sections examined the market conditions in which alternative stabilisation strategies were applied. This section now looks at how whole supply chains can be stabilised. For example, Techmould's high volume supply chain was initially stabilised by its customer holding finished goods inventory and supplying demand forecasts to its suppliers. Further investigation showed that, at the time, Techmould was only aware of the demand forecast and did not realise that its customer was using an inventory cushion. Independently to its customer, Techmould chose to use a similar inventory cushioning mechanism and the supply chain was stabilised. This strategy worked well until Techmould's customer changed from an inventory to an excess capacity cushioning strategy to release cash to invest elsewhere in its business. This change destabilised the whole chain increasing costs and cash holdings within Techmould and its suppliers. This resulted from information not being shared within the supply chain about the cushioning strategies used at each stage and the impact on suppliers of changes to these.

Further research showed that this was also true for the other six supply chains. Information for reducing demand variation is shared, but cushioning strategies are not. For example, Hartland's high volume customers share demand forecasts showing one month firm and two months tentative with Hartland, who in turn shares them with its high volume suppliers. However, none of the companies tell other parts of the supply chain the cushioning strategies that they are using such as inventory for Hartland's suppliers and order-backlog for Hartland. In the case of Phoenix's high volume supply chain, information regarding its customer's fixed production schedules are also communicated to Phoenix who then pass it on to its suppliers. However, again information regarding the cushioning strategies used at each stage in the chain is not communicated to the other companies within the chain. In the low volume supply chains of Mechapump, Pheonix and Hartland, no information regarding the cushioning strategies used at each stage is shared across the chain either, even though no demand uncertainty-reducing mechanisms are used. Based on these findings, we forward our seventh proposition:

P7. *While information for reducing demand uncertainty is shared across the supply chain, information concerning cushioning strategies used at each stage is not shared.*

This has important implications for supply chain management practitioners. Techmould illustrates the need for information on cushioning strategies used at each stage of the supply chain to be shared. If Techmould had known that its customer was going to change its cushioning strategy, then it could have modified its own strategy at the same time and the supply chain would have remained stabilised. However, interviews with Techmould's management team revealed that its customer had not recognised the need to inform its suppliers that it was moving to annualised hours as it did not realise it would impact them. The lack of understanding of the impact of a company's cushioning strategy on the rest of the chain was also present in the other seven supply chains researched. However, supply chains were only stabilised when all the cushioning strategies across the chain were aligned. For example, Phoenix's high volume customer makes-to-stock in line with forecasts and fixes its production schedule to create the stability that allows the rest of the supply chain to operate at minimal cost and meet the price sensitive nature of its markets. By contrast, it hold raw material inventory and assigns capacity to certain customers in order to meet the delivery speed requirement of its low volume market. Hartland and Mechapump both use a similar approach for their short lead-time, low volume products by having raw material inventory and capacity agreements at their suppliers.

Thus, all seven supply chains researched were stabilised by understanding market needs, determining appropriate cushioning strategies, aligning these strategies across the chain and then reducing demand uncertainty to decrease the cushioning levels held. Therefore, we forward our eighth proposition:

P8. *Cushioning strategies must be aligned across the supply chain to collectively stabilise it.*

5. Conclusions

The research reduces the gap between theory and practice in supply chain management (Storey et al., 2006) by making several contributions to the study of supply chain stabilisation. Firstly, it develops the supply chain stabilisation framework to help practitioners manage supply chain stability as shown in Fig. 3. Organisations should first select a cushioning strategy and then reduce demand uncertainty to lower the level of cushion held. However, they need to recognise that other organisations within the supply chain are making similar decisions and the whole supply chain needs to be stabilised. Cushioning strategies used at one stage of a supply chain affected those used elsewhere and, therefore, businesses need to consider the cushions used elsewhere in the chain before selecting their own strategy. The organisations researched found these insights useful for stabilising their own delivery systems and the supply chain as a whole.

Secondly, a number of propositions were developed showing the suitable market and business environments for alternative cushioning strategies and demand uncertainty-reducing mechanisms. This supports the assertion that mechanisms are not better or worse than each other, they are simply more suited to different market and business conditions (Hopp and Spearman, 1995; Fisher et al., 1997):

- **Inventory**—cushioning strategy is appropriate for price-sensitive products with a narrow range and high volume stable demand
- **Excess capacity**—cushioning strategy suits non-price sensitive, short lead-time wide ranging products with low volume uncertain demand
- **Order-backlog**—cushioning strategy is appropriate for long lead-time price sensitive products
- **Forecasting**—is a suitable approach for reducing demand uncertainty for price-sensitive products with a narrow range and high volume stable demand
- **Scheduling**—can be used to reduce demand uncertainty with an inventory cushioning strategy for a narrow range of products with high volume stable demand

Thirdly, it was found that the organisations within the supply chain typically make cushioning decisions in isolation of one another, being unaware of the consequences on other parts of the chain. This supports the view that the chain must be managed as a whole (Frohlich and Westbrook, 2001) and that firms need to move outside of the boundaries of their own organisation to consider both the impact of their decisions on the whole of the chain and the impact of decisions made in other parts of the chain on them (Crooks and Combs, 2007).

Fourthly, the organisations researched seemed to be more likely to share information on demand uncertainty-reducing mechanisms and unlikely to share information on cushioning strategies. These findings support similar views regarding supply chain information integration (Lau et al., 2002; Hartland et al., 2007) and are of concern given the increasing complex and fragmented nature of many supply chains (Choi et al., 2001).

With all case-based research, there are limits to the findings and conclusions made. Although replication logic was used to select the supply chains studied, the research findings may not be generalisable to all organisations. Future research is now required to test if the stability framework and propositions generated here are true for a wider sample of organisations. Although the organisations researched only used cushioning and demand uncertainty-reducing mechanisms to stabilise their supply chain, it seems logical that some organisations may also choose to reduce delivery system uncertainty. Future research needs to future explore how organisations reduce delivery system uncertainty and the role these mechanisms play within their overall stabilisation strategy. Other research that has been conducted using 'quick scan' research methodology such as Banomyong et al. (2005) and Childerhouse et al. (2009) may generate some additional insights given the similarity of research methodology used within this study.

References

Adler, P.S., 1995. Interdepartmental interdependence and coordination: the case of the design/manufacturing interface. Organisation Science 6 (2), 147–168.

Adler, P.S., Goldoftas, B., Levine, D.I., 1999. Flexibility versus efficiency? A case study of model changeovers in the Toyota production system. Organisation Science 10 (1) Jan-Feb.

Banomyong, R., Basnet, C., Childerhouse, P., Deakins, E., Disney, S.M., Naim, M.M., Towill, D.R., 2005, Internationalising the quick scan audit methodology. In: Proceedings of the 18th International Conference on Production Research, Italy, 31 July–4 August 2005, pp. 1–6.

Bertsimas, D., Thiele, A., 2006. A robust optimisation approach to inventory theory. Operations Research 54 (1), 150–199.

Bivin, D.G., 2008. Production stability in a supply-chain environment. International Journal of Production Economics 114, 265–275.

Bogataj, M., Bogataj, L., Vodopivec, R., 2005. Stability of perishable goods in cold logisitic chains. International Journal of Production Economics 93, 345–356.

Burgess, K., Singh, P.J., Koroglu, R., 2006. Supply chain management: a structured literature review and implications for future research. International Journal of Operations and Production Management 26 (7), 703–729.

Caputo, M., 1996. Uncertainty, flexibility and buffers in the management of the firm operating system. Production Planning and Control 7 (5), 518–528.

Chan, H.K., Chan, F.T.S., 2009. Effect of information sharing in supply chains with flexibility. International Journal of Production Research 47 (1), 213–232.

Chen, F., Drezner, Z., Ryan, J., Simchi-Levi, D., 2000. Quantifying the bullwhip effect in a simple supply chain: the impact of forecasting, lead times and information. Management Science 46 (3), 436–443.

Childerhouse, P., Disney, S.M., Towill, D.R., 2009. The effects of schedule volatility on supply chain performance. International Journal of Logistics 12 (4), 313–328.

Choi, T.Y., Dooley, K.J., Rungtusanatham, M., 2001. Supply networks and complex adaptive systems: control versus emergence. Journal of Operations Management 19, 351–366.

Christopher, M., Towill, D., 2001. An integrated model for the design of agile supply chains. International Journal of Physical Distribution & Logistics Management 31 (4), 1–10.

Chu, C.-L., Leon, V.J., 2008. Power-of-two single-warehouse multi-buyer inventory coordination with private information. International Journal of Production Economics 111 (2), 562–574.

Crook, T.R., Combs, J.G., 2007. Sources and consequences of bargaining power in supply chains. Journal of Operations Management 25, 546–555.

Deming, W.E., 1982. Quality, Productivity and Competitive Position. MIT Press, Cambridge, MA.

de Treville, S., Shapiro, R.D., Hameri, A.-P., 2004. From supply chain to demand chain: the role of lead time reduction in improving demand chain performance. Journal of Operations Management 21 (6), 613–627.

Disney, S.M., 2008. Supply chain aperiodicity, bullwhip and stability analysis with Jury's inners. IMA Journal of Management Mathematics 19, 101–116.

Dyer, J.H., 2000. Collaborative Advantage: Winning Through Extended Enterprise Supply Networks. Oxford University Press, New York.

Eisenhardt, K.M., 1989. Building theories from case study research. Academy of Management Review 14 (4), 532–550.

Feitzinger, E., Lee, H.L., 1997. Mass Customization at Hewlett-Packard: the power of postponement. Harvard Business Review Jan-Feb, 116–121.

Ferdows, K., Lewis, M.A., 2004. Rapid-fire fulfilment. Harvard Business Review Nov, 104–110.

Fisher, M., Hamond, J., Obermyer, W., Raman, A., 1997. Configuring a supply chain to reduce the cost of demand uncertainty. Production and Operations Management 6 (3), 211–225.

Frohlich, M.T., Westbrook, R., 2001. Arcs of integration: an international study of supply chain strategies. Journal of Operations Management 19 (2), 185–200.

Ganeshan, R., Boone, T., Stenger, A.J., 2001. The impact of inventory and flow planning parameters on supply chain performance: an exploratory study. International Journal of Production Economics 71 (1), 111–118.

Gattorna, J.L., Walters, D.W., 1996. Managing the Supply Chain: A Strategic Perspective. Macmillan, London.

Geary, S., Disney, S.M., Towill, D.R., 2006. On bullwhip in supply chains—historical review, present practice and expected future impact. International Journal of Production Economics 101 (1), 2–18.

Germain, R., Claycomb, C., Droge, C., 2008. Supply chain variability, organizational structure, and performance: the moderating effect of demand unpredictability. Journal of Operations Management 26, 557–570.

Gill, J., Johnson, P., 1997. Research Methods for Managers. Paul Chapman Publishing, London.

Gunasekaran, A., Ngai, E.W.T., 2005. Build-to-order supply chain management: a literature review and framework for development. Journal of Operations Management 23 (5), 423–451.

Hamister, J.W., Suresh, N.C., 2008. The impact of pricing policy on sales variability in a supermarket retail context. International Journal of Production Economics 111 (2), 441–455.

Harrison, A., 1996. An investigation of the impact of schedule stability on supplier responsiveness. International Journal of Logistics Management 7 (1), 83–91.

Hartland, C.M., Caldwell, N.D., Powell, P., Zheng, J., 2007. Barriers to supply chain information integration: SMEs adrift of eLands. Journal of Operations Management 25, 1234–1254.

Hill, T., 2005. Operations Management: Strategic Context and Managerial Analysis, 2nd ed. Palgrave Macmillan, Basingstoke.

Hopp, W.J., Spearman, M.L., 1995. Factory Physics. Irwin/McGraw Hill.

Hsu, H.-M., Wang, W.-P., 2004. Dynamic programming for delayed product differentiation. European Journal of Operational Research 156, 183–193.

Irvine, F.O., Schuh, S., 2005. Inventory investment and output volatility. International Journal of Production Economics 93–94, 75–86.

Jain, V., Wadhwa, S., Deshmukh, S.G., 2009. Revisiting information systems to support a dynamic supply chain: issues and perspectives. Production Planning and Control 20 (1), 17–29.

Kadipasaoglu, S.N., Sridharan, V., 1995. Alternative approaches for reducing schedule instability in multistage manufacturing under demand uncertainty. Journal of Operations Management 13, 193–211.

Kin Chan, C., Lee, H.W.J., Wong, K.H., 2008. Optimal feedback production for a two-level supply chain. International Journal of Production Economics 113 (2), 619–625.

Kehoe, D.F., Dani, S., Sharifi, H., Burns, N.D., Backhouse, C.J., 2007. Demand network alignment: aligning the physical, informational and relationship issues in supply chains. International Journal of Production Research 45 (5), 1141–1160.

Krajewski, L., Wel, J.C., Tang, L.-L., 2005. Responding to schedule changes in build-to-order supply chains. Journal of Operations Management 23 (5), 452–469.

Lai, K.-H., Cheng, T.C.E., Yeung, A.C.L., 2005. Relationship stability and supplier commitment to quality. International Journal of Production Economics 96 (3), 397–410.

Lau, J.S.K., Huang, G.Q., Mak, K.L., 2002. Web-based simulation portal for investigating impacts of sharing production information on supply chain dynamics from the perspective of inventory allocation. Integrated Manufacturing Systems 13 (5), 345–358.

Lee, H., 1998. Postponement for mass customisation: satisfying customer demands for tailor made products. In: Gattorna, J. (Ed.), Strategic Supply Chain Alignment. , Gower, Aldershot, pp. 77–91.

Lee, H.L., 2002. Aligning supply chain strategies with product uncertainties. California Management Review 44 (3), 105–119.

Lee, H.L., Padhamanabhan, V., Whang, S., 1997. The bullwhip effect in supply chains. Sloan Management Review (Spring), 93–102.

Lovejoy, W., 1998. Integrated operations: a proposal for operations management teaching and research. Production and Operations Management 7 (2), 106–124.

Lowson, R., King, R., Hunter, A., 2000. Quick Response: Managing the Supply Chain to Meet Customer Demand. John Wiley and Sons, London.

Mason-Jones, R., Naylor, J.B., Towill, D.R., 2000. Engineering the leagile supply chain. International Journal of Agile Manufacturing Systems 2 (1), 54–61.

Menda, R., Dilts, D., 1997. Manufacturing strategy formulation process: linking multifunctional viewpoints. Journal of Operations Management 15 (4), 223–241.

Meixell, M.J., 2005. The impact of set-up costs, commonality, and capacity on schedule stability: an exploratory study. International Journal of Production Economics 95, 95–107.

Meredith, J.R., 1998. Building operations management theory through case and field research. Journal of Operations Management 16, 441–454.

Miles, M.B., Huberman, A.M., 1984. Qualitative Data Analysis. Sage, Beverly Hills, CA.

Mills, J., Neely, A., Platts, K., Gregory, M., 1998. Manufacturing strategy: a pictorial presentation. International Journal of Operations and Production Management 18 (11), 1067–1085.

Naylor, J.B., Naim, M.M., Berry, D., 1999. Leagility: integrating the lean and agile manufacturing paradigms in the total supply chain. International Journal of Production Economics 62 (1), 107–118.

Newman, W., Hanna, R., Maffei, M.J., M., 1993. Dealing with the uncertainties of manufacturing: flexibility, buffers and integration. International Journal of Operations and Production Management 13 (1), 19–34.

Ohno, T., 1988. The Toyota Production System; Beyond Large-Scale Production. Productivity Press, Portland, OR.

Olhager, J., 1994, On the positioning of the customer order de-coupling point. In: Proceedings of the 1994 Pacific Conference of Manufacturing, Jakarta, Indonesia, pp. 1093–1100.

Olsen, T.L., Parker, R.P., 2008. Inventory management under market size dynamics. Management Science 54 (10), 1805–1821.

Poole, M.S., Van de Ven, A.H., 1989. Using a paradox to build management and organisation theori. The Academy Management Review 14 (4), 562–579.

Preiss, K., Goldman, S.L., Nagel, R.N., 1996. Cooperate to Compete: Building Agile Business Relationships. Van Nostrand Reinhold, New York.

Saeed, K., 2008. Trend forecasting for stability in supply chains. Journal of Business Research 61, 1113–1124.

Sahin, F., Robinson, E.P., 2005. Information sharing and coordination in make-to-order supply chains. Journal of Operations Management 23, 579–598.

Sahin, F., Robinson, E.P., Gao, Li-Lian, 2008. Master production scheduling policy and rolling schedules in a two-stage make-to-order supply chain. International Journal of Production Economics 115, 528–541.

Schonberger, R.J., 1982. Japanese Manufacturing Techniques: Nine Hidden Lessons in Simplicity. Free Press, New York.

Schonberger, R.J., 1986. World Class Manufacturing: The Lessons of Simplicity Applied. The Free Press, New York, NY.

Shingo, S., 1981. A Study of the Toyota Production System from an Industrial Engineering Viewpoint, revised edition Productivity Press, Portland, Oregon.

Sipahi, R., Ilker Delice, I., 2010. Stability of inventory dynamics in supply chains with three delays. International Journal of Production Economics 123 (1), 107–117.

Son, J.Y., Sheu, C., 2008. The impact of replenishment policy deviations in a decentralised supply chain. International Journal of Production Economics 113 (2), 785–804.

Storey, J., Emberson, C., Godsell, J., Harrison, A., 2006. Supply chain management: theory, practice and future challenges. International Journal of Operations and Production Management 26 (7), 754–774.

Swafford, P.M., Ghoush, S., Murthy, N., 2008. Achieving supply chain agility through IT integration and flexibility. International Journal of Production Economics 116 (2), 288–297.

van Donselaar, K., Van Den Nieuwenhof, J., Visschers, J., 2000. The impact of material coordination concepts on planning stability in supply chains. International Journal of Production Economics 68 (2), 169–176.

Van Hoek, R.I., 1998. Reconfiguring the supply chain to implement postponed manufacturing. International Journal of Logistics Management 9 (1), 95–110.

Villegas, F.A., Smith, N.R., 2006. Supply chain dynamics: analysis of inventory vs. order oscillations trade-off. International Journal of Production Research 44 (6), 1037–1054.

Voss, C., Tsikriktsis, N., Frohlich, M., 2002. Case research in operations management. International Journal of Operations Management 22 (2), 195–219.

Waller, M.A., Williams, B.D., Eroglu, C., 2008. Hidden effects of variable order review intervals in inventory control. International Journal of Physical Distribution and Logistics Management 38 (3), 244–258.

Warburton, R.D.H., Stratton, R., 2005. The optimal quantity of quick response manufacturing for an onshore and offshore sourcing model. International Journal of Logistics 8 (2), 125–141.

Womack, J.P., Jones, D.T., Roos, D., 1990. The Machine that Changed the World. Macmillan, New York.

Womack, J.P., Jones, D.T., 1996. Lean Thinking—Banishing Waste and Creating Wealth in Your Corporation. Simon and Schuster, New York.

Yang, B., Burns, N.D., Blackhouse, C.J., 2004. Management of uncertainty through postponement. International Journal of Production Research 42 (6), 1049–1064.

Yin, R.K., 1994. Case Study Research—Design and Methods, 2nd ed. Sage, London.

Zhao, X., Xie, J., Jiang, Q., 2001. Lot-sizing rule and freezing the master production schedule under capacity constraint and deterministic demand. Production and Operations Management 10 (1), 45–67.