KULWANT S. PAWAR
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DEVELOPMENTS IN LOGISTICS AND SUPPLY CHAIN MANAGEMENT

PAST, PRESENT AND FUTURE

Developments in Logistics and Supply Chain Management

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Developments in Logistics and Supply Chain Management

Past, Present and Future

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1
Introduction

1.1

Introduction and Overview

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Over the last couple of decades, the whole domain and discipline of logistics and supply chain has developed quite significantly. If one reflects back to the early 1990s, logistics had its roots firmly within the context of inbound and outbound transport and warehousing. The whole sector was fragmented, unorganised and run by a number of small operators, and the concept of third party logistics did not exist. In fact, the term "logistics" was often labelled as "sheds and lorries". On the other hand, there was a realisation of the importance of getting the right goods to the right place at the right time and at the right quality.

In parallel, during the early 1990s, there was huge debate surrounding the so-called new environment of intensified global competition, the removal of national barriers and the emergence of regional trading blocks such as the Single Market in Europe, the Pacific Rim, Continental America and the opening up of Eastern Europe and the Russian subcontinent. All of this was creating new challenges and opportunities for businesses and, indeed, for expanding and professionalising logistical operations. Thus, many organisations sought to focus their attention on managing logistics more efficiently.

Similarly, professional bodies like institutes and societies were focused on production planning, materials management, purchasing and production management, etc., and the term "logistics" was still not used extensively until mid-1990s. Equally, there was a lack of attention to logistics within various courses at universities and higher educational institutes. Logistics was considered to be part of materials and production management courses with a few odd exceptions where logistics was taught as a module within a course on production or operations management.

In early 1992, a proposal was made to the United Kingdom's Operations Management Association (OMA), which subsequently expanded as the European Operations Management Association (EurOMA), to provide support for the launch of the inaugural International Symposium on Logistics (ISL) in Nottingham, UK, in July 1993. The launch of ISL came about from the growing realisation that a common forum to bring together and stimulate the exchange of ideas between academic research and industrial practice did not exist. Previous similar events had tended to be rather focused in the area of operations, materials or inventory management, and there was a need to bridge this gap. After the success of 1993, subsequent ISL events were held in Nottingham in 1995, Padua in 1997 and Florence in 1999. There was a huge interest from the Japanese academic community to organise ISL 2000 in Iwate, which proved to be an even bigger success. This also led to the concept of alternating ISL between Europe and outside Europe on an annual basis. To date, this event has been held in Salzburg (2001), Melbourne (2002), Seville (2003), Bangalore (2004), Lisbon (2005), Beijing (2006), Budapest (2007), Bangkok (2008), Istanbul (2009), Kuala Lumpur (2010), Berlin (2011), Cape Town (2012), Vienna (2013) and Ho Chi Minh City (2014), with the 20th ISL being planned in Bologna in July 2015.

The papers in this book have been carefully selected from the 19 proceedings of ISL to celebrate this 20th anniversary. It has become a regular, well-established and premier international event in the field of Logistics and Supply Chain Management. To date, over 1700 papers have been published in the conference proceedings; hence, making it a very difficult and challenging task to select the papers to be included in this book. The title "Developments is Logistics and Supply Chain: Past, Present and Future" has been chosen to reflect a collection of the most influential contributions from the last two decades. These contributions also reflect wider research activity being undertaken within the logistics and supply chain community.

Content overview

The 1990s

The 1990s saw the discovery of "lean production" (see Womack et al., 1990; Womack and Jones, 1996), and it is not surprising that the lean paradigm influenced much research and debate in the academic community as well as making an impact on practice.

Learning from good industrial practice was a common theme, especially if the learning came from Japan and the Toyota Production System.

One such knowledge transfer opportunity was the role of suppliers in ensuring the successful operation of an automotive supply chain and how the model of "supplier associations", or *kyoryoku kai*, is transferred into a non-Japanese context (Hines, 1997).

The role of suppliers in the chain is endorsed by Ghobadian et al. (1993). They articulate a computer based architecture for aiding purchasing and sourcing decision makers when selecting suppliers utilising multiple qualitative and quantitative criteria. Interestingly, following the law of unintended consequences as has happened with Forza et al. (1993), Ghobadian et al. (1993) is often cited for its claim that raw materials account for much as 70 per cent of the total production costs rather than the supplier rating system that it promotes.

The lean thinking community also sought various forms of continuous improvement tools and techniques. An often cited paper for the use of a process mapping approach is that by Forza et al. (1993) who undertook research on the application of information and communication technologies (ICT) to enable a quick response in the textile apparel industry.

Christopher et al. (1999) provide an example of the discourse that prevails to the present day – what are the tenets and the differentiators of lean and agile production/supply chains? The need to develop resilient supply chains able to respond to and recover from endogenous and exogenous disturbances, and yet maintain costs as low as possible, means that there is still considerable interest in the characteristics of lean and agile strategies and how they may be combined.

Bringing together two themes of ICT and supplier development, Barratt (1999) determines the extent to which ICT enables information transparency along the supply chain. The biggest challenge is the lack of trust and the lack of awareness of the benefits that may result if there is a free exchange of information.

Related to the lean thinking paradigm is Flapper's (1995) advocation of what we would now call the "circular economy". With the need to minimise waste, a business model that may reuse end-of-life products has particular advantages but also logistical challenges. The latter includes the unpredictability of the availability of end-of-life components and the utilisation of resources to recover and process them into sufficient quality for their reuse.

The 2000s

The 2000s continued to see an interest in lean, efficient supply. However, the focus also moved from the factory to consider logistics as well. Potter et al. (2003) examine Factory Gate Pricing (FGP) as a further evolution of the grocery supply chain. FGP provides a mechanism for retailers to take control of their supply chain upstream of distribution centres and realise efficiencies. The inefficiencies often come from less than truck-load consignments, and Katayama and Yurimoto (2002) provide an analytical approach for consolidating these to minimise costs for a given service level. Finally, Holweg and Bicheno (2000) develop the reverse amplification effect, where deliveries to customers are further distorted in comparison to the orders placed.

However, reflecting the work of Christopher et al. (1999), researchers have developed the concept of agile, responsive supply chains. Avittathur and Shah (2004) design an allocation model for retailers in deciding how much to stock of customised versions of a generic product. They identify that the fixed costs of retailing can play a crucial role in this decision. Meanwhile, Tang and Tomlin (2007), Pearson et al. (2008) and Colicchia et al. (2009) all consider the risks inherent in agile supply chains. The first of these three articles considers the role of flexibility in mitigating risks while the other two contribute simulation based decision support systems to evaluate risks in global supply chains.

Risks are not just present in agile supply chains, and Vlajic et al. (2009) develop a framework to evaluate these risks more generally. They conclude by proposing a number of redesign strategies to mitigate these. As well as flexibility, they also suggest greater levels of integration and effective use of ICT. Potential business models for integration are proposed by Holmström et al. (2003), including vendor managed inventory and collaborative planning, forecasting and replenishment. By contrast, van der Vaart and van Donk (2005) critically review survey research on integration and highlight the wide range of factors and constructs used to measure integration. They also show that the level of integration is dependent upon the buying firm.

The use of ICT is examined by Timm et al. (2001) and Takeno et al. (2006). Timm et al. (2001) propose a multi-agent system to enable a network of SMEs to achieve mass customisation. They establish an architecture for such a system as well as consider aspects such as confidentiality and robustness. Takeno et al. (2006) also develop a prototype system, this time for traceability in the seafood supply chain. The system not only informs the operations of the supply chain but also enables quality risks to be identified quickly.

Finally, the papers published during the 2000s have demonstrated the academic impact of the ISL conference. Two of the conference papers (Holmström et al., 2003, and van der Vaart and van Donk, 2005) have been extended into journal format and subsequently received several hundred citations. Such use by the wider academic community highlights the value of conference papers as a stepping stone on the way to journal publication.

The 2010s

By 2010, there was an assumption of global reach for many organisations in terms of utilising suppliers and fulfilling customer requirements across the world. As such, effective management of freight logistics had become a central aspect of competitiveness. How freight transport options are evaluated and selected is examined by Lirn and Wong (2010), who use the grain industry as the focus of their case study on freight choice. They found that the four most important service dimensions influencing freight transport choice selection were grain market value, inventory holding cost, transport cost and the in-transit inventory cost. A key contribution of this paper is that an understanding of the level of importance attached to service attributes can provide insights into ways to improve carrier performance, increase shippers' and importers' patronage and improve containers' flow imbalances. Somewhat related to this theme, owing to increased customer and governmental awareness of the importance of the "carbon footprint" as a performance measure, is the issue of carbon emissions arising from logistics operations. In his 2012 contribution, McKinnon (2012) proposes six principles for defining carbon emission targets and discusses their potential corresponding implications.

Supply chain integration continued to be seen as a key way to become and remain competitive in the global environment. This issue is addressed by Schadel et al. (2011) who focus on the rising role of China in the automotive industry. More specifically, using an inductive approach, they investigate the important concept of readiness of the supply chain partners for collaboration and integration. At the point in time when the article was written, integration of the automotive industry suppliers was found to be "low to very low".

Performance measurement is a recurring theme throughout the years and is looked at in many different supply chain contexts. By investigating food supply chains, Bourlakis et al. (2013) examine the issue of sustainable performance. They found small firms to be the best performers, particularly in terms of flexibility and responsiveness across their supply chains. This research has implications for the development of sustainability-related benchmarks in the food sector and beyond. Another important recurring theme that has occupied supply chain researchers in a variety of settings is that of Business Process Measurement (BPM). Tying in with some of the issues raised in Schadel et al.'s 2011 paper, Pradabwong et al. (2014) take four cases in Thailand as a setting for examining how internal and external BPM influence the degree of supply chain collaboration. Their findings indicate there is a strong connection between the two, in that together they can be used to drive collaborative advantage and hence firm performance.

As individual consumers and organisations have adapted their buying behaviour, with online purchasing becoming a major business force, increasing research attention was paid to the corresponding supply chain implications. This is captured well by the Hjort et al. (2012) paper that examines the online returns process in the fashion industry. In the fast moving world of e-commerce, customer returns are a valuable service parameter, whereby the costs are often under estimated. In particular, the cost and time involved to re-enter returned goods into the supply chain are not transparent within many organisations.

Future trends

Looking beyond 2015, there are numerous challenges and opportunities for innovations in logistics and supply chains. Solutions will be underpinned by ever growing technological development whether they are in processes, products or information and communication based technology. These technologies on the one hand are offering solutions to specific problems yet their overall integration and impact within the extended logistics and supply chain remains an open issue for researchers to explore. Similarly, the data generated from the deployment of these technologies in the form of so-called "big data" equally poses huge opportunities for researchers and analysts to support decision making processes. The recent explosion in social media related technologies is imposing greater demands from users and consumers for personalised and customised products and services. This in turn will necessitate the development of robust systems and processes which are based on theoretical underpinned and applied models, tools, techniques and methodologies for the provision of risk averse, resilient, cost effective, environmentally friendly practices. The increasing trend towards online shopping and the mode of "last mile" deliveries, especially the use of drones and driverless vehicles, is changing the landscape for decision makers and the academic community alike.

In parallel, for the efficient and timely deliveries of goods and services the development of flexible yet resilient network of suppliers and vendors is desirable, based upon open, transparent and trustworthy relationships. This also imposes an important challenge and responsibility on the educators, professional societies and institutes to train, develop and professionalise the entire logistics and supply chain community around the world and instil a customer oriented culture and ethos. Finally, an entrepreneurial and innovative culture which promotes disruptive behaviour amongst users and service providers will lead to the development of creative solutions such as the "Uberisation" of shipping containers and lorries for better use of capacities and capabilities.

In addressing these future research challenges, the support of the academic community remains essential. The International Symposium on Logistics, and other similar conferences, will continue to provide a platform for developing these challenges and encouraging researchers from many disciplines to work together in finding novel solutions.

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2
Supply Chain Design and Configurations

2.1
Framework for Designing Robust Supply Chains

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Introduction

Today's business environment and harsh competitiveness force companies and entire supply chains to increase their efficiency as much as possible. As a consequence, supply chains have become highly sensitive to disruptions and less tolerant to deviations in operations, that is, supply chains have become more vulnerable (see Kleindorfer and Saad, 2005). Vulnerability of supply chains may result in less consistent supply chain performances, and consequently, their competitive power in the market may diminish. In order to maintain stability of supply chain performances, it is necessary to design robust supply chains. Robust supply chains should be able to continue to function well in the event of a disruption as well as in the normal business environment (see Dong, 2006; Tang, 2006; Waters, 2007). Generally, robustness of the supply chain depends on its capability to respond adequately to different kinds of risks of disturbances. Recently, supply chain vulnerability and robustness has become a hot research topic, and as such, it is still in its infancy. With this paper, we aim to contribute to the existing knowledge in these areas.

Research model

Our research model consists of four research variables: supply chain scenario, sources of vulnerability, redesign strategies, supply chain disturbances and supply chain performances (Figure 2.1.1).

A *supply chain scenario* is an internally consistent view of a possible instance of the logistics supply chain concept, that is, the managed, managing and information systems and organisation structure in the supply chain (van der Vorst, 2000). *Managed* system refers to the physical design of the network and facility and all other elements that

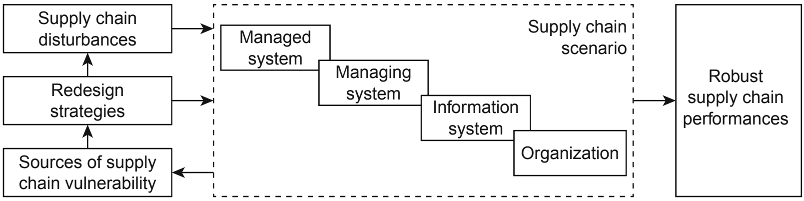

Figure 2.1.1 Research model for robust supply chain design

perform the execution of logistic activities (such as equipment, vehicles and people) as well as product characteristics (element in transformation). *Managing* system (control concept) refers to planning, control and coordination of logistic processes in the supply chain while aiming at realising logistical objectives within the restrictions set by the supply chain configuration and strategic SC objectives. It also considers relevant contextual factors (i.e., specific characteristics of food supply chains such as product quality requirements and requirements that come from specific product–market combinations). *Information* system refers to decision-making support within each of the decision layers of the managing system as well as the IT infrastructure needed. *Organisation* structure refers to tasks, authorities and responsibilities of the departments and executives within the organisation and supply chain.

The design of the supply chain scenario results in higher or smaller susceptibility of a supply chain to disturbances, that is, supply chain vulnerability. According to Waters (2007, p. 99): "supply chain vulnerability is the exposure of a supply chain to disruption arising from the risks to operations within each organization, to interactions within the supply chain, and from the external environment". In this paper, we focus on supply chain vulnerability from the aspect of disturbances[1] (more about that in the section about supply chain disturbances and vulnerability).

In order to sustain competitiveness in today's highly dynamic environment, it is necessary to maintain robust performances and supply chain resilience (see Dong and Chen, 2007). The degree of performance robustness depends on the level of supply chain flexibility (see Barad and Sapir, 2003) and the flexibility in performance requirements. Therefore, the selection of the best supply chain scenario that will enable robust supply chain performances requires:

- An analysis of supply chain vulnerability sources;
- An analysis of supply chain disturbances and their estimated impact on relevant supply chain performance indicators (KPIs);

- An identification of appropriate supply chain redesign strategies (that consequently change the supply chain scenario) per source of vulnerability;
- Modelling and quantification of supply chain performances for alternative supply chain scenarios subject to different disturbances.

The focus of this paper is on classification of supply chain vulnerability sources, disturbance characteristics and classification of supply chain redesign strategies.

Supply chain robustness concept

In supply chain literature, robustness is mainly defined in a broad, conceptual level as the ability of the system to continue to function well in all circumstances (see Vlajic et al., 2008 for an extended review). According to Dong and Chen (2007), extensive literature exists on the measurement of supply chain performance, but little of this work has focused on measuring supply chain's robustness, that is, its ability to cope with disturbances (deviation, disruptions and complete failures). According to (Waters, 2007, p. 159), a traditional way in business specifies an acceptable range for specifications, and performance is considered acceptable if it stays within this range. This effect can be describes as "loss function", which gives a notional cost of missing the target. Therefore, we can conclude that a supply chain (scenario) is robust if values of its KPIs are sustained between minimal required values and target or norm values for a defined period, in normal as well as disrupted regime of work. Here, it is necessary to consider that target (or norm) values as well as minimal required values are case dependent as the selection of KPIs and their values depend on company objectives and problem characteristics (i.e., strategic versus operational problems) and KPIs might not be equally important.

By developing a tool for measuring supply chain robustness, such as the robustness index (e.g., see Gupta and Rosenhead, 1968; Dong, 2006; Dong and Chen 2007; Vlajic et al., 2008), one can gain insight into the current state of supply chain vulnerability as well as to the potential of the supply chain to overcome different kinds of disturbances.

Supply chain disturbances and supply chain vulnerability

In order to better understand supply chain vulnerability, it is necessary to get insight into the sources of vulnerability (i.e., what is causing the vulnerability) and to distinguish levels of disturbance magnitude and related impacts on performance. In the literature, there are several approaches to classification of *sources of vulnerability* (from this aspect, classification of sources of supply chain vulnerability is complementary with sources of disturbances, risk and uncertainty). Based on the reviewed literature (e.g., Mason-Jones and Towill, 1998; Asbjørnslett and Rausand, 1999; Svensson, 2000; van der Vorst and Beulens, 2002; Waters, 2007; Simchi-Levi et al., 2008; Asbjørnslett, 2009), we distinguish two basic levels of vulnerability sources: internal and external (Figure 2.1.2).

Roots of internal sources of supply chain vulnerability lie within the logistics concept of the supply chain, that is, within the elements of the supply chain scenario: managing, managed, information system and organisation. However, from the company perspective, these internal sources are more or less controllable (see Simchi-Levi et al., 2008, p. 316), and they have two levels: the company level and the supply chain level. Roots of external sources of supply chain vulnerability lie in the environment; some of them are controllable to some extent (e.g., market or

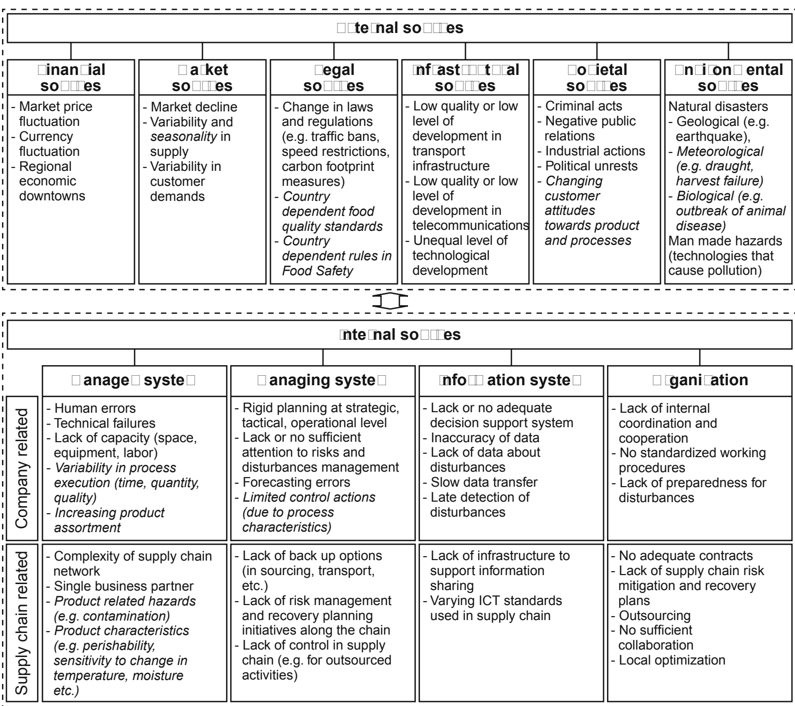

Figure 2.1.2 Preliminary list of sources of supply chain vulnerability (*italic* letters denote specific sources related to food supply chains)

financial sources), others are not (mostly environmental sources) – see Simchi-Levi et al. (2008, p. 316). We base our classification of external sources on the work of Asbjørnslett and Rausand (1999). Additionally, it has to be taken into account that sources of vulnerability are interconnected with each other, both within each level and across the levels (Asbjørnslett and Rausand, 1999; Peck, 2005).

We define the *magnitude of a disturbance* by the impact it has on the KPIs, that is, the variation in process KPIs in a defined time period. In principle, the level of variation has to be considered in the context of the norms and requirements on the KPIs. Melnyk et al. (2009) proposed "quantity loss" as measure of magnitude (quantity dimension), but other KPIs have to be considered as well (e.g., time and quality dimensions of KPIs – van der Vorst and Beulens, 2002). A similar categorisation is given by Viswanadham and Gaonkar (2007) who categorised uncertainty manifestations to deviations, disruptions and disasters. In line with the thoughts of Vorst and Beulens (2002) and Viswanadham and Gaonkar (2007), we categorise disturbances in supply chain processes as deviation, disruption or complete failure of process execution expressed in loss of value of relevant KPIs (Table 2.1.1). Minor KPI deviations from the norm represent small disturbances, that is, acceptable variation in process outcome and it can be considered as part of business as usual. High KPI deviations represent disruptions in process outcomes, that is, the process outcome is much below the norm. Extreme values of process KPIs represent a failure of the process execution, that is, there is no process outcome at all (e.g., due to the burndown of a production plant).

Another aspect that is relevant is the impact that disturbance has on performance. *Impact of disturbances* on other processes within the company, supply chain or even environment is particularly important

Table 2.1.1 Example of classification of disturbances in delivery process

	Quantity dimension	**Quality dimension**	**Time dimension**
Magnitude/ KPI	**Loss of material during transport**	**Number of products damaged in transport**	**Transport time**
Deviation	Few product lost	Few product damaged	Slight delay
Disruption	Shipment partially received	Significant part of the shipment damaged	Significant delay
Failure	Complete loss	All products damaged	Inability to perform delivery in required time window

due to the fact that a disturbance in one process can have a domino effect to other processes (see Waters, 2007). In principle, the impact of a disturbance depends on the flexibility and responsiveness of the system to adapt to the new situation caused by a particular, accidental event. Therefore, the impact of a disturbance can be local (e.g., delivery failure can have local impact on transport performance, but it will not jeopardise the production process if there is enough inventory or if a backup delivery option exists) or system wide (e.g., harvest failure or animal diseases outbreak can cause lack of raw material which effects will be transmitted through the whole chain). According to Wu et al. (2007), perturbations originating in a localised point of a supply chain have the potential to be passed onto subsequent tiers or branches of the supply chain, with possible amplification effects. Therefore, the bullwhip effect can be also seen as a system wide impact of disturbances in demand along the chain (Wagner and Bode, 2006).

Categorisation of redesign strategies

In the literature, there are many concepts related to responses of uncertainty (van der Vorst, 2000; Lee, 2002; Shimchi-Levi et al., 2002; van der Vorst and Beulens, 2002; Simangunsong et al., 2008) and recently, more focused to disturbance and risk (e.g., Zsidisin et al., 2000; Tang, 2006, 2006a; Tomlin, 2006; Waters, 2007; Hopp, 2008; Macdonald, 2008; Shimchi-Levi et al., 2008; Dani, 2009). In general, response concepts are based on three elements: when to plan and act, what is the frequency of the disturbance and what is the consequence of the disturbance. The time perspective refers to the moment when to make a plan and when to execute it. In principle, the right choice depends on the probability and consequences of disturbances (see Hopp, 2008) (Table 2.1.2).

In this paper, we focus on disturbances that are characterised by medium to high frequency and light to severe consequences. These kind of disturbances usually come from market, financial, infrastructural and legal sources of vulnerability as well as from internal sources, and they are more or less predictable and controllable (see Shimchi-Levi et al., 2008, p. 316). In general, responses to these kinds of risks and disturbances are *planned in advance*, and it can be seen as a *mitigation concept* (see Macdonald, 2008). However, within this concept there are two approaches:

- Based on the moment of the response itself, that is, the moment when plan is executed – before disturbances happen (e.g., buffering and pooling concepts, Hoop, 2008) or after that (contingency

Table 2.1.2 Categorisation of responses to disturbances from the aspect of time, frequency and consequences (coloured part is focus of this paper)

Frequency		**Consequences (i.e., business impact)**					
		Light		**Medium**		**Severe**	
	Low	Ignore risk		Contingency planning		Crises management	
		Plan – ignore	Act – no	Plan – before it happens	Act – after it happens	Plan – while it is happening or after	Act – while it is happening or after
	Medium	Ignore risk		Contingency planning		Contingency planning	
		Plan – ignore	Act – no	Plan – before it happens	Act – after it happens	Plan – before it happens	Act – after it happens
	High	Buffering or pooling		Buffering or pooling		Buffering of pooling	
		Plan – before it happens	Act – before it happens	Plan – before it happens	Act – before it happens	Plan – before it happens	Act – before it happens

concept – Tomlin, 2006; Waters, 2007, p. 156; Hoop, 2008). According to Hopp (2008), buffering denotes maintenance of excess resources (inventory, capacity, time) to cover for fluctuations in supply or demand. Pooling denotes buffers sharing in order to cover multiple sources of variability. Contingency planning implies the establishment of a pre-set course of action for an anticipated scenario.

- Based on the purpose of the response – to prevent the disturbance or reduce its impact (Waters, 2007). Disturbance prevention implies reduction of disturbance frequency, that is, acting in advance in order to eliminate, control or avoid direct cause of disturbances. Reduction of the impact of disturbance mostly implies passive protection, that is, building in redundancy, but another concept may be appropriate as well.

In line with the work of van der Vorst and Beulens (2002), we classified redesign strategies using the second type of approach. Therefore, we classified redesign strategies that can be used to reduce the impact of disturbance (Table 2.1.3) and redesign strategies that can be used to prevent disturbances (Table 2.1.4). Here, we have to mention that some of these strategies can be used for both purposes (especially in the part related to information system and organisation).

Table 2.1.3 Redesign strategies that can be used to reduce impact of disturbances by acting to elements of logistic concept

	Redesign strategies – to reduce impact of a disturbances
Managed system	**Adjust the structure of the supply chain** (e.g., Zsidisin et al., 2000; Snyder et al., 2006; Tang, 2006; Tomlin, 2006; Waters, 2007) – Increase the width of the supply chain – Use multiple modes of transportation **Buffering in capacity and inventory** (e.g., Zsidisin et al., 2000; de Neufville, 2004; Snyder et al., 2006; Tomlin, 2006; Waters, 2007; Hopp, 2008; Simangunsong et al., 2008; Simchi-Levi et al., 2008) – Increase number of equipment, vehicles or workers – Increase capacity of equipment, vehicles or space – Make strategic (safety) stocks – Make well stocked supply pipeline **Increase flexibility of the supply chain** (e.g., Tang, 2006; Tomlin, 2006; Waters, 2007; Hopp, 2008; Simangunsong et al., 2008) – Use multiple modes of transportation – Use flexible automation – Use temporary workers – Use multiple purpose resources (e.g., standardised equipment, vehicles, cross-trained employees) **Use product management** (e.g., Tang, 2006/a; Waters, 2007; Hopp, 2008; Simangunsong et al., 2008) – Use possibilities of product substitution, e.g., silent product rollover – Use product postponement
Managing system	**Hedging** (e.g., Tang, 2006; Tomlin, 2006; Waters, 2007; Hopp, 2008) – Using business disruption insurance – Diversifying operations across multiple markets – Produce certain products in-house and outsource other products **Make backup options** (e.g., Snyder et al., 2006; Tang, 2006; Tomlin, 2006; Waters, 2007; Hopp, 2008, Simchi-Levi et al., 2008) – Use alternative suppliers – Use a flexible supply contracts for non-strategic components, such as: Long-term contracts (forward or fixed commitments contracts), Flexible or Option contract or Spot purchase – Make alternative transport routes **Increase flexibility of planning and control** (e.g., van der Vorst, 2000; Tang, 2006, 2006a; Waters, 2007; Hopp, 2008) – Increase manufacturing flexibility, e.g., use flexible receipts, coordinate and redesign policies – Use postponement – Do tasks parallel instead sequential – Allow time and capacity buffering in plans and operations **Use lead time management** (e.g., van der Vorst, 2000; Tang, 2006; Waters, 2007; Simangunsong et al., 2008)

Information system	**Use IT to increase speed of disturbance detection and support decision-making** (e.g., Zsidisin et al., 2000; Shukla and Naim, 2007) **Create support for information transparency in the chain** (e.g., van der Vorst, 2000; Zsidisin et al., 2000; Lee, 2004; Waters, 2007; Hopp, 2008; Simchi-Levi et al., 2008; Simangunsong et al., 2008) – Implement real time information systems – Enable continuous data exchange with partners in the supply chain – Insure infrastructure to enable information exchange and sharing
Organisation	**Increase preparedness to disturbances** (e.g., Hopp, 2008) – Enable empowerment (authorisation of employees to make independent decisions) – Build awareness for crises situations **Increase collaboration in chain** (e.g., Zsidisin et al., 2000; Tang, 2006; Simchi-Levi et al., 2008) – Establish strategic alliances **Create an adaptive supply chain community** (e.g., Tang, 2006; Simchi-Levi et al., 2008) – Establishment recovery planning systems along the chain **Make backup options** (e.g., Tang, 2006, 2006a; Simchi-Levi et al., 2008; Hopp, 2008) – use risk sharing supply contracts for strategic components, such as: – Revenue sharing contracts – Backup (advance purchase) contracts – Quantity flexibility contracts – Wholesale price contracts – Sales rebate contracts – Capacity reservation contracts – Cost sharing contracts – Buy-back contracts

Table 2.1.4 Redesign strategies that can be used to prevent disturbances by acting to elements of logistic concept

	Redesign strategies – to prevent disturbances	
Managed system	**Adjust the structure of the supply chain** (e.g., van der Vorst, 2000; Waters, 2007)	
	– Reduce the length of the supply chain	– Change the location of facilities
	Use product management (e.g., Waters, 2007)	
	– Avoid risky products	– Rationalise the product range
Managing system	**Carefully plan investment** (e.g., Tang, 2006)	
	– Regular replenishment of equipment, vehicles – Economic supply incentives to cultivate additional suppliers	– Innovations (e.g., to packaging, information system, etc.) – Increase capacity
	Control variability (e.g., Zsidisin et al., 2000; Tang, 2006a; Waters, 2007; Hopp, 2008, Simangunsong et al., 2008; Simchi-Levi et al., 2008; Dani, 2009)	
	– Careful supplier selection process by using vendor rating techniques; supplier audits and quality certification programs – Use (virtual) pooling: centralisation of decisions – Increase price stability	– Use standardised work (procedures) – Use procedures and techniques to improve quality control, as well as industry standards – Develop proactive maintenance) – Use demand postponement strategy
	Use revenue management strategies (e.g., Tang, 2006; Simchi-Levi et al., 2008)	
	– Use dynamic pricing (convenient for perishable products) – Use promotion	
	Decrease lead time and use short-term forecasts or aggregate forecasts (e.g., Waters, 2007)	

Information system	**Use IT to increase data accuracy and speed and support decision-making** (e.g., van der Vorst, 2000; Hopp, 2008; Simchi-Levi et al., 2008; Simangunsong et al., 2008) – Implement real time information systems – Use the same information standards – Use Tracking and Tracing system **Create support for information transparency in the supply chain** (e.g., van der Vorst, 2000; Zsidisin et al., 2000; Waters, 2007; Hopp, 2008) – Insure infrastructure to enable information exchange and sharing **Collect relevant data about disturbances** (e.g., Hopp, 2008) – MTTF (mean time to failure), MTTR (mean time to repair), Lead times
Organisation	**Increase collaboration in supply chain** (e.g., Zsidisin et al., 2000; Tang, 2006; Waters, 2007; Simchi-Levi et al., 2008; Hopp, 2008) – Use information sharing – Joint forecasts and planning – Establishment of strategic alliances, such as transport alliances, VMI, etc. **Increase cooperation and coordination between departments** (e.g., Waters, 2007) – Closer cooperation between people who are doing planning and people who execute plans **Create an adaptive supply chain community** (e.g., van der Vorst, 2000; Zsidisin et al., 2000; Waters, 2007; Simchi-Levi et al., 2008) – Establishment of risk mitigation plans together with suppliers – Align objectives and define KPIs

Case study

In order to test our framework, we performed a case study in a company that processes meat. Data was collected from September 2008 to February 2009 based on interviews with company managers, as well as on the observation of researcher who spent six months in the company. The supply chain consists of suppliers (slaughter houses), transport, warehousing, production and customers (processing companies). Our research was focused on production and production related processes. Preliminary data analysed showed that disturbances in production are: *disruptions in the production process* (e.g., half-day closure of production lines) caused by variability in supply (in quantity, quality and time); *deviations in planned daily production outcome* caused by variability in quality of supplied raw material, technical failures of production line, rigid planning of incoming shipments, lack of decision support system (DSS) for production planning and scheduling, late detection of low quality material and human errors (in quality control, production and data entry and processing). For the identified sources of disturbances, we proposed the following redesign strategies (Table 2.1.5) using our framework.

Table 2.1.5 Redesign strategies that could be used to prevent disturbances or its consequences

Sources of vulnerability	**Redesign strategies – to prevent disturbances**	**Redesign strategies – to reduce impact of a disturbances**
Variability in supply (in quantity, quality and time)	– Control variability by careful supplier selection process – Increase collaboration in supply chain by establishing strategic alliances – Create an adaptive supply chain community by aligning objectives and mutual definition of KPIs – Use quality certification programs	– Adjust the structure of the supply chain by increasing the width of the supply chain – Buffering in inventory (make strategic stock) – Make backup options by use of alternative suppliers and risk sharing supply contracts for strategic components – Increase collaboration in supply chain by establishing strategic alliances
Technical failures	– Control variability by using standardised work (procedures) and proactive maintenance	– Increase flexibility of the supply chain by using flexible automation or by using resource to serve multiple purposes

Continued

Table 2.1.5 Continued

Sources of vulnerability	**Redesign strategies – to prevent disturbances**	**Redesign strategies – to reduce impact of a disturbances**
Rigid planning of incoming shipments	– Decrease lead time – Use IT to increase data accuracy and speed – Increase cooperation and coordination between departments	– Increase flexibility by allowing time buffering in plans and operations
Lack of DSS	– Use IT to support decision-making – Collect relevant data about disturbances	– Use IT to increase data accuracy, speed and to support decision-making
Late detection of disturbance	– Control variability by using procedures and techniques to improve quality control	– Use IT to increase data accuracy, speed and to support decision-making
Human mistakes	– Control variability by using standardised work procedures and IT to increase data accuracy and support decision-making	– Use IT to increase data accuracy and speed and support decision-making

Our current work is related to the selection of the most appropriate redesign strategies. That requires: (1) a deeper analyses of the sources of vulnerability and disturbances itself (e.g., duration, time of detection frequency), (2) modelling and quantification of supply chain KPIs for alternative supply chain scenarios (i.e., use of alternative redesign strategies) and disturbance levels.

Conclusion

In order to sustain competitiveness in today's highly dynamic environment, it is necessary to maintain robust performances. The degree of robustness, that is, what will be the impact of disturbances on business/chain performances, depends on the flexibility of the system itself (e.g., how much system can adapt to new situation caused by accidental event and how fast it can respond to it) and the flexibility of performance requirements (e.g., how flexible are customer demands or industry standards). This paper presented a preliminary framework that aims to support companies in designing robust (food) supply chains. More research is needed to extend and validate the categorisations of redesign strategies and sources of vulnerability.

Note

1. In the supply chain literature, disruptions and disturbances are interchangeably used; however, in most of the papers, the term "disruption" is associated with high consequences and less frequent unexpected events while disturbances usually cover wider areas (low and high consequences, more and less frequent unexpected events).

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2.2 Collaborative Supply Chain Configurations: The Implications for Supplier Performance in Production and Inventory Control

Jan Holmström, Johanna Småros, Stephen M. Disney and Denis R. Towill

Introduction

Changing how and when a supplier delivers a product can transform a business model (Hoover et al., 2001). Vendor managed inventory (VMI) is one such mechanism that has been popular in recent literature (Holmström, 1998; Sabath et al., 2001). Unfortunately, however, practical examples of how VMI and other collaborative supply chain configurations can be precisely used to improve production planning and inventory control in *supplier* firms are difficult to find in industry. For example, the scope of standard solutions for VMI in commercial enterprise resource planning applications does not include recommendations for linking the replenishment collaboration to production and inventory control.

By using distribution requirements planning (DRP) (Bookbinder and Heath, 1988) in the supply chain, it is possible to link replenishment collaboration with the production and inventory control (PIC) decision of the supplier in principle. This requires reliable and timely sales, inventory and forecast information from all the inventory locations in the distribution network. Even within the more limited scope of a company controlled distribution network, a major obstacle to DRP has been the difficulty to obtain reliable forecasts from individual inventory locations.

The issue of how to integrate external collaboration with internal processes is seen to be a gap in the body of knowledge (Lapide, 2001).

The open question is how to link external sources of information into the vendor's production and inventory control processes when the same level of detailed information cannot be obtained from all of the distribution channels (Stank et al., 2001). Considering the high hopes (Lee et al., 1997; Mason-Jones and Towill, 1997; Yu et al., 2000) predicted from the benefits of utilising demand visibility for improving supply chain efficiency, this gap is in a surprisingly critical area for enabling the success of supply chain management. A barrier to progress is seen to be the evidence that optimisation of the interests of individual firms mitigate against supply chain collaboration (Cachon and Lariviere, 1999).

The research questions to be answered in this paper are the following: what are the possible external collaboration mechanisms and how may they be integrated with supplier internal production and inventory management processes?

Classification of collaborative supply chain configurations

Reducing uncertainty via transparency of information flow (Geary et al., 2002) is a major factor in matching collaboration type to system objectives. To guide our investigation on what makes it difficult to link external and internal integration, a simple framework can be defined of the alternative collaborative supply chain configurations. In this paper, five different supply chain configurations will be discussed and compared. These are shown in Table 2.2.1. These configurations are distinguished by the differences in the control of material flows, information flows and the decision making processes. Each configuration will be discussed in terms of industrial practice to highlight, from a supplier

Table 2.2.1 Supply chain configurations defined for investigating implementation problems

Configuration	Description of collaborative or vendor managed functions
Type 0	Traditional supply chain
Type I	Replenishment only
Type II	Replenishment and forecasting
Type III	Replenishment, forecasting and customer inventory management
Type IV	Replenishment, forecasting, customer inventory management and distribution planning

perspective, the opportunities and challenges to benefit production and inventory control.

Challenges of production and inventory control in the supply chain

Magee (1958) recognised the challenge in developing an effective process solution for production and inventory control that takes into consideration both the supplier's and customer's interests. Magee also states that both parties' interests may be satisfied by defining the responsibilities in a particular way. Quoting directly from his book:

> It is possible to restate the question slightly differently and thereby reach a solution. For example, the user has to be sure that the material will be there when needed. He has corresponding responsibility to state what his maximum and minimum requirements will be. Once these limits are accepted as reasonable, the supplier has the responsibility of meeting demand within these limits, making whatever use he can of the flexibility that (holding the) inventory provides. Thus both (players) have a share in the responsibility for and control over a stock unit. One specifies what the maximum and minimum demands on the stock unit will be; the other has the responsibility of keeping the stock unit replenished but not overloaded as long as demand stays within the specified limits. (1958, p. 298)

This way of redefining the responsibilities together with the sharing of information on the true supply chain state can contribute to overcoming divergent interests. But how can this be carried out in practice, when a supplier has hundreds of SKUs and hundreds of customers to consider? What are the challenges of increasing the use of customer information in the production and inventory control decision when moving from Type O to Type IV in the collaboration typology? The different types differ in the external information sources used for production and inventory control. First, only customer orders are included; then, the customer inventory situation; and finally, the distribution requirements.

Type 0: traditional supply chain

In Type 0 supply chains, the only information available to the supplier is a purchase order. Purchase orders often cause the bullwhip problem (Lee et al., 1997). This happens when the variance of orders increases as demand moves up the chain. This variance amplification causes a lot of unnecessary costs in supply chains. For example, it has been estimated that the economic consequences of the bullwhip effect can be as much as 30% of factory gate profits (Metters, 1997). The negative effects of bullwhip problem have been further summarised by Carlsson and Fullér (2000) as follows:

- Excessive inventory investments throughout the supply chain to cope with the increased demand variability
- Reduced customer service due to the inertia of the production/distribution system
- Lost revenues due to shortages
- Reduced productivity of capital investment
- Increased investment in capacity
- Inefficient use of transport capacity
- Increased missed production schedules

It is possible to redesign the replenishment order to remove bullwhip, that is, to smooth the ordering pattern, but this often (but not always) comes at the cost of either extra inventory or lower availability unless care is taken (Disney et al., 2003).

We have developed a set of "water tank" models of each of the five categories of collaborative arrangements in supply chains. The Type 0 traditional supply chain water model is shown in Figure 2.2.1. We

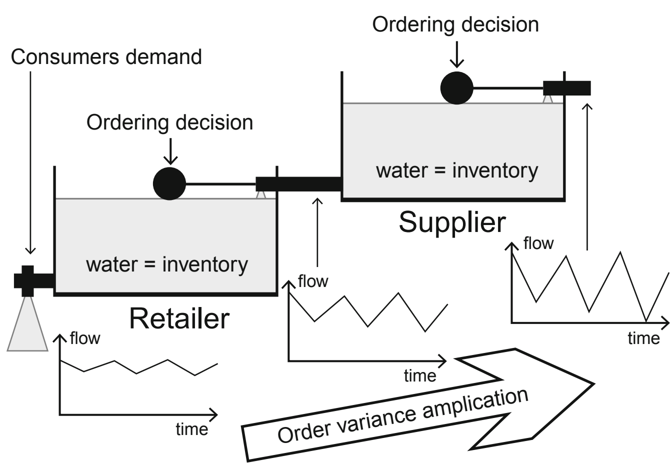

Figure 2.2.1 A Type 0 supply chain conceptualised by a water tank model

can see that there are two ordering decisions ("ball-cocks") in series in this two level supply chain. Water represents inventory and the flow of water represents sales of products. For example, a consignment stocking arrangement is a still a Type 0 supply chain as the only thing that changes is the ownership of the inventory. The same decisions are being made based on the same information as in a traditional supply chain.

Type I: replenishment only

In Type I relationships, the customer has given the responsibility for placing replenishment orders to the supplier. Using the customer information, the inventory investment needed to maintain customer service levels can potentially be reduced. But in effect, the supplier has a dedicated process to generate exactly the same replenishment orders based on the same information that the customer previously used to make its purchase decisions. Because the supplier has failed to incorporate the customer information into his PIC process, the supplier has lost an opportunity, and the only change is who is carrying out the new process. A Type 1 relationship can be visualised in Figure 2.2.2. In principle, the customer's inventory and sales information is available for the supplier to use in controlling his own production and inventory. But rarely do suppliers use this information for their PIC process in practice. Why is it that the information is not used to improve the PIC process?

The challenge to exploit this valuable information provided through collaboration with the retailer is that this retailer is typically one of many requesting the supplier's products. Generating the replenishment order in the place of the customer's purchasing department is

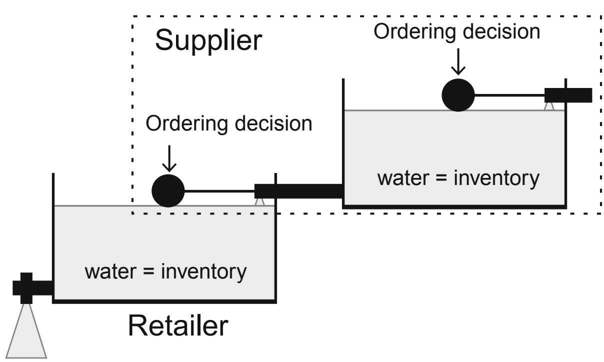

Figure 2.2.2 A Type I supply chain conceptualised by a water tank model

straightforward. It is much more difficult to set up a separate production and inventory management system to serve the customer. Setting up a separate PIC process for a customer – which is not integrated with that of the rest of the supplier company – has consequences. More safety stocks, smaller production batches or longer intervals between production runs may be the result.

Type II: replenishment and forecasting

Taking end customer sales into consideration when generating the forecast – even when complete visibility is not available – is easier than complete customer specific control processes. Figure 2.2.3 highlights the strategy. This step is frequently advertised as a key objective in VMI implementation projects, but is less frequently implemented. It is also a cornerstone of the collaborative forecasting, planning and replenishment (CPFR) strategy. What are the obstacles here?

The primary challenge is that the supplier needs to react to the replenishment order generated based on the customer's inventory situation. As a consequence, an important obstacle for using Type II collaboration to improve a supplier's PIC process is that the benefit from incorporating visibility of end customer demand in the supplier PIC process is undermined by the need to respond to changes in customer inventory policy over time. Dejonckheere et al., (2003) have shown that bullwhip increases geometrically in Type 0 and Type I supply chains and linearly in Type II supply chains, so the potential benefits could be high.

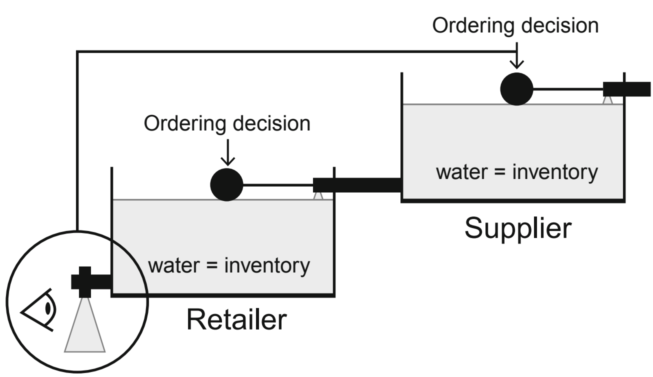

Figure 2.2.3 A Type II supply chain conceptualised by a water tank model

Type III: replenishment, forecasting and customer inventory planning

There is a further piece of information in the supply chain that can be utilised to great benefit in the suppliers PIC process. That is information about the customer's inventory position, and it is important because control over the inventory management process of the customer can provide enough flexibility to avoid the bullwhip effect. The transition to the next level in the collaboration framework requires incorporating the customer inventory information, that is, customer specific inventory management. The potential benefits for the supplier PIC performance derive from better control of both the replenishment and inventory management process one level down the supply chain. This makes it possible to use downstream requirements that are smoother than purchase orders generated based on a reorder rule. The principle is here illustrated using our water tanks models, Figure 2.2.4, based on a solution first proposed by Magee (1958).

Experience from real world supply chains confirms that this levelling of requirements provides the supplier with more flexibility in choosing how to respond. In an example from the grocery supply chain, the supplier gained between two and three weeks more time to respond to demand by considering customer specific requirements in the production and inventory control process (Kaipia et al., 2002). The benefit was more pronounced for the slower moving items in the product range.

Type IV: replenishment, forecasting, inventory and customer distribution planning

In this type of supply chain configuration, the supplier plans distribution on the customer level. This may be needed when there is a long transportation delay relative to stock cover at the customer or where the products are perishable, see Figure 2.2.5.

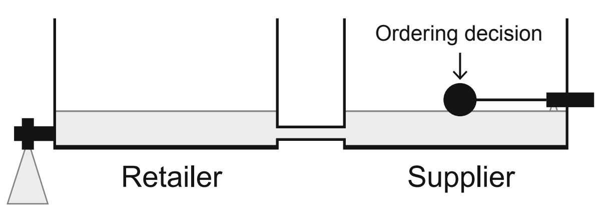

Figure 2.2.4 A Type III supply chain conceptualised by a water tank model

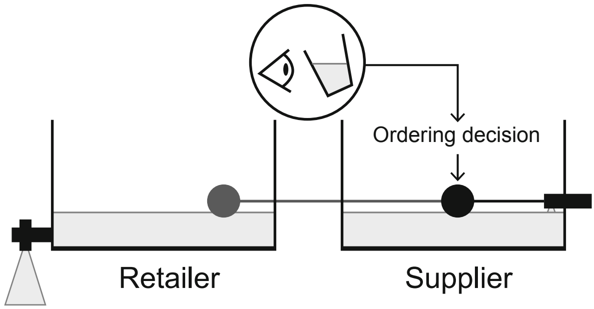

Figure 2.2.5 A Type IV supply chain conceptualised by a water tank model

How can the customer's specific information be incorporated in the supplier's PIC in this type of collaboration configuration? This is more complicated than for the Type III configuration. A brute force solution would be incorporating the new information in the suppliers PIC system by using a DRP approach. Companies controlling their own distribution channels have refined and developed the approach to enable dynamic and continuous optimisation of the supply chain. Bookbinder and Heath (1988) developed the concept of DRP based on previous industrial work (e.g., Stenger and Cavinato, 1979). The goal is to minimise inventory and cost in the distribution system for a certain service level and demand forecast through a periodic – rolling schedule – planning of inventory levels and replenishments. In the collaborative supply chain configuration, the supplier attempts to do the same based on information from customer controlled channels.

The primary problem with utilising a Type IV collaboration configuration is the periodic rolling schedule and long lead times. The link between distribution requirements and supply disruptions lead to system nervousness. Additionally, the costs for stock-outs obsolescence, for example, are not the same for supplier as for retailers. This leads to diverging interests and gaming, when making both demand forecasts and supply allocation decisions (Stevens, 1989).

Collaborative supply chain configurations and their implications for supplier performance

Potentially, the supplier can benefit greatly from incorporating customer demand, inventory and distribution requirements in his PIC process. The potential benefit is increased flexibility in scheduling production capacity and allocating scarce inventory. However, there are several serious obstacles in practice.

Research on supply chain visibility efforts, such as VMI, rarely comments on the problems that arise when only part of the customer base are willing to share information. That is, when a company has to deal with several supply chain structures concurrently. Many of the most important contributions on supply chain visibility simply assume that all downstream data is always shared, but this is rarely the case, for example, see Table 2.2.2.

Lee et al. (1997), for example, suggest that retail data can be used to align forecasts in the supply chain, but assume that the information is always available from all retailers and they do not discuss how this should be done if some data is missing. This in effect would mean that to benefit in its own operations a company should move from a Type 0 or I configuration to a Type II in all customer relationships. Yu et al. (2000) compare different levels of information sharing in the supply chain. Also in this case, the assumption is that comparable data is always available from all customers, that is, that the supplier is able to change the supply chain configuration for all of its customers.

In the rare cases where partial information availability is discussed, the link to production planning and inventory control is still not explicitly examined. Waller et al. (1999), for example, use simulation to examine the effect of VMI adoption rates on inventory levels in a supply chain. The core of their VMI model, however, is increased inventory review and replenishment triggering frequency – the demand information available through VMI is not utilised in the model, that is, no production planning and inventory control solution that would utilise the sell-through information available from the VMI-customers is presented.

Considering the link between collaborative supply chain configurations and supplier production and inventory control performance, it

Table 2.2.2 Percentage of large US companies making specific information available to business partners

Type of data made available	In 1998	Estimated 2001
Inventory and capacity	50%	75%
Demand history and forecasts	30%	72%
Order status	30%	66%
Project design and specifications	34%	54%
Financial information	3%	20%

Source: Price Waterhouse Coopers 1999 Survey Results Reported by Knolmayer et al., 2002 becomes clear that there is a significant gap in the literature. In practice, to benefit from collaboration, the supplier PIC needs to be seamlessly integrated into a number of different collaborative or vendor managed supply chain configurations. Still, a majority of the research conducted examines situations in which information is available from all customers or focuses on the relationship between one supplier and one customer. Real life companies trying to benefit from partial visibility do not get much guidance from the existing literature.

Acknowledgements

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2.3
A Critical Review of Surveys in Supply Chain Integration Research

Dirk Pieter van Donk and Taco van der Vaart

Introduction

Over the past decade, one of the main themes in the supply chain management literature has been integration as a key factor in achieving improvements (e.g., Tan et al., 1999; Romano, 2003). Many authors agree that integrative practices and a high level of integration have a positive impact on corporate and supply chain performance.

Recent empirical work (Frohlich and Westbrook, 2001; Vickery et al., 2003; Childerhouse and Towill, 2003) shows convincing empirical evidence for the relationship between integration and performance. As the amount of survey-based research in the field is growing, it seems to be appropriate to summarise and evaluate the current situation.

The aim of our paper is to review the survey-based research and to come up with a number of concerns with regard to the empirical survey-based research on the relationship between supply chain integration and performance. Based on those concerns, we investigate what might be the consequences for the theoretical background of the work done so far and for future scientific work.

Our evaluation is based on some initial observations with respect to the published survey research over the last years. A first observation is that it seems that if we aggregate over all surveys on integration, we encounter a large list of different constructs and measurements. If we look at single articles usually only a limited number of variables is included. Another remark is made by Ho et al. (2002), who formulate doubts with respect to the relationship between integration and performance in most survey studies. They state that there is little consistency about the basic definition and content of the constructs used in these studies (Ho et al., 2002, p. 4415). Sound constructs and adequate methodologies are thus needed that help us to understand the relationship between integration and supply chain performance.

A first point of discussion in current research is that a large variety of supply chain management and integration definitions exist, ranging from purchasing type of description to almost transcendent definitions (see Croom et al., 2000; Tan, 2001). A second point that relates to the integration-performance relationships is that there is a great variety of constructs and measurements used: ranging from patterns of behaviour (Johnston et al., 2004) to operational practices (Frohlich and Westbrook, 2001). Mostly, only a small number of variables is included to explore the integration-performance relationship and interaction between variables is often ignored. The concept of supply chain integration is measured both in a broad sense as well as in a limited sense. Another measurement and construct issue is that the level of analysis varies in different studies. Some survey-based research on integration considers single links and relationships (Johnston et al., 2004). Most other papers seem to measure integration or integrative practices and the relationship with performance as an organisational variable, valid for all links with suppliers or buyers. Aggregated constructs are used to measure the integrative practices conducted by for instance a buying company in the links with all its suppliers. All these observations and concerns are more or less ad hoc, and interesting papers have been published recently. A systematic analysis of recent research (also of research published later than the work of Ho et al., 2002) can provide us with an answer with regard to what is the current status of the field and what is required in future research.

Our paper reviews and analyses the current papers that report on survey research. We will evaluate the constructs, dimensions, measurements and scales used for integration. Our analysis will result in an assessment of the current state of survey research in supply chain integration. Moreover, based on the assessment, we develop a framework to measure supply chain integration that aims at more comprehensively covering all of its different dimensions and aspects and taking into account possible interaction effects between its different dimensions. Business conditions and contextual factors are linked to the framework. The ultimate aim is to help guide future research.

The paper is organised as follows. The next section will describe the methodology employed for our review. Then, we will give some general remarks. The main sections of the paper describe and analyse SCM factors, performance, and in the discussion section, their relationship will be analysed. The last section will give our main conclusions.

Methodology

The literature on SCM is growing at a fast rate. For the present paper, we mainly selected papers from *JOM*, which is considered to be the top journal in the field with the highest impact factor. Moreover, this journal specifically focuses on sound methodology and publishes a lot of survey-based research. We added a number of articles from other well-established journals: *Omega*, *IJOPM*, *Interfaces*, *Journal of Business Logistics*, and *IJPR*. In principle, only articles that were published in 2000 or later were considered, with a few exceptions before 2000. We selected those that explicitly investigated the relationship between supply chain integration (integrative practices) and supply chain performance in a survey research design. Out of 26 papers in these journals, we investigated 16 articles for this paper due to time and page limitations. The articles were carefully considered, and for each article, we summarised the hypothesis, the SCM factors, the items (and variables) considered, the sample and industry, the focus (suppliers, buyers and relationships), performance measures and additional remarks to make a comparison across our sample of articles possible. Both authors took independently part in assessing the articles.

In this paper, we restrict the discussion to the external SCM factors. In the selected surveys, internal factors are also included like strategic purchasing (Carr and Pearson, 1999; Chen et al., 2004), internal integration or collaboration (Stank et al., 2001; Droge et al., 2004; Gimenez and Ventura, 2005) and supplier evaluation communication strategy (Prahinski and Benton, 2004).

General descriptions and findings

As might be expected, most of the surveys considered have as their main hypothesis that there is a positive relationship between the level of integration and the performance of the focus company. With respect to SC integration, most researchers choose to look at integration with suppliers and relate that directly or indirectly to the (financial) performance of the focal company. Important factors are supplier development and relationship, strategic purchasing and sourcing, managing or limiting the supply base. There are only a few exceptions. Frohlich and Westbrook (2001) take into consideration both upstream and downstream integration in their contribution. In general, the hypotheses about the relationship between integration and performance are confirmed.

With respect to the focus or population of the surveys it seems that research in the automotive industry is most popular (33% of the surveys). It is also striking that the majority of the response rate (as far as reported) is relatively low (about 30% or lower) with the clear exceptions of Ramdas and Spekman (2000) and De Toni and Nassimbeni (1999), who report respectively 75% and over 60%. In general, low response rates might imply low validity of the outcomes of a survey, specifically if the non-response is biased towards some specific groups of respondents. Most surveys rely on a single respondent, although a number of surveys use multiple respondents within each unit investigated or respondents from two companies to investigate the relationship between these two (e.g., Johnston et al., 2004). A last general remark is that measurement tends to use Likert scales (5,7 or 10 points).

The overall conclusion with respect to the above is that empirical research confirms the relationship between the level of SC integration and performance, but that response rates and choice of respondents and populations limit the validity and generalizability of the results in a number of articles. We will now have a closer look at how integration is actually measured.

SCM factors in survey-based research

Starting point for the current status of survey-based research in SCM literature are the factors used to investigate the relationship between SCM (or SC integration) and performance. To do so, we focus on the factors, constructs and items used in the selected surveys. The second column of Table 2.3.1 shows that a large number of different SCM factors are employed in the surveys. A first group of factors seem to relate to the relationship a firm maintains with its supplier or customer. Examples of these factors are buyer-supplier relationships, closer customer relationships and joint responsibility. The aim of a second group of factors seems to be to measure the mindset of the (buying) firm with respect to their suppliers. Examples are long-term orientation, sourcing policies, flexibility in arrangements and supply management orientation. The last group of SCM factors that can be distinguished are factors that relate to practices or technologies. Examples are operational practices, information practices and integrative information technologies.

If we look at the detailed level of the items or constructs that are used to measure these factors, this grouping seems not sufficient for two related reasons. The first reason is that authors use different items or constructs to measure the same or closely related SCM factors. For

Table 2.3.1 SCM factors and items in SCM research

Article	SCM factmor	SCM items		
		Attitude	Pattern	Practice
Carr and Pearson (1999)	Buyer-supplier relationship	X	x	X
Chen et al. (2004)	Limited number of suppliers	x		
	Communication		x	
	Long-term orientation	x		
De Toni and Nassimbeni (1999)	Operational practices			X
	Sourcing policies	x		
Droge et al. (2004)	Supplier development		x	X
	Supplier partnership	x	x	
	Closer customer relationships	x		
Frohlich and Westbrook (2001)	Arcs of integration			X
Gimenez and Ventura (2005)	External integration		x	
Johnston et al. (2004)	Buyer's benevolence (supplier's perception)	x		
	Buyer's dependability (supplier's perception)	x		
	Joint responsibility	x		
	Shared planning	x	x	
	Flexibility in arrangements	x		
Prahinski and Benton (2004)	Buyer-supplier relationship	x	x	
Ramdas and Spekman (2000)	Information practices			X
	Partner selection practices	x		
Salvador et al. (2001)	SC interactions			X
Shin et al. (2000)	Supply management orientation	x		(x)
Scannell et al. (2000)	Supplier development		x	x
	Supplier partnering	x	x	
	JIT purchasing			x
Stank et al. (2001)	External collaboration	(x)	(x)	
Stanley and Wisner (2001)	Cooperative purchasing/supplier relationship		x	(x)
Tan et al. (1999)	Supply base management practices	x	x	(x)
Vickery et al. (2003)	Integrative information technologies			X
	Supply chain integration	x		

instance, both Carr and Pearson (1999) and Prahinski and Benton (2004) examine the relationship between the buyer-supplier relationship and performance. Carr and Pearson only use six items varying from loyalty and frequent face-to-face communication to direct computer links with suppliers. Whereas in Prahinski and Benton (2004, p. 42) buyer-supplier relationship is a second-order factor and defined as "the supplier's perception of the buying firm's behavioural and operational relationship attributes: buying firm's commitment, cooperation and operational linkages". From the 17 items used to measure these attributes, 10 were dropped in the analysis. The remaining 7 factors are all items measuring the perception of the supplier of the attitude of the buyer towards the supplier. Another example can be found if we consider the factors SC integration (Vickery et al., 2003) and external integration (Gimenez and Ventura, 2005). Vickery et al. operationalise SC integration with the items supplier partnering, closer customer relationships and cross functional teams. Gimenez and Ventura use items like informal teamwork, shared information and joint development of logistics processes.

The second reason why the initial grouping of factors is not sufficient, is that part of the selected papers use heterogeneous groups of items to measure SCM factors. Again, we refer to Carr and Pearson (1999) with items varying from loyalty and frequent face-to-face communication to direct computer links with suppliers.

Based on a close examination of all items used in the selected surveys, we propose to categorise these items as attitude, pattern or practice. SC practices are concrete activities or technologies that play an important role in the collaboration of a focal firm with his suppliers and/or customers. Examples are the use of Electronic Data Interchange (EDI), integrated production planning, packaging congruence and deliveries synchronisation (see for instanceDe Toni and Nassimbeni, 1999; Frohlich and Westbrook, 2001). Related to these practices are the SC patterns or interaction patterns between the focal firm and its suppliers and/or customers. Examples are regularly visits to the supplier's facility, frequent face-to-face communication, high corporate level communication on important issues with key suppliers and formal, periodic written evaluation of suppliers (see for instance Carr and Pearson, 1999; Tan et al., 1999; Stanley and Wisner, 2001). The last category of items includes items that measure attitude of buyers and/or suppliers towards each other or towards supply chain management in general. Examples used in the questionnaires are "we expect our relationship with key suppliers to last a long time", "we view our suppliers as an extension of our company", "problems that arise in the course of this relationship are treated as joint rather than individual responsibilities" and "the responsibility for making sure that the relationship is works for both the other party and us is shared jointly" (see for instance Chen et al., 2004; Johnston et al., 2004).

Table 2.3.1 provides an overview of the SCM factors used in the survey and the type of items used to measure these factors. In a number of surveys, it is difficult to decide whether items are to be considered as attitude, pattern or practice. This is mainly because some of the authors use rather aggregated constructs, like supplier partnership defined as "bringing all of the participants in the product life cycle into the process early on so even suppliers and customers can provide input to each others' processes" (Droge et al., 2004). The results presented in the table confirm that a wide variety of items are used to measure supply chain management and/or integration. Moreover, detailed comparison of the items or constructs used shows that most authors do not build upon research of their predecessors. A more principle observation from the 16 papers examined is that there is too little consideration for the interrelationships between attitudes, patterns and practices. We return to this aspect in the discussion part of this paper.

Performance measurement

All the included surveys examine the relationship between supply chain management and performance. Most surveys examine the relationship between SCM attitudes, patterns and/or practices and the performance of the focal firm, in many cases the buying firm. The performance of the suppliers of the focal firm is not measured in most articles.

Again, there are also large differences between the surveys selected. The surveys differ with respect to the items used to measure performance and the way performance is measured. Table 2.3.2 shows that the majority of the surveys examine the effect of SCM on financial or overall performance as well as on customer service. Chen et al. (2004), Droge et al. (2004) and Vickery et al. (2003) examine the direct relationship between SCM factors and financial performance and the indirect relationship with customer service as a mediating variable. Others only examine direct relationships and use factors that include financial as well as customer service items in their research. Table 2.3.2 also shows that there is a smaller group of surveys in which performance is restricted to customer service or financial performance.

With respect to the measurement of performance, all authors except Salvador et al. (2001) use subjective assessment of performance. The use of subjective assessment is some cases justified by referring to Narasimhan and Das (2001) and Venkatraman and Ramanujam (1986). In a recent paper on subjective measures, Ketokivi and Schroeder (2004) conclude that perceptual measures are a viable alternative in large-sample studies as long as rigorous examinations of validity are performed. In the next section, this viewpoint is discussed in a broader context.

Eleven out of 16 assess the performance relative to the performance a number of years ago or relative to major competitors. For instance, in Chen et al. (2004) financial performance is operationalised by items indicating the extent of changes in (1) return on investment, (2) profits as a per cent of sales and (3) net income before taxes over the past three years. Vickery et al. (2003) measure customer service relative to major competitors and with respect to five items: product support, pre-sale customer service, responsiveness to customers, delivery speed and delivery dependability/reliability. Ramdas and Spekman (2000), Stanley and Wisner (2001) and Johnston et al. (2004) use perceptual measures

Table 2.3.2 Performance measures in SCM research

Performance measurement	**Customer service, responsiveness and/or time-based performance**	**Overall performance, market share and/or financial performance**	**Combination or path**
Subjective assessment	Ramdas and Spekman (2000), Stanley and Wisner (2001)	Johnston et al. (2004),	
Subjective assessment relative to performance × years ago		Carr and Pearson (1999)	Gimenez and Ventura (2005), Chen et al. (2004), Frohlich and Westbrook (2001), Shin et al. (2000)
Subjective assessment relative to major competitors	Stank et al. (2001)	Tan et al. (1999)	Droge et al. (2004), Scannell et al. (2000), De Toni and Nassimbeni (2000), Prahinski and Benton (2004), Vickery et al. (2003)
Objective assessment	Salvador et al. (2001)	Carr and Pearson (1999)	

for performance but not relative to the performance a few years ago nor relative to the major competitors. Stanley and Wisner, for instance, ask the focal firm to assess the *current* level of service and quality provided by the focal firm to its external customers with respect to items like fast delivery of products/services and flexibility to customer's changing needs.

Variety with respect to performance measurements appears to be as large as it is with respect to the measurement of supply chain management or integration. More fundamental is the observation made at the start of this section that most authors measure the performance of the buying firm, whereas the integration is measured in the relationship with its suppliers. If we assume that integration means investing in a buyer-supplier relationship, it would make sense to measure performance in terms of the aims of these efforts with respect to this particular relationship. Possible aims are to reduce reaction times and/or stocks but also to increase the visibility in the chain or to attain a more effective and efficient way of communication. Only a few of the selected papers measure the performance of the relationship or the performance of the supplier in the relationship. Johnston et al. (2004) measure the buyer's perception of the relationship's performance and the buyer's satisfaction with the relationship. Giménez and Ventura (2005) measure the manufacturer's performance in the relationship with their customer (retailer). Other exceptions with respect to this issue are Prahinski and Benton (2004) and Shin et al. (2000).

Relationship between SCM factors and performance

An important conclusion based on the previous two sections is that there is no consensus on how to capture the essence of SCM or SC integration and on how to measure the effect of SCM or SC integration on performance. In this section, we take this point of concern as a starting point for the discussion on the current status of SCM survey research. The main point is to investigate if and how the surveys help in understanding how SC performance can be improved and which integrative practices help.

We already stated that it is at least risky to examine the relationship between SCM factors and performance without measuring, investigating and understanding the interrelationships between different SCM factors. This is especially true for the relationship between SCM attitudes (like loyalty, trust and commitment), SC patterns and SC practices. The daily interactions within a relationship will affect the attitudes towards each other and towards supply chain management and vice versa (compare IMP group, 1990). Because of these complex interactions, it seems dangerous to investigate the relationship between attitudes and performance without properly accounting for these interactions. More generally, it seems far fetching to establish relationships between the attitude of a buying firm towards their suppliers and the financial performance of the buying firm. For instance, the fact that a buying firm is loyal to its suppliers has no immediate relationship with the ROI of the buying firm. Therefore, it is also not surprising that Vickery et al. (2003) did not find a significant direct relationship between supply chain integration and firm performance. An additional complicating factor is that in many of the contributions, integration is only measured in relation to the relationship with the most cooperative partner (supplier or customer) or the relationship with key partners. If integration is measured in one or a small number of relationships of the focal firm, it is especially difficult to establish a relationship with the overall performance of the focal firm. To conclude this point, it is unclear what the theoretical model is and if the relationships found have value for managerial decision-making. Who believes that increasing the trust in your supplier will raise profits?

In line with the arguments provided in this section and the previous ones, it seems more logical, especially from a conceptual point of view, to start with the relationship between SC practices (or patterns) and the performance of the supplier or the buyer-supplier relationship (BSR) itself. Attitudinal aspects are then primarily relevant in understanding the level of integration (practices and patterns) within the particular relationships (see Figure 2.3.1). As mentioned before, the interaction between the parties will influence the attitude and vice versa.

If the aim of SCM research is to relate integration efforts in buyer-supplier relationships to the buyer's firm financial performance, we

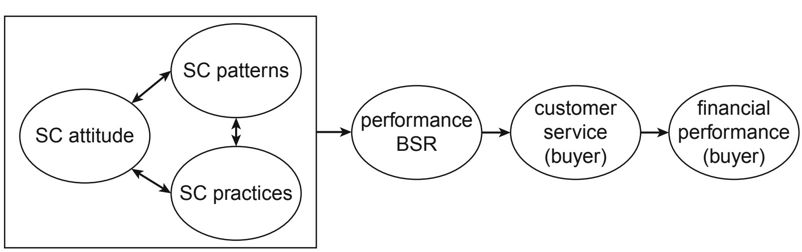

Figure 2.3.1 Research model

propose to investigate a path from the performance of the buyer-supplier relationship, via customer service, to the financial performance of the buying firm. A possible advantage of relating integration to the performance of the relationship is that is relatively easy to acquire reliable, less subjective, performance measures for the performance of the relationship especially compared to financial performance measures. From a methodological point of view, we advocate an approach in which research is not only based on data obtained from more than one respondent per firm, but also on data obtained from respondents of both companies in the buyer-supplier relationship (e.g., Johnston et al., 2004).

In many of the selected papers and in our discussion so far, there is an implicit assumption that higher levels of integration in the supply chain automatically lead to an improved performance. Van Donk and van der Vaart (2004, 2005) disagree with the assumption that more integration is always better. Based on both theoretical concerns and empirical evidence, they show that it is important to understand the influence of business conditions on the level of integration and the type of integrative activities employed. One of the main factors is the influence of demand characteristics or uncertainty on the type of practices employed: an issue also addressed by Fisher (1997), Mason-Jones and Towill (1998) and Childerhouse and Towill (2002). Other relevant business conditions are the decoupling point (MTO/MTS), time window for delivery, volume-variety characteristics, process type (batch size, set-ups and routings) and order winners. In line with Davis (1993), these factors are important indicators for the amount of uncertainty suppliers are facing in their production planning and delivery schedules. Van Donk and van der Vaart (2004) state that higher levels of integration can be expected in supply links if suppliers' business conditions are characterised by low volume, high product variety, small batches, make-to-order, a long time window for delivery and flexibility among the main order winners. These conditions correspond with a high level of uncertainty within the supply link. If business conditions are to a larger degree characterised by high volume, low product variety, large batches, make-to-stock, a short time window for delivery and costs as a major order winner, lower levels of integration are expected.

Among the survey papers selected, only the paper by Ramdas and Spekman (2000) explicitly includes business conditions or context. They find differences in supply chain practices in functional products supply chains as opposed to those in innovative products chains. This stream of research partly answers the remark by Frohlich and Westbrook (2001,

p. 185): "Our knowledge is relatively weak concerning which forms of integration manufacturers use to link up with suppliers and customers". The general conclusion is that in complex business conditions higher levels of integration are required and different SC practices are appropriate. This implies that there should be a fit between the SC practices and patterns and the business conditions (see also van Donk and van der Vaart, 2004, 2005).

Conclusions

The aim of this paper is to review a number of recently conducted surveys. In view of the fast developments in the field of SCM, it is not surprising that there is not yet a coherent view on the relationship between SC integration and performance. From our review, we derive a number of conclusions. The general conclusion is that the convergence in research is relatively small. Each author starts by developing a new model with new factors and measurement scales, and diversity is thus large.

In the papers, one can distinguish three different categories of variables and items: those measuring attitudes, those measuring patterns and those measuring practices. However, this is not made explicit in the research. We submit that each category should be conceptually distinguished and measured separately.

The measurement of performance is diverse as well. The main point addressed here is that performance of the SC relationship under study is hardly assessed, but that mostly the effect of SC initiatives for the performance of the focal firm is investigated.

The surveys reviewed have investigated relationships in different types of industries, but a systematic analysis of the effect of business conditions has been neglected. Here, an important area for future survey-based research can be distinguished.

A major limitation of the current review is that we have not yet included all survey-based papers and that we have limited our search to a restricted number of journals. Another restriction might be that the authors of some of the articles might share part of our criticism but have valid arguments for their particular choices. However, we strongly advocate taking into account the points brought forward in the previous sections and summarised above. Supply chain management research can and should try to better understand under what circumstances which integrative efforts pay off. If we better understand that type of relationship, we will be able to improve our teaching and help managers in improving their business.

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2.4
The Reverse Amplification Effect in Supply Chains

Matthias Holweg and John Bicheno

Introduction

Ever since the pioneering work of Jay Forrester in the late 1950s, academics, consultants and practitioners have been searching for methods to improve supply chains by controlling the dynamics of the information and material flows within.

Several different effects within the supply chain have been described, the most known is the "demand amplification" or "bullwhip" effect (Forrester, 1961; Lee et al., 1997). Several major different approaches to this effect have been taken: the first, defined by the authors as the Control Theory approach, focuses on applying the principles used, for example, in electrical circuits and process control, to devise ways to dampen the dynamics within the supply chain. A second avenue can be defined as the behavioural science approach. This was developed particularly from investigations into human decision-making using a simulation of Forrester's supply chain, called the "Beer game" (Sterman, 1989).

Research in a steel supply chain in the UK (e.g., Holweg and Bicheno, 1999; Hines and Taylor, 2000), however, found these conventional approaches in some cases insufficient to explain the pattern distortions of information and material flow. The empirical evidence suggests that a further level of distortion exists, which in previous research has been neglected, whereby distorted and highly amplified material deliveries – in response to amplified demand and large backlogs – are supplied to downstream tiers. These "supply waves" cause further short-term distortions in the information flow (due to necessary rescheduling). This effect was named "reverse amplification" and will be discussed in the following section.

Classification of supply chain effects

Each theory or approach has demonstrated certain reasons for distortion or even amplification of demand of demand patterns in the system. However, it was felt that in many cases, this research has been too linear in thinking as it has often adopted frameworks or solutions grounded within narrow causal explanations. The majority of past research has suggested all-encompassing solutions that ignore the existence or competing position of other theories. Most of these approaches have also ignored the wider institutional environment in which companies work (Hines, Wilding and Holweg, 1999).

This paper aims to aggregate past research on supply chain dynamics and to group the different approaches to distortion and amplification into six levels of distortion (see Table 2.4.1), extending the dimensional concept primarily introduced by Hines, Wilding and Holweg (1999).

Table 2.4.1 Six level matrix for distortion sources in supply chains

Level	Dimension	Type of Distortion	Causes of Distortion	References
1	Intra-company information flow	"Burbidge Effect"	Information distortion order and stock policies, double forecasting, multi-phased ordering	• Towill (1984, 1996) • Evans et al. (1993)
2	Inter-company information flow	"Forrester Effect"	Transmission delays	• Forrester (1961) • Towill and Naim (1993)
3	*Inter-company material flow*	*"Reverse Amplification"*	*Process unreliability and batch processing*	
4	Inter-supply chain	"Parallel Interaction"	Interacting value streams Internal procedures, e.g., customer prioritisation	• Hill and Wilding (1999)
5	Institutional environment	External influence, e.g., other supply networks, government policies	n/a	• Hines, Wilding and Holweg (1999)
6	Chaos	Applies to all levels	n/a	• Gordon and Greenspan (1997) • Levy (1994) • Wilding (1998)

Table 2.4.1 shows major contributors to the current state of "supply chain dynamics" knowledge, divided into the different "dimensions" where these apply.

However, the authors believe in addition a third level of distortion exists, which in previous research has been neglected, whereby distorted and highly amplified demand patterns coupled with certain process batching and capacities settings leads to highly amplified "supply waves".

The reverse amplification effect

The findings discussed in this section are drawn from research in the UK steel supply chain. The demand amplification effect has been previously discussed and could be shown in the steel supply chain research called the "Lean Processing Programme" (see e.g., Hines and Taylor, 2000).

However, a second and similar effect could be observed which is not described in the system dynamics research so far – whereby not on the demand patterns tended to be amplified, but also the supply patterns, in reaction to the demand amplification, was highly amplified and distorted. In many cases, the supply quantities matched or exceeded the amplified demand patterns, as simple all available material was shipped as soon as it became available. This "wave-like" supply pattern was hence called the "reverse amplification", as it could be seen as the equivalent to the "demand amplification" in the information flow but on the reverse or material flow side.

What happens is that in case of a supply constraint, as, for example, the caster operation in the steel supply chain, order backlogs build up over time. As described by Lee et al. (1997), customers of this bottleneck operation start to over-order as a safety measure (the "rationing game") – the demand amplifies and soon an order backlog builds up. As the constraint generally is operated on large batches, it will not be able to supply against these orders until the next batch of the right product is run through the bottleneck. If, however, the right product is produced, suddenly a large quantity of products becomes available and can be supplied. As the order backlog has built up, a large "wave" or quantity of material is subsequently sent down the system, flooding the stocking points with material. The downstream tiers will then stop ordering immediately until the product is in short supply again. Then the over-ordering starts again, etc., and the circle is closed.

In most cases, reverse amplification will be a response to amplified demand patterns, where this amplified demand covers orders far ahead of actual demand, for safety reasons. A backlog at the supplying tier is therefore building up. If this backlog were to be cleared all at one time, a huge wave of material would hit the downstream tiers and result in excessive stocks. This effect was initially described by Hines, Holweg and Sullivan (1999) as the "Splashback" effect, using a wave analogy to describe supply chain dynamics, but the effect also could be demonstrated in a simulation by Holweg and Bicheno (2000).

The steel supply chain is an obvious candidate for this effect; yet potentially, any other supply chain which has a common bottleneck operation through which several products have to flow might be affected. Any additional process unreliability, quality problems or other delays worsen this effect.

Root causes for reverse amplification

As far as our initial research shows, reverse amplification appears in supply chains under particular circumstances; in fact, three critical factors could be identified, plus additional contributing factors.

Critical Factors

- **A throughput constraint operation** upstream, most probably at raw material level, which operates in large and inflexible batches, possibly due to technical constraints (e.g., the coffin type scheduling in steel mills)
- **Multiple products that need to go through the constraint operation**, leading to long order lead times due to the large production batch sizes
- **A high degree of demand amplification and distortion**, leading to large order backlogs at the throughput constraint operation. High orders are a safety measure by the subsequent tiers ("rationing game") to ensure supply and to build up safety stock

Contributing Factors

- **Process unreliability and quality failures**, further compromising the throughput reliability and causing further supply uncertainty
- **Order batching and minimum delivery quantities**, that is, "one steel coil", which might itself be equivalent to many weeks supply

This profile is not uncommon, as almost every supply chain relies on one or several generic raw material suppliers who act as "breakwaters". The reason for this profile is the process orientation of many raw material plants, such as steel mills or chemical plants. These types of industries are driven by technical constraints such as production sequences, minimum production batches and long lead times. Therefore, these industries tend to sell their products only in minimum order quantities, enabling them to fit the orders into their production scheduling system more easily.

The industries hardly respond to the demand "pull" at all, but tend to push their material in big waves through the chain as occurs when waves crash against a breakwater followed but a long period where there is not backflow of water down the beach until the next wave breaks (or large batch is pushed produced).

Hence, when the returning "wave", which represents the physical return product flow occurs, instead of being neatly proportional to the incoming information wave, it is greatly distorted and magnified in very large infrequent batches.

Reverse amplification – example

In the example from the steel supply chain below, the underlying demand from the first tier company is on average 15 tonnes/week. The service centre, however, orders in batches of 60 tonnes. The steel mill acknowledges the deliveries for weeks 14, 15 and 18 (in case of week

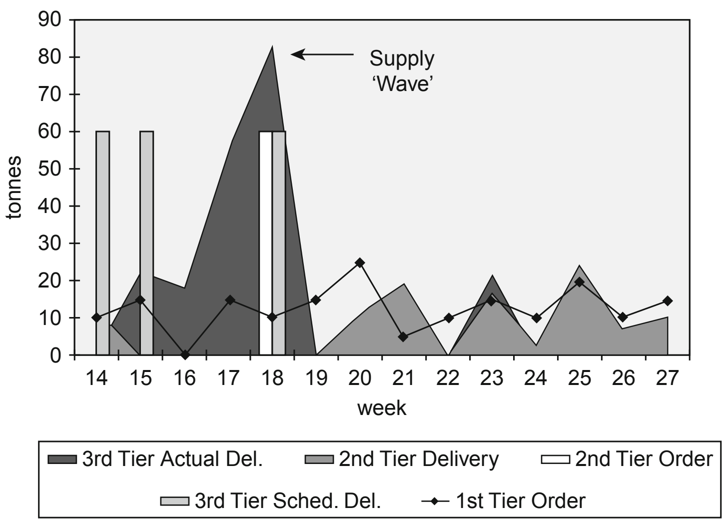

Figure 2.4.1 Reverse amplification effect

14 and 15, the order on the mill has been put earlier on, but delivery is acknowledged late). The actual deliveries only start in week 14 and 15 with small amounts, the "wave", though, comes in week 18, when the main part of the production batch/campaign is ready for shipment and is then supplied against the backlog and exceeding the ordered quantity for that week by 33%.

After the "wave" hit the service centre, no more deliveries are made until week 23, where another remainder is supplied.

Conclusion

This paper puts up for discussion the initial analysis of research in a three-tier steel supply chain in the UK automotive industry. A previously unknown effect in the dynamics of this multi-tier supply chain could be described, called "reverse amplification". This effect, for which conventional supply chain dynamics theory was found insufficiently explanatory, was defined as "amplified and distorted supply patterns caused by supply/throughput constraints in response to amplified demand patterns".

So far, the empirical evidence relies on the research in the UK steel supply chain; hence, further research is needed in other industry sectors to further understand the cause and effect of the reverse amplification and to ultimately quantify and predict the effect.

Within our current research, we aim to further understand the phenomenon by using a participative game as a simulation tool to model both the human decision-making process (the players) and the particular supply chain characteristics (game settings). So far, the effect could be qualitatively reproduced modelling the steel supply chain, and further analyses of different scenarios are carried out presently.

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3

Agility, Flexibility and Risk

3.1
Creating the Agile Supply Chain: Issues and Challenges

Martin Christopher, Alan Harrison and Remko van Hoek

Introduction

Demand for standard products has fragmented in markets as diverse as fast foods, sunglasses, breakfast cereals and banking, where niches are smaller and constantly changing. In fact, the niches are the market (Pine, 1993). The concept of *mass customisation* assumes that such trends will continue well into the next century, and that the challenge is for greater product variety to be achieved at prices comparable to those of the mass producers (Gilmore and Pine, 1997). This is unlikely to be achieved without a fuller understanding of the logistics tradeoffs that are implied. The purpose of the research design presented in this paper is to investigate these tradeoffs by studying the issues involved at organisational level.

The capability of lean production to meet the challenges of product diversity across all products and markets is now being widely questioned. Concern focuses on two major areas. First, there is the relative inflexibility built into lean supply chains by the requirements for long-term partnership and pull scheduling. Synchronisation of material movements upstream is achieved by fixing schedules in advance. Inflexibility is further reinforced by Japanese ideals like *nemawashi* (watering the roots) and the *ringhi system* (everyone must register consent), which slow down decision-making. Second, there is the "competitive greyness" (Skinner, 1996) of supply chain strategies that are defined by an "absolute standard" of an overarching practice such as the elimination of waste proposed by Womack and Jones (1996). While functional products with predictable demand benefit most from "physically efficient" supply chain processes (Fisher, 1997), innovative products demand "market responsive" supply chain processes that are focused on speed and flexibility rather than on cost. Figure 3.1.1 shows

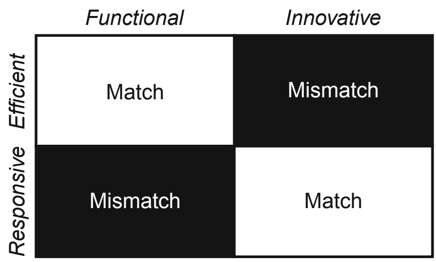

Figure 3.1.1 Fisher's supply chain matrix

Fisher's supply chain matrix: efficiency has been defined in "lean" terms of productivity and quality. A different approach to production scheduling called *accurate response* (Fisher et al., 1994) is proposed to distinguish stable demand items from unpredictable items. The latter are treated separately by assessing early market signals using a risk-based sequencing that demands highly responsive production facilities and supply chains.

A further approach is to reduce the lead time gap so that the manufacturing cycle is based on a richer mix of known orders and less on forecasts (Christopher, 1999). This is one way to "shrink the uncertainty cycle" (Mason-Jones and Towill, 1998). Effective strategies for such responsive supply chains are based on linking core capabilities to product differentiation (Swink and Hegarty, 1998).

An emerging development of the lean production mindset that claims to address the needs of market responsive supply chain processes is the concept of *agility* (Goldman et al., 1995; Preiss et al., 1996). Agility is defined by the Agility Forum at Lehigh University, PA, as "the ability of an organisation to thrive in a constantly changing, unpredictable business environment". While Japan has "won the race to lean manufacturing", agility is "based on some uniquely American strengths, such as entrepreneurialism, and information systems technology". Some illustrations have been published to illustrate the application of agile concepts to operating companies, but the evidence so far is largely partial and US based.

Research design

We have initiated a program of research, an "agility audit", to investigate the dimensions of agility in UK, Dutch and Belgian-based companies. A questionnaire was designed with the objective of better understanding the balance between "lean" and "agile" logistics practices within a given organisation.

First, it was necessary to identify the main pillars of agility and how these might differ from leanness. A suitable starting point was the agility audit by Goldman et al. (1995, p. 358). Here, the "principal dimensions of agility" are defined as:

- enriching the customer
- cooperating to enhance competitiveness
- mastering change and uncertainty
- leveraging people and information

Assuming that the principles of agility would be unfamiliar, it was necessary to interpret them in a way that would be understandable to European respondents. Further, individual organisations would presumably only have adopted some agile principles, and then only partially. So it would be necessary to search for clues about what is going on and to use terminology that would be widely understandable.

Using the principles of agility as a template, we constructed questions to find out about the above practices by focusing on a given major product line within the organisation in terms of the following characteristics:

- customer centred v product centred logistics policies (ten questions): assumes that agile policies emphasise customers and markets while lean policies focus on the elimination of waste in products and processes
- fluid clusters v long-term supply chain partnerships (six questions): assumes that agile policies emphasise fluid clusters of network associates while lean policies focus on a more fixed set of long-term partnerships
- capabilities v "world class" measures of performance (seven questions) assumes that agile policies are based on broad-based measures that underpin capabilities while lean policies emphasise hard measures such as quality and productivity
- self-management v work standardisation (five questions) assumes that agile policies focus on operator self-management to maximise autonomy and immediate response while lean policies emphasise work standardisation to ensure conformance to quality and productivity standards

- immediate conversion of demand information into new products using knowledge-based methods v multi-stage, multi-function methods (three questions) and assumes that agile policies focus on instantaneous demand capture, interpretation and response while lean policies emphasise stable production periods and protecting the operations core

Respondents were asked to provide some background data on sales, seasonality, demand predictability and product complexity for a major product line. The questionnaire then asked respondents to rate each criterion on a 1–5 Lickert scale "by circling the number that represents your view of your strategic business unit". Copies of the questionnaire were then mailed to individuals who had attended a Cranfield agility seminar or who were otherwise considered by the researchers to be interested in the concepts of agility. The latter consideration applied particularly to the sample of Dutch- and Belgian-based organisations. When respondents returned the questionnaire (the response rate was about 40%), they were contacted by telephone to discuss their answers in a brief, structured interview. The purpose of the interview was to elicit further views and information surrounding the questionnaire response. These interviews were recorded and transcribed.

Results

So far, only the data from 20 UK-based organisations has been analysed. Many of the responding companies were product-based organisations whose major product lines were currently in the "functional-efficient" box in Figure 3.1.1. Most dealt downstream on a business-to-business basis, that is, through a retailer or distributor rather than directly with the end customer. These organisations – which included examples from household paints, brewing, grocery suppliers, pharmaceuticals and stationery – regarded themselves as having standardised products that had limited capability of reconfiguration to specific customer needs manufacturing tasks were similarly standardised, a mix of operating procedures with risk-taking frowned upon and a relatively slow response times to volume and variety changes for new products. And stability was the name of the game in the supply chains too, with companies tending to favour a fixed set of long-term partners for supply.

Measures of performance within such companies were already fairly broad-based, as exemplified by a producer of groceries:

> We use service level fulfilment; we use on time delivery; we use order ship complete on time; we use refusal targets; we use customer satisfaction surveys; product freshness forecast accuracy. I might have missed one or two, but that's most of the ones we use as measurement in the supply chain.

And further service-related measures had been introduced:

> The extra benefit we offer is the quality of service that we provide through the customer service people. We have a program called Proficiency Interface Management which sets out what we believe to be the main cause of operational excellence, and we discuss those programs with the retailers who operate with us, and we use them as a way in improving the service we give to them.

But already the pressures for change were mounting. Access to EPOS data was already a reality for three of the top five retailers, and at the time, the company was "trying to agree how best to use the information we have the access, but how do we use it?" It was still unclear about how this could be used to cope with expected increases in demand uncertainty in future:

> How do we cope with [demand uncertainty] Fairly well at the moment, but historically not awfully well. I think that the factory units are probably more flexible then they have been in the past, and this allows capacity in the factories to encourage flexibility, but not as much as there needs to be in the future.

Most organisations surveyed considered that they had a low level of predictability of customer demand over the next six months. But a tier 2 supplier in the automotive supply chain saw the problem as depending on the assembler you were dealing with:

> It's not so much the [end customer that drives demand], it's the [assembler] that's giving up the information, and it's all dependent on the [assembler]. For some, we get no notification of changes in demand; others we'll know 3 months in advance what therr changes their going to be.

This potentially negative interference in inbound supply chain dynamics by automotive assemblers is a factor to which we have referred before

(Harrison, 1996), and one which resolution we see as a more fundamental task of increased pipeline control. Modelling four-level logistics system, Mason-Jones et al. (1997) arrive at similar conclusions. They proposed that agility is not a solution for turbulence created by unstable pipeline control systems at the assemblers.

An example of a very different organisation included in our survey was one making hydraulic cylinders. Here, some 30–40% of sales were built to custom specification, while the remainder were standard products that were often tailored customer requirements. Rapid response to new orders was essential: "if you don't respond rapidly, you're dead".' And demand was on a very short fuse:

> Because of the nature of our business and the way we've geared ourselves up to work, most of our products are on a very rapid turn round, and therefore people tend to order [them] very late. We've probably got the next twenty weeks at variable demand. But on a week to week basis, we probably only got enough work on a Monday to last us to Wednesday or Thursday; the rest comes in during the course of the week.

There were "a lot of spikes of demand, and you have to deal with them as and when the happen, rather than be able to plan them". The company dealt with the demand uncertainty in a variety of ways:

> We have a very flexible workforce that we have retrained over the last 5 years, so we are very capable of doing just about everything; we can swap them around a lot. But, also, if we do get overloaded, we do have a series of sub-contractors that we can use. We do tend to keep [work] in house wherever possible. We carry a lot of inventory.

Such a description from a small batch/jobbing environment was reminiscent of Remmele Engineering, widely quoted by the Agility Forum as an example of agility (e.g., Arnott et al., 1996).

Finally, the service edge was seen by most of our surveyed companies as a key business imperative. When asked to choose between a core skills focus and product/process focus, most said "both". But it was the core skills focus that was usually seen as the bigger challenge, for example:

> It happens that we think we have the best product range in our business, better technology than any of our competitors, and there are swings and roundabouts in this. There are some that we are good

at and some bits we're better at. Overall we think we have a very competitive product offering but we actually see long term competitiveness coming from our people, differentiation from our people, so we invest in the people.

Conclusions

This exploratory research project is far from complete. Early indications are that a rich and dynamic supply chain scenario is unfolding. Breaking through the retailers' barrier to visibility of end customer demand places further challenges on the supplier: the turbulence may be different, but it is still there. Once we have analysed all of the data at our disposal, we will target the next stage of this project at the logistics implications of actual time-phased end customer demand.

Acknowledgements

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3.2
Process Control in Agile Supply Chain Networks

Michael Pearson, Ron Masson and Anthony Swain

Introduction

For businesses to compete in the commercial sector where markets are increasingly more volatile and unpredictable demands create uncertainty, their supply chains have needed to adapt to respond to such unpredictability. This capability a supply chain has of becoming flexible is referred to as *agility* (Christopher, 2000; Prater et al., 2001) and some of the conditions in which an agile approach is best suited can be described by the following characteristics: (i) short life cycle products; (ii) high product variety in the face of unpredictable demand; (iii) small volumes and higher profit margins; (iv) competition based on product specification. With this agility, the supply chain more frequently operates in a global context and there is an increasing trend to outsource the supply and manufacturing overseas, through a complex supply network (Prater et al., 2001; Storey et al., 2005; Masson, 2007), to reduce costs.

The global fashion industry is a prime example, particularly in the high end of the fashion market, in which businesses are competing in a fickle, volatile and unpredictable market where high variety, high margin, short life products are being sourced globally (Storey et al., 2005; Masson, 2007). Fashion retailers exploit this unpredictable market by introducing new products to their stores as frequently as possible, where product life cycles, from first offering in a store to discounting, average six weeks. There can be few industries where there is a greater need for a more responsive and rapid design/manufacturing/delivery lead time throughout a complex global supply chain (Masson, 2007).

Using the fashion industry as a case study, this paper aims to introduce a new theoretical development (Pearson, 2003, 2006, 2008a, b) to aid agile supply chain decision-making under uncertainty and the remainder of the paper is structured as follows. We first describe the agile global fashion industry supply chain in more detail and highlight some of the key decisions, in particular for the retailers while exploring the relevance of earlier research and literature. We then outline the modelling approach and an equilibrium solution in such a supply chain. The methodology of prediction capability using phase plane analysis is then illustrated with an example from the agile fashion industry making use of simulation. The paper ends with a conclusion and details of further research and collaborative work in progress.

In attempts to exploit the unpredictable UK market, high fashion retailers introduce new products to their stores as frequently as possible which in most cases requires global sourcing. Figure 3.2.1 illustrates their key decisions throughout this process of introducing new products, from the start of a season to the final product phase.

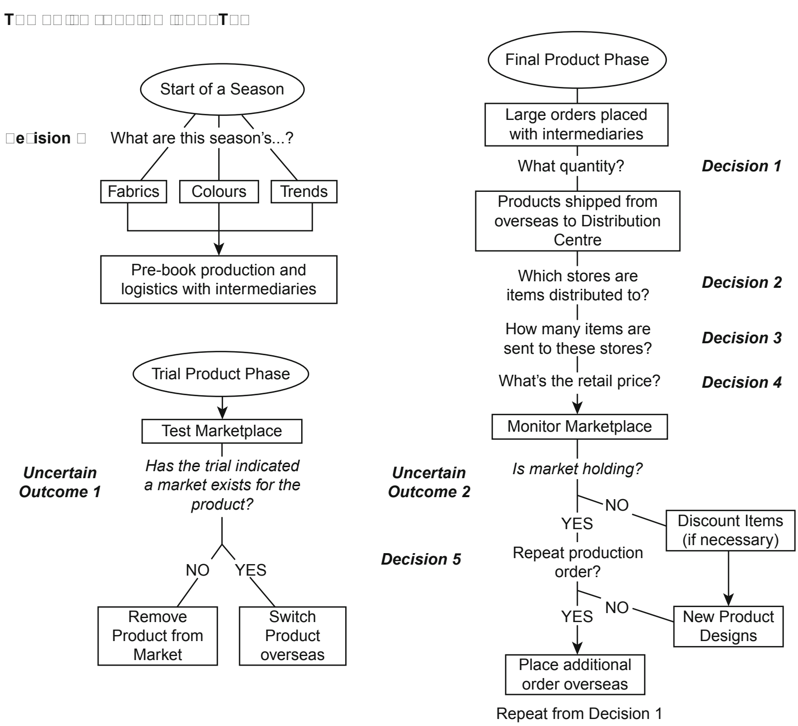

Figure 3.2.1 Key retailer

The process begins with the UK retailer's product design conception at the start of a season. Market trends will be continuously monitored, and once the retailer has made a decision on fabrics, colours and trends (**Decision 0**), which they anticipate will be fashionable for a forthcoming season, the production and logistics are pre-booked. This relates to a tactic known as postponement, which is based on the principle of early product design and the delaying of final production until the final market destination and/or customer requirement is known (Christopher, 2000). In this case, postponement allows for any changes the retailer wants to make to the product specification before its introduction into the market. The pre-booking is predominantly done through overseas intermediaries who are agents with no manufacturing capabilities or assets (if they do own assets it is normally major logistics capability), but have access to an appropriate supplier network, which their role is to manage. At this stage, before the product definition and launch, the intermediary would select preferred fabrics and suppliers.

Once the product design is complete, it may go through a trial period in the retailer's flagship store (this is not always the case). At the trial stage, the product can often be sourced and produced locally in small quantities (<20 items). The outcome of the trial (**Uncertain Outcome 1**) determines whether the production is switched overseas in large volume (>500 items) or the product is removed from the market.

When the production is switched overseas a large order is placed with an intermediary (**Decision 1**) who is responsible for sourcing the product at the lowest cost and lead time possible. The most common approach to sourcing (Masson, 2007) is through competitive auctions, organised by the intermediary, for garment manufacturing by passing product specifications and volume requirements to approved manufacturers in the supply network base. Manufacturers send back an "offer package" based on price and lead time and the best "offer" would be selected. The finished products would undergo quality checks by the intermediary and then dispatched to the retailer's distribution centre.

The remaining decisions the retailer has to make are when the finished product has been delivered, regarding its distribution among the stores and complete introduction into the market (**Decisions 2–4**). The average time such products exist in the market is six weeks, but can be as short as three weeks. During this time, if customer feedback indicated the market was holding for the new product (**Uncertain Outcome 2**), a repeated order may be placed (**Decision 5**). Otherwise, the products are discounted or sold through less fashion conscious outlets towards the end of its six week life cycle (Christopher et al., 2004; Masson, 2007).

Modelling approach

The approach adopted in this paper firstly recognises the distinct difference between the specialist skills of forecasting and those acquired by decision-makers in operations management. Given an environment in which customer demand is increasingly uncertain, errors in forecasts are expected, and when these errors are acknowledged and shared, real strategic progress can be achieved. The methods we use identify phenomena of practical interest, such as push and pull effects which occur in manufacturing systems, marketing strategies and the bullwhip effect, whereby variability is pushed upstream through a variety of transactional strategies and agreements (Pearson, 2008b).

The problem type, which is a specific case of a general type of mathematical problem, the two-echelon (primal-dual) problem, is illustrated in Figure 3.2.2 where the distribution of new products in the agile fashion industry (from the base of suppliers to the retailer) is divided by one of four possible decision frontiers. Each decision frontiers acts as a line-cut and divides the connected network into two components, which can be treated as primal or dual (Pearson, 2008a). There can be as many decision frontiers as there are line-cuts in the graph representing the network, each generating a set of decisions and efficient frontiers. For instance, the two-echelon problem defined on Decision Frontier 3, where an intermediary determines the cost to charge a retailer, and a retailer determines the amount of inventory to order through an intermediary and the retail price.

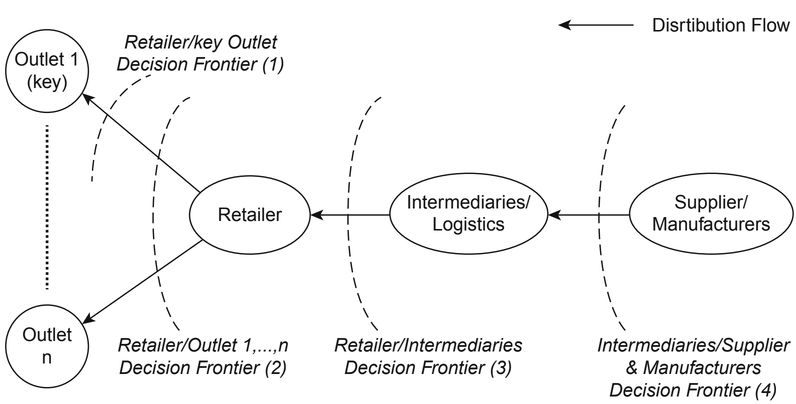

Figure 3.2.2 Decision frontiers for a typical agile supply chain network

The objectives in this problem are to increase profit, reduce waste and improve customer service in a coordinated way under current business practice. At Decision Frontier (3), for example, this requires a profit maximising solution to the decision set $\{\mu,\eta,\sigma_e(\mu,\eta)\}$, which is derived from the variables μ_D (the mean demand) and μ_Q (the mean supply) by applying the primal-dual transformation, that is, $\mu = \mu_Q - \mu_D$, $\eta = \mu_Q + \mu_D$, and σ_e is the standard deviation of the combined forecasting errors for the demand and supply. The following formulation is based on the model described in detail in Pearson (2003), which assumes that unbiased demand and supply fitting or forecasting techniques are already applied and the prediction errors are normally distributed. The primal-dual objective is to maximise:

E{Profit} = E{Contribution from captured demand – Costs of overage – Costs of underage}

$$= \mu_D c_p - \{(\varphi(k) - k(1-\Phi(k)))(c_{u_1} + c_{o_2} + c_p) + (k\Phi(k) + \varphi(k))(c_{o_1} + c_{u_2})\}\sigma_e \quad (1)$$

subject to: $\mu - k\sigma_e = 0$, (Newsvendor Constraint) (2)

where $\phi(k)$, $\Phi(k)$ are normal distribution density and cumulative distribution functions, respectively, for safety factor, k. The contribution to profit is c_p which includes the contributions from the retailer and intermediary. The overage and underage costs of the retailer are c_{o_1} and c_{u_1}, respectively, while for the intermediary they are c_{o_2} and c_{u_2}. An interesting feature of the problem and the way it is formulated is that the retailer's (primal) overage is the same as the intermediary's (dual) underage, though they may have different attitudes to these phenomena resulting in unequal costs .

The equilibrium solution under conditions of constant variability is described by the following equation (Pearson, 2003):

$$\Phi(k) = \frac{c_{u_1} + c_{o_2} + c_p}{c_{o_1} + c_{u_1} + c_{o_2} + c_{u_2} + c_p} \quad (3)$$

The equilibrium solution under conditions of changing variability is described by the following equations (Pearson, 2003):

$$\Phi(k) + \frac{\partial \sigma_e}{\partial \mu}\phi(k) = \text{Const}\left\{ = \frac{c_{u_1} + c_{o_2} + c_p/2}{c_{o_1} + c_{u_1} + c_{o_2} + c_{u_2} + c_p} \right\} \quad (4)$$

$$\varphi(k)\frac{\partial\sigma_e}{\partial\eta} = \text{Const}\left\{= \frac{c_p}{2(c_{o_1} + c_{u_1} + c_{o_2} + c_{u_2} + c_p)}\right\} \tag{5}$$

Equation (4) is the “mix” (overage/underage) solution, which tracks the way partners across decision frontiers synchronise their efforts to reach optimality, and Equation (5) is the “global” (volume) solution. Together, they form a dynamic system of stochastic differential equations which trace the optimal solution in circumstances where uncertainty increases or decreases over time and with relation to differing contractual and marketing strategies.

The model outlined here fulfils many of the requirements of modern agile supply chain networks. One of the requirements is the incorporation of non-deterministic demand, lead time and supply mechanisms into the modelling methodology (Nilsson and Darley, 2006). The patterns identified in such contexts frequently do not match deterministic assumptions, which are more generally associated with periods of stable operation. The complexity of events occurring in a local context is particularly difficult to express in a simple model. Nilsson and Darley (2006) describe the need for complex adaptive systems (CAS) and agent-based modelling (ABM). Our approach to the study of network flow uncovers a duality between networks as knowledge structures and networks as decision-making structures (Pearson, 2007) across naturally occurring decision frontiers (Pearson, 2008a). The approach also identifies through the use of phase planes, the way in which two decision-makers (agents) coordinate their efforts to achieve capable solutions in environments experiencing changing variability and increasing uncertainty (Pearson, 2006, 2008b). Patterns in the “local” phase plane reflect the way in which endogenous variables, such as negotiated costs and contractual agreements between agents (Tsay, 1999; Cachon 2004), affect the optimal solution. Patterns in the “global” phase plane reflect the way in which exogenous variables (such as pricing promotion strategies and quality of forecasting in the global market) affect the optimal solution. The two phase planes are significantly uncorrelated (Pearson, 2008b). Each phase plane has an efficient frontier derived from the solution of the stochastic differential equations (Equations (4) and (5)). This is now demonstrated in the following section.

Illustration

We illustrate the use of prediction capability and phase plane analysis at Decision Frontier (1) with an example representative of a high fashion product which has been introduced for the first time into the market, such as a woman's camisole or vest top. The contribution to profit is $c_p = 6$, and $c_{o_1} = 5$, $c_{u_1} = 0$, $c_{o_2} = 0$, $c_{u_2} = 1$. The equilibrium solution is found to be $k = 0$ (derived from Equation (3)). Simulation is used to demonstrate the strategies employed in the marketing of high fashion clothing and data was simulated based on this illustrative example using a Java program. In this simulation, the forecast demand is calculated using simple exponential smoothing with smoothing constant 0.2 and the forecast supply is calculated using the coordination constraint, $\hat{Q} = \hat{D} + k\sigma_e$, with $k = 0$. The demand, D, is randomly generated from the standard normal distribution whose mean increases for the first three weeks and decreases for the remaining six, and similarly for the supply, Q. This is presented in Figure 3.2.3 for a nine week period, which is representative of an average life cycle for a high fashion product in a retail outlet, where sales peak in weeks three to four (Christopher et al., 2004).

From Figure 3.2.3, the supply for this example product displays a lag behind the demand. This describes a common approach in marketing a new product, whereby the retailer attempts to generate demand for a high fashion garment in the early stages of its life cycle, pulling the quantity amount up gradually, and branding the product as exclusive. Then in the latter stages of the life cycle as the demand drops, it pulls the quantity along with it, after a delay. Associated with this is the product's profile illustrated by the global and mix phase planes in Figures 3.2.4 and 3.2.5 respectively. The global phase plane identifies changes in the error variability, σ_e, to the expected volume, η, of trade as new markets are investigated and the mix phase plane identifies the way in which two decision-makers (agents) coordinate their efforts to achieve capable

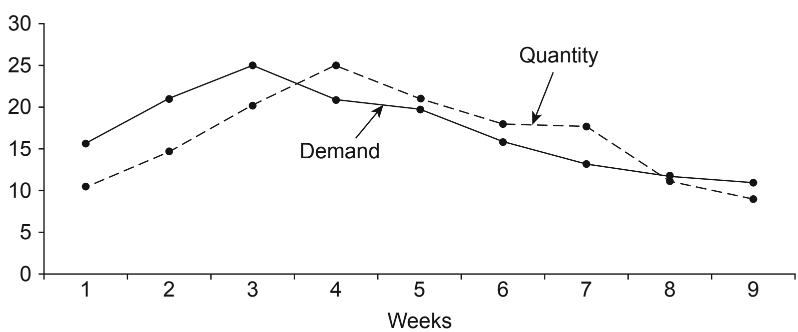

Figure 3.2.3 Time series life cycle of high fashion product over nine-week period

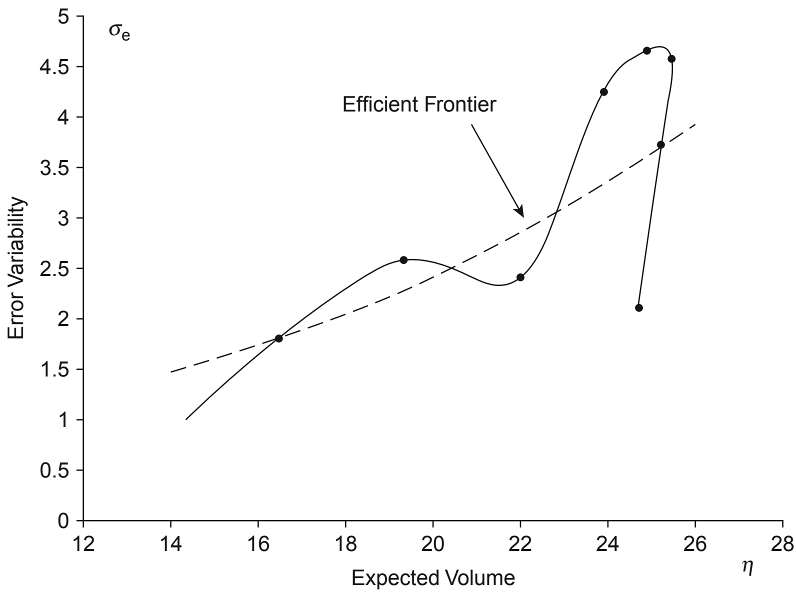

Figure 3.2.4 Global phase plane

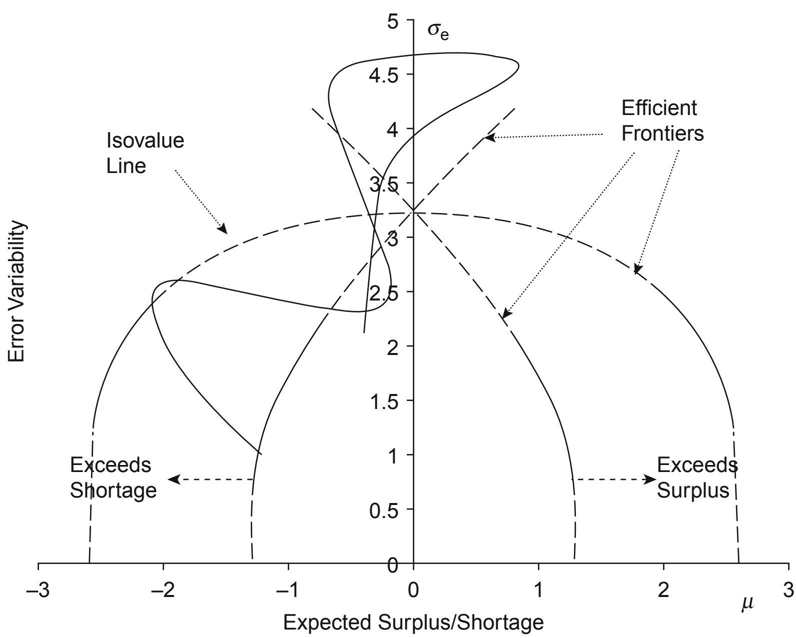

Figure 3.2.5 Mix phase plane

solutions in environments experiencing changing variability and increasing uncertainty.

The profile in Figure 3.2.4 displays a typical increase in variability as volume increases. The efficient frontier for optimal allocation of stock volume can also be mapped onto this phase plane. Market operation along this efficient frontier ensures maximum profit levels for a desired area of risk. Figure 3.2.5 illustrates the relationship between the two operators functioning across a decision frontier by mapping the changes in error variability, σ_e, against the expected surplus/ shortage, μ. So in this example, it shows how well the retailer and the outlets coordinate the flow of the product upstream in the supply chain network (SCN) and the way in which error variability (and hence risk) varies through this process. The variability we speak of here is not just demand variability but the joint variability experienced by both operators on either side of the decision frontier. The path of variability in Figure 3.2.5 (bold line) displays an overall clockwise movement, indicating a "pull" effect, which corresponds to the description for this product's life cycle presented in Figure 3.2.4. Also mapped onto the mix phase plane are three efficient frontiers. The isovalue line shows, using k as a parameter, the efficient frontier for solutions which have the same profit level as that obtained by the maximum profit solution (at $k = 0$), which achieves the desired target levels of surplus and shortage. The other two efficient frontiers, which are derived from parametric equations given constant surplus and shortage targets (Pearson, 2003), plot the area of capable optimal solutions using k as a parameter again. The optimal solution occurs at the point where all three efficient frontiers meet, so that agreed targets on customer service and overproduction match the maximum profit achievable in the area of market uncertainty for which the product is retailed.

Conclusion

Agile supply chain networks, which are characterised by their complexity and flexibility due to the extended global networks of different suppliers required for high product variety, operate within high risk levels. There is therefore a requirement for more suitable decision-making models as management tools to monitor and audit, as well as improve supply chain performance. The model outlined in this paper incorporates non-deterministic demand, lead times and supply mechanisms into the methodology fulfilling many requirements of ABM and CAS. It identifies the non-linear behaviour of the product's market area and the relationship between operators in the SCN across explicitly defined decision frontiers, which can be used to enhance the decision-making for businesses operating in such volatile markets. Much research has been carried out in lean supply chain networks but relatively little quantitative work has been done in agile networks. Furthermore, although the methodology we have proposed can be applied in both the lean and agile contexts, the innovative facility to map changes in variability is a key feature which should enhance research and understanding of the mechanisms occurring in such supply chains. The next stage of research will involve developing a commercial model through collaborative work which will aid the decision-making throughout the whole process of introducing a new product into the market.

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3.3
The Power of Flexibility for Mitigating Supply Chain Risks

Christopher Tang and Brian Tomlin

Introduction

Despite the fact that many firms are instituting risk assessment programs to systematically uncover and estimate supply chain risks, very few firms are making concomitant investments to reduce risk. While the exact reasons for this are not known, Rice and Caniato (2004), Zsidisin et al. (2001, 2004) suspected that the lack of precise cost/benefit or return on investment (ROI) analyses can be one of the key reasons. To garner support for implementing certain risk reduction programs without exact analyses of certain risk reduction programs, Tang (2006) argued that risk reduction programs must provide strategic value to the firms regardless of the occurrence of major disruptions that rarely occur. Indeed, in addition to disruption risks, firms should be concerned about routine risks: frequently occurring problems that cause mismatches in supply and demand or higher than expected procurement costs. Specifically, Tang (2006) highlighted the strategic value of nine different supply chain risk reduction programs that would enable a firm to reduce these routine risks and those rare but severe supply disruption risks.

Risks are often measured on two dimensions – the "likelihood" of occurrence and the "impact" if the event occurs. In this paper, we focus on examining the power of flexibility for reducing the impact of certain routine supply chain risks (e.g., uncertain supply cost, uncertain supply capacity, uncertain demands, etc.). While it is clear that flexibility provides strategic value to a firm and it enhances the supply chain resiliency, it is unclear how much flexibility is needed to mitigate supply chain risk. Without a clear understanding of the value associated with different levels of flexibility, firms are reluctant to invest in risk-reducing flexibility strategies, especially when precise cost/benefit analysis is unavailable. In this paper, we present a framework for examining the value of flexibility. Based on our analysis, it appears that firms can obtain significant value by implementing a risk reduction program that calls for a relatively low level of flexibility. Our findings highlight the power of flexibility and provide convincing arguments for deploying flexibility to mitigate supply chain risks.

This paper is organised as follows. We first present four different flexibility strategies for mitigating different types of supply chain risks. Then we introduce a flexibility measure and review some stylised models that are intended to illustrate the value of flexibility. Based on our models, we show that only a small amount of flexibility is required to mitigate risk. We note that this paper is a summary of the research presented in Tang and Tomlin (2007).

Flexibility strategies for mitigating supply chain risks

We focus on four types of flexibility strategies for mitigating various types of routine supply chain risks (see Table 3.3.1). (For discussion of other types of risks and flexibility strategies, please see Tang and Tomlin

Table 3.3.1 Flexibility strategies for reducing supply chain risks

Supply chain risk	Measure of risk	Flexibility strategy	Measure of flexibility	Underlying mechanism
Supply cost risk	Uncertain supplier costs	Multiple suppliers	The number of active suppliers	Shift orders quantities across suppliers
Supply commitment risk	Uncertain product demand over time	Flexible supply contracts	The percentage of allowable changes in order quantities	Shift order quantities across time
Process risk	Uncertain process capacities	Flexible manufacturing processes	The number of products that a plant is capable of producing	Shift production quantities across plants
Demand risk	Uncertain end-product demands	Postponement	The time at which a generic semi-finished product is customised into end products	Shift production quantities across different products

(2007) for details.) Although these four types of strategies are listed separately, firms can implement some of these strategies jointly. Since our focus is on the value of flexibility, we do not consider the cost for implementing flexibility in our models. Clearly, one can combine the cost and the benefit associated with different levels of flexibility to determine the optimal level of flexibility. However, the determination of the optimal level of flexibility is beyond the scope of this paper.

The power of flexibility: how much flexibility do you need?

Before we examine how much flexibility is needed to mitigate supply chain risks, let us introduce a general flexibility measure that can be used for each of the flexible strategies. Let f denote the level of flexibility for a particular flexible strategy such that a higher f refers to a more flexible supply chain. For example, in the multiple-supplier strategy, f would refer to the number of suppliers. Each of the four flexibility strategies has a minimum and maximum level of possible flexibility. The minimum level, denoted by $f_{\min}$, corresponds to a supply chain with no flexibility. For example, $f = 1$ when the firm sources from a single supplier in the multiple-supplier strategy. Similarly, $f_{\max}$ corresponds to a supply chain with the maximum level of flexibility theoretically possible.

Let $P(f)$ be a performance metric for a supply chain with flexibility level f. Depending on the context, the performance metric $P(f)$ might be measured in terms of cost or profit. For example, in the case of the multiple-suppler strategy that aims to mitigate the impact of uncertain supplier costs, $P(f)$ might be the expected per unit cost. We can measure the "relative value" of flexibility by using the following term:

$$V(f) = \frac{\dfrac{P(f) - P(f_{\min})}{P(f_{\min})}}{\dfrac{P(f_{\max}) - P(f_{\min})}{P(f_{\min})}} = \frac{P(f) - P(f_{\min})}{P(f_{\max}) - P(f_{\min})}$$

Notice that $V(f)$ measures the percentage of benefit obtained by a supply chain with flexibility level f as compared to one with the maximum possible level of flexibility. Specifically, $V(f_{\min}) = 0\%$ and $V(f_{\max}) = 100\%$. Given the performance metric $V(f)$ associated with a flexibility level f, we can evaluate the impact of flexibility associated with each of the four flexibility strategies. The measure $V(f)$ is increasing in f because a more flexible supply chain performs better than a less flexible supply chain. However, what is less clear is whether $V(f)$ is concave or convex in

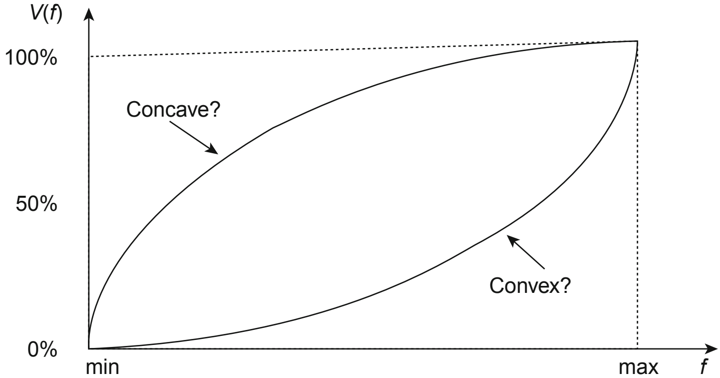

Figure 3.3.1 The relative value of flexibility

f (see Figure 3.3.1). If $V(f)$ is concave, then significant benefits associated with a flexibility strategy can be obtained with a low level of flexibility: that is, when f is small. On the other hand, if $V(f)$ is convex, then a firm needs to invest in a high level of flexibility in order to obtain significant benefit.

We now show that the flexibility measure $V(f)$ associated with each of the four flexibility strategies is indeed concave (see Tang and Tomlin (2007) for the technical details). Therefore, firms can obtain most of the benefits at low levels of flexibility. This is of great practical importance. The higher the degree of flexibility required the more costly the investment and, therefore, the more likely it is that a precise ROI analysis will be required to justify the investment. The fact that a relatively low degree of flexibility is often sufficient may enable managers to justify flexibility investments more readily, even if precise estimates of costs, impacts and likelihoods are not available.

The value of flexibility via multiple suppliers

Firms faced with uncertain supplier costs may choose to maintain an active set of suppliers so that, at any given time, it can place orders with those suppliers who currently offer the lowest cost. Consider the following stylised example in which a manufacturer has an unlimited number of pre-qualified suppliers with uncertain supply costs. Let the unit cost of supplier $j = 1, 2, \ldots, \infty$, denoted by Cj, be \$5, \$10 or \$15 with equal probability 1/3. To satisfy the demand in each period, we assume that the manufacturer always orders from the supplier who offers the lowest unit cost. In this case, the flexibility level f can be defined in terms of the number of active suppliers and the performance metric $P(f)$ can be defined as the expected unit cost associated with sourcing from f suppliers.

Suppose that the manufacturer is committed to sourcing from one exclusive supplier, that is, it chooses an inflexible sourcing strategy. Then the expected unit cost, denoted by $P(f_{\min}) = P(1)$, is given as: $P(1) = 1/3$ $(5 + 10 + 15) = \$10$. Next, consider the case in which the manufacturer can source from two suppliers, and so it has some flexibility. Because the manufacturer selects the supplier with a lower unit cost, the corresponding expected unit cost associated with sourcing from two potential suppliers, denoted by $P(2)$, can be expressed as $P(2) = E(\text{Min}\{C1, C2\})$, that is, the expected value of the minimum of the two supplier costs. By enumerating all possible scenarios, it can be shown that $P(2) =$ \$7.8. Similarly, one can show that $P(3) = \$6.6$, $P(4) = \$5.9$, $P(5) = \$5.6$, and so on. Finally, if the manufacturer sources from $f_{\max} = \infty$ suppliers, then $P(f\text{max}) = \$5$. In this case, it is easy to check that $V(2) = 44\%$, $V(3) =$ 68%, $V(4) = 82\%$, $V(5) = 88\%$, and that $V(f)$ is concave. (As shown in Tang and Tomlin (2007), $V(f)$ is concave regardless of the specific costs and probabilities used.) Notice that 44% of the benefit associated with an infinite number of suppliers can be achieved when a firm orders from just two suppliers. Therefore, limited flexibility is very effective at managing supply cost risk.

The value of flexibility via a flexible supply contract

In many supply chains, contracts with suppliers limit the ability of a manufacturer to alter a previously placed order. A contract might specify an upper bound on the percentage by which the manufacturer can revise, upwards or downwards, a previous order. In this case, the flexibility level f can be defined in terms of the percentage bound placed on quantity revisions. Consider the following stylised supply chain comprising a supplier, a manufacturer and a retailer. The supply cost is \$c per unit, the wholesale price is \$p per unit, and all unsold units have \$0 salvage value. We consider a 2-period model in which the retailer places his order only at the end of period 1. (Tsay and Lovejoy (1999) analysed this type of supply contracts previously. However, due to the multi-period nature of their model, an analytical characterisation of the value of flexibility is not feasible.) However, due to the supply lead time, the manufacturer needs to place an order with the supplier at the beginning of period 1, which occurs prior to the actual order to be placed by the retailer. At the beginning of period 1, the manufacturer estimates that the retailer will order a quantity $D = a + \varepsilon$ at the end of period 1, where ε corresponds to the uncertain market condition to be realised in period 1. Based on the information about c, p, and D, the manufacturer orders x units at the beginning of period 1. Under a flexible supply contract, the manufacturer is allowed to modify this order from x units to y units after receiving the actual order from the retailer at the end of period 1. Consider the case when the retailer orders $d = a + e$ at the end of period 1, where e is the realised value of ε. Under the f-flexible contract, the modified order y must satisfy: $x(1 - f) \leq y \leq x(1 + f)$, where $f \geq 0$ represents the allowable percentage adjustment as specified in the contract. Let $P(f)$ be the manufacturer's expected profit under the f-flexible contract based on the optimal initial order x^* and the optimal adjusted order y^*. When ε is uniformly distributed, Tang and Tomlin (2007) showed that the benefit associated with the f-flexible supply contract is increasing and concave in f. Therefore, significant benefits associated with the f-flexible contract can be obtained when f is relatively small, say 5%.

The value of flexibility via flexible manufacturing processes

Process risks, resulting from yield or quality issues for example, cause fluctuations in the effective capacity of plants. Firms that produce multiple products can mitigate this capacity variability by building plants that have the ability to produce more than one product. Consider the following stylised example in which a firm sells four different products (1, 2, 3 and 4), each with a demand of $D1 = D2 = D3 = D4 = 100$ units. The firm owns four different plants; the capacity of each plant $j = 1, 2, 3, 4$, denoted by Cj, is equal to 50, 100, or 150 units with equal probability 1/3. In this setting, there is no redundant capacity in the sense that the average total aggregate capacity of all four plants is 400 units, which is equal to the total aggregate demand of all four products. To illustrate the value of process flexibility, we focus on the following system configurations: a system is considered to possess "f-flexibility" when each plant has the capability of producing exactly f products and when the system is configured as illustrate in the Figure 3.3.2, which depicts the f-flexibility system for $f = 1, 2, 3, 4$. When $f = 1$, each plant j is capable of producing product j only, where $j = 1, 2, 3, 4$. Hence, 1-flexibility system corresponds to the system with no flexibility, and so $f_{\min} = 1$. The 4-flexibility system corresponds to a system with total flexibility, and so $f_{\max} = 4$. (To simplify our exposition, we restrict attention to this particular type

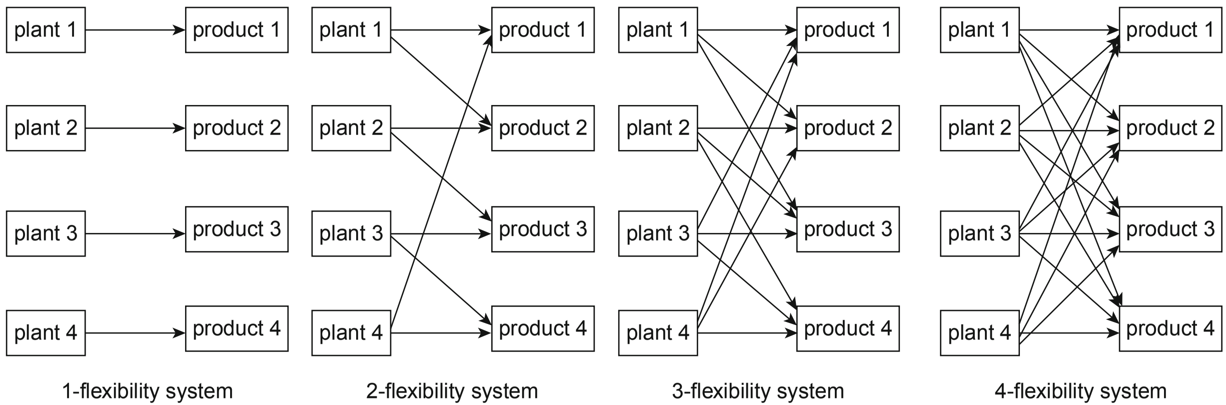

Figure 3.3.2 f-flexibility manufacturing systems

of system configurations. The reader is referred to Jordan and Graves (1995) for an in-depth analysis of a model in which different plants are capable of producing different number of products.)

Since each plant has three capacity scenarios, there are 81 possible plant-capacity scenarios for each of the *f*-flexibility manufacturing systems. By considering the probability of each of the 81 possible plant-capacity scenarios, Tang and Tomlin (2007) showed that the expected sales associated with the *f*-flexibility system, denoted by $P(f)$, is given as follows: $P(1) = 333.33$, $P(2) =367.9$, $P(3) = 367.9$, $P(4) = 367.9$. By noting that $V(2) = 100\%$, we can conclude that significant benefits associated with process flexibility can be obtained with limited flexibility, that is, the 2-flexibility system. (See Tang and Tomlin (2007) for a more general version of managing process risks with limited process flexibility.)

The value of flexibility via postponement

Postponement, or delayed differentiation, is an increasingly popular strategy for managing demand risk. By postponing the point of differentiation, a firm has increased flexibility in matching its production mix to the demand mix. It can, therefore, reduce the amount of inventory required to provide a high customer service. The following description is a simplified version of the postponement model presented in Lee and Whang (1998). A firm produces two end products by using a 2-stage production process. The firm adopts an "*f*-postponement" strategy when it takes *f* time periods to produce a generic semi-finished product at the first stage and $(T - f)$ time periods to customise these generic products into two different end products. Since the generic product is flexible, the production process is more flexible as f increases. We note that $f\text{min}= 0$ and $f\text{max}= T$. For any f-postponement strategy, define the performance metric $P(f)$ be optimal average inventory level of the two end products.

Let $Di(t)$ denote the demand for product *i* to be realised t periods in the future, where $i = 1, 2$. Let the demand follows a Random Walk (RW) model; that is, $Di(t) = \mu i + \varepsilon i1 + \varepsilon i2 + \ldots + \varepsilon i,t - 1 + \varepsilon it$, where $i = 1, 2$, $t = 1, \ldots, T$, and the εit are independently and identically (i.i.d.) normally distributed random variables with mean 0 and standard deviation σ. Lee and Whang (1998) proved that $V(f)$ is increasing and concave in *f*. Therefore, significant benefits associated with postponement can be obtained even if the point of differentiation is placed at an early stage of the production process, that is, when *f* is small.

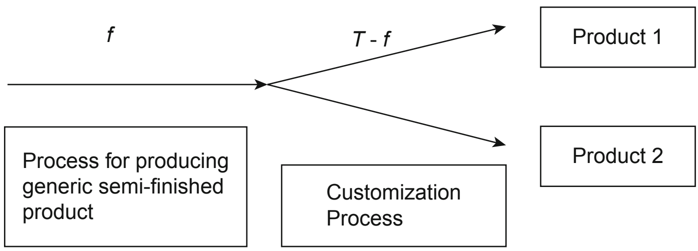

Figure 3.3.3 A manufacturing process associated with the *f*-postponement strategy

Conclusion

We have examined the benefits of different flexibility strategies in the context of supply chain risk management. By considering four different flexibility strategies and reviewing the stylised models presented in Tang and Tomlin (2007), we have shown that a firm does not need to invest in a high degree of flexibility to mitigate supply, process and demand risks; most of the benefits are obtained at low levels of flexibility. Even though we have focused our attention on "defensive" flexibility strategies, that is, strategies that mitigate the negative impact of undesirable events, it is important to realise that flexibility can also be used as an "offensive" mechanism that enables firms to compete more effectively in the marketplace. The reader is referred to Tang and Tomlin (2007) for details.

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3.4
Managing Risk in International Inbound Supply Chains

Claudia Colicchia, Fabrizio Dallari and Marco Melacini

Introduction

Supply chain risk has recently gained considerable attention. This is mainly due to the fact that the more complex the relationships among the nodes of the supply network, the more prone modern global supply chains are to disruptions. Although it is not a brand new problem, these days, due to higher competitiveness levels in the economic context and increased interconnections between businesses, companies are affected by a wider exposure to risk sources than before (Sheffi, 2005). Despite increasing awareness of this topic among both academics and practitioners, most of the existing research has addressed the sources of risk in the supply chain from a general perspective (Blackhurst et al., 2005) while few systematic approaches for their evaluation are actually available.

The objective of supply chain risk management is the protection of business from adverse events. A first approach to reach this aim is represented by the introduction of operational buffers along the supply chain (e.g., excess inventory or productive capacity, backup sourcing, multiple sourcing) (Chopra and Sodhi, 2004). Other two risk management approaches move towards the reduction of risk by addressing its probability (mitigation actions) and its direct impact (contingency plans) (Faisal et al., 2006); the former approach is based on the analysis of the processes with the aim of reducing the likelihood of occurrence (Zsidisin et al., 2004; Christopher and Lee, 2004; Sheffi, 2005), while the latter "provides alternative modes of operation for those activities or business processes which, if interrupted, might bring a damaging or loss to the supply chain"(Norrman and Jansson, 2004).

An effective risk management strategy should consider all the aforementioned approaches, taking into account the respective activation cost as well.

We focus on one of the main sources of vulnerability studied in the literature: supply lead time variability. Supply chain processes, and in particular transportation one, are often measured against time (Christopher and Rutherford, 2004). For this reason, supply lead time (SLT) and its variability are often recognised as the main vulnerability areas in inbound logistics, especially in a global sourcing context (Goetschalckx et al., 2002; Manuj and Mentzer, 2008; Wu, 2008).

Therefore, the aim of this research is to analyse how alternative strategies can be applied for managing risk in inbound supply chains, with reference to the global sourcing process. Furthermore, it provides supply chain managers with a framework that could be used to assess the efficiency of different risk reduction strategies.

Identification of strategies of managing supply chain risk

The present research refers to a supply process of a European company (manufacturer or retailer) with suppliers located in the Far East and shipping product by means of FCL (Full Container Load). We assumed EXW (Ex-Works) as Incoterm trade term, thus allowing the sourcing company to have full control of the process and the related supply risks (Dallari et al., 2006). We refer to a Hub & Spoke network as the base transportation case, usually resulting as the less expensive one to ship goods from supplier's plant to the European warehouse.

Such a complex process presents several areas of vulnerability (Svensson, 2000), each of them characterised by high or low level of impact and likelihood of occurrence. A set of contingency plans and mitigation actions validated with freight forwarders, are herein proposed.

Contingency plans provide alternative ways of transport to be utilised when the SLT might result longer than expected. Four contingency plans are proposed (sorted by increasing cost and decreasing lead time):

- C1. Use of multi-port calling, that is, shipping containerised goods from port of origin to port of destination without changing vessel in the transhipment hub.
- C2. Bypass the local feeder service in the Mediterranean Sea, by means of road haulage from the transhipment hub to the final destination.
- C3. Use of sea/air service, that is, a mix of sea and air freight, where the initial phase is represented by sea shipping. During the ocean shipping leg, the container can be unloaded at one of the scheduled ports of call in the Middle East (e.g., Dubai) where the goods are

transferred onto an aircraft flying to the airport nearest to the final destination.
- C4. Use of air freight, that is, shipping non-containerised goods by means of a direct flight leaving from the airport nearest to the supplier's plant.

Mitigation actions, as opposed to contingency plans, are risk management approaches that need to be put in place beforehand, without waiting for unpredicted events to happen. Their role is to reduce the likelihood of a negative event. The main mitigation actions are:

- M1. Pre-booking containers as soon as possible (in order to have scheduled departures).
- M2. Bonded warehouse, shifting the customs inspections from the port of destination directly to the European warehouse, with the supervision of custom authorities on site.
- M3. Agreements with shipping companies or freight forwarders on loading priorities at ports.

Based on these approaches and consistent with the literature review outcome, five strategies for risk management are identified:

- S1. Passive acceptance of risk, in which none of the approaches are applied
- S2. Setting up a buffer safety stock at the company warehouse
- S3. Adoption of contingency plans
- S4. Adoption of mitigation approaches
- S5. Adoption of both contingency plans and mitigation actions

These five strategies differ both in terms of effectiveness (on SLT mean value and variability) and efficiency. To evaluate the performance of the proposed strategies, different cost items are taken into account: transportation costs, inventory carrying costs (at the company warehouse and in-transit), stock-out costs. These cost are dependent on the duration and on the variability of SLT for each order.

The model: a simulation-based framework

The effectiveness and the efficiency of the proposed strategies are herein evaluated according to a framework composed by two steps:

- Defining the input parameters required to calculate the logistics cost (LC)
- Simulating the physical logistics flows for a significant time horizon and calculating the related LC

The main input parameters, common for all the five strategies, are:

- Demand characteristics: number of items, average item volume, product value density (ratio between item value and unit volume) and weekly demand (mean value and variability)
- Lead time components: duration of each activity in the FCL shipping process
- Supplier performance: average lead time of the supplier and its variability

According to the second step of the framework, the flow of goods between supplier's plant and company warehouse is simulated. For a given time horizon, the weekly demand according to Monte Carlo method is generated. Company warehouse operates with an (*R*, *S*) inventory control policy, where *R* indicates the review interval and *S* indicates the order-up-to level (Nahmias, 1997). *S* is updated at the beginning of each replenishment cycle to reflect the changes in demand patterns. The quantity ordered by the company warehouse depends on the demand of each item, on the inventory review interval, corresponding to the shipping frequency and on the order batch size (depending on container volume constraints). The inventory control parameters are regularly updated including demand forecast (moving average of the last 12 weeks).

Therefore, extending the target SLT leads to an increase in the forecasting horizon and to a reduction of forecast accuracy, thus increasing the occurrence of stock-outs. Out-of-stock could also occur when SLT results longer than expected. Unlike other approaches for assessing supply risk available in literature (e.g., Tomlin, 2006), our model considers lead time as a result of the simulation, depending on the adopted strategies for risk management, and not as an input parameter for the problem.

We propose to represent the supply process under consideration as a sequence of N single activities, each modelled by defining the best fitting time-frequency distribution. The proposed framework can be applied regardless of the time-frequency distributions, even though the type of distribution selected and its parameterisation affect its accuracy. It is important to underline that when mitigation actions are employed the sequence of activities in the supply process is the same of the base case, while some time-frequency distributions change. On the contrary, when contingency plans are put into action, the overall supply process varies.

As represented in Figure 3.4.1, there are few points in the process, called trigger points, in which contingency plans could be started, thus modifying the remaining process and its duration.

At each trigger point j, if the elapsed time up to that point ($LT1$) does not exceed a threshold value (TH), the supply process proceeds as planned. Otherwise the most suitable contingency plan is put into action.

Setting the threshold value TH_j at each trigger point j is critical. Therefore we define:

$$TH_j = SLT^* - LT2_j \tag{1}$$

where SLT^* = target value of the SLT; $LT2_j$ = the expected duration of the remaining base process, from the trigger point j onwards.

For a given trigger point j, $LT2$ ranges from a minimum to a maximum value following its time-frequency distribution. Given that the aim of the present study is to reduce the overall supply process variability by activating contingency plans only when strictly required and cost efficient, we introduce a degree of safety (DS) corresponding to the likelihood of the SLT being less than or equal to the SLT^* (i.e., the DSth percentile of $LT2$ that determines a TH value such that in DS per cent of cases a delay does not occur).

Therefore, following the proposed approach and for a given trigger point j, a contingency plan will be activated if:

$$LT1_j > SLT^* - LT2_j\,(DS) \tag{2}$$

where $LT2_j\,(DS)$ = the DSth percentile of time-frequency distribution of $LT2_j$ from the trigger point j onwards.

In a given trigger point j, it is possible to select a contingency plan k among a few alternatives ($C1$, $C2$, $C3$, $C4$), each with different impact on the SLT and implementation cost. Therefore, it is necessary to put into action the fastest and most expensive contingency plan only if the accumulated delay cannot be recovered by other less expensive alternatives.

Similarly to the approach of contingency plan activation, the choice between different plans depends on a degree of safety corresponding to the likelihood of the SLT resulting from the activation of a contingency plan being less than or equal to the SLT^*. Defining DC as the degree of safety for all contingency plans, we identify the alternatives that assure

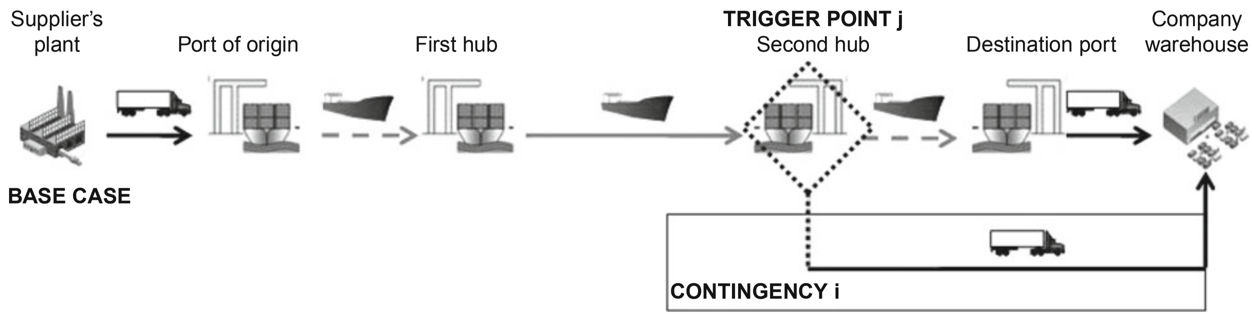

Figure 3.4.1 Exemplification of contingency plans in the supply process

a *DC* probability for the *SLT** of not being exceeded when the Equation (3) is satisfied:

$$LT2_{j,k}\ (DC) \leq SLT^{*} - LT1_{j} \tag{3}$$

where $LT2_{j,k}$ (DC) = the *DC*th percentile of time-frequency distribution of $LT2_{j,k}$ resulting from the activation of contingency plan *k* at trigger point *j*.

This simulation-based framework gives an estimate of the *SLT* for each replenishment order and could be applied in different scenarios.

On the basis of the assumed unit costs and of simulation results (in terms of shipped volumes, lead time, and average inventory and stock-out units), we derived the *LC* for each strategy.

Case study: main data and results

The analysis has been performed with respect to a case study, derived from a manufacturer of electrical appliances, operating in Western Europe, which has Chinese suppliers located in the Bejing area, whose identity has not been reported here for confidentially reasons. The analysis of the company's business environment allowed deriving the input parameters connected to the demand characteristics and to the logistics network model.

As considered by other authors (e.g., Tomlin, 2006), we focused on the supply process of a single component for a family of appliances. This component is critical for the target SLT (86 days) and for its technological characteristics as well, which make it difficult to find alternative sources of supply. The stock out of this component can interrupt the production of the finished product and could also have an impact in terms of lost sales of the finished product.

The weekly demand of components is represented by a normal distribution, with a mean value (*D*) equal to 1,000 units/week and demand variability described by the coefficient of variation, that is, the ratio between the standard deviation of the weekly demand and the relative mean value equal to 0.3. The unit volume is equal to 0.01 m^3 and the product value density equal to 3,000 €/m^3. According to other studies on global sourcing (e.g., Zeng and Rossetti, 2003), we have assumed fixed shipping frequency on a quarterly basis (*R* equal to 3 months).

As regards transportation, we considered a door-to-door cost of 50 €/m^3 in the base case, assuming a FCL shipping via 40′ container. For each contingency plan, we assume an increase in transportation cost, ranging from +20% (*C*1) to 1000% (*C*4). This evaluation was derived from interviews with global freight forwarders. Furthermore, we considered mitigation adoption cost equal to 200 € for each container and inventory holding cost (including cost of capital, space, insurance and depreciation) equal to 13% of inventory value on a yearly basis.

For all the five aforementioned strategies, the type of time-frequency distribution for each activity has been set. With respect to *S*1 and *S*2, Table 3.4.1 summarises the time-frequency distribution and the parameters used for each activity in which the overall supply process has been broken down. An average SLT equal to 24 days was considered and a supplier's reliability (i.e., the ratio between the variability and the mean value) equal to 0.3.

Table 3.4.1 Frequency distributions assumed in the simulation model for the base case

Activity	**Time-frequency distribution**	**Min**	**Max**	μ	**Md1**	**Md2**	σ
Manufacturing	Triangular	10	40	21.7	15	–	6.6
Road haulage to the loading port	Normal	0.2	1.5	0.7	0.7	–	0.3
Customs and handling operations at loading port	Bimodal	2	18	6.8	4	9.5	3.6
Feeder service to the first hub port	Triangular	5	15	9.3	8	–	2.1
Transhipment from feeder to mainline vessel	Bimodal	3	18	7.6	5	10.5	3.5
Main ocean route to the second hub port	Triangular	13	19	15.7	15	–	1.25
Transhipment from mainline to feeder vessel	Triangular	3	10	6	5	–	1.47
Feeder service to the port of destination	Triangular	2	5	3.3	3	–	0.62
Handling and custom clearance at port	Triangular	6	21	11.7	8	–	3.3
Road haulage to final destination	Normal	0.7	2	1.2	1.2	–	0.3

Note: *All values refers to durations in days

Legend:

Min	Minimum value	Md1	Mode value
Max	Maximum value	Md2	Second mode value, only for bimodal distributions
μ	Mean value	σ	Standard deviation value

For each strategy, replications were carried out using @RISK, the Monte Carlo simulation software for risk analysis, and processed by means of a spreadsheet, in order to obtain SLT value for each replenishment cycle. With these values, it was possible to simulate, with Matlab software, the process and the related inventory level for a significant time horizon (two years) and calculate the related logistics cost (LC) for the supply process. The resulting LC depends, in each simulation run, on the values of the items' weekly demand. In order to reduce the impact of random variations, the same random numbers have been used to simulate all the five strategies (thus generating the same weekly demand time series for all the configurations). In addition to this variance reduction technique, we performed 500 simulation runs to reach the stability of the system (Law and Kelton, 1991). Moreover, as far as *S*3 and *S*5 are concerned, the DC and DS values connected to the minimum expected LC value are used for the simulation. For *S*3, the minimum cost occurs, as shown in Figure 3.4.2, for DS equal to 0.5 and DC equal to 0.9 (i.e., using contingency plans only when significant delays occur and, in this case, recurring to the fastest alternatives). In *S*5, the optimal solution is both DS and DC equal to 0.9 (i.e., using as much as possible contingency plans in case of delays, recurring to the fastest alternatives).

The results of this case study, in terms of impact on SLT (Table 3.4.2) and expected annual logistics cost (Table 3.4.3), highlight:

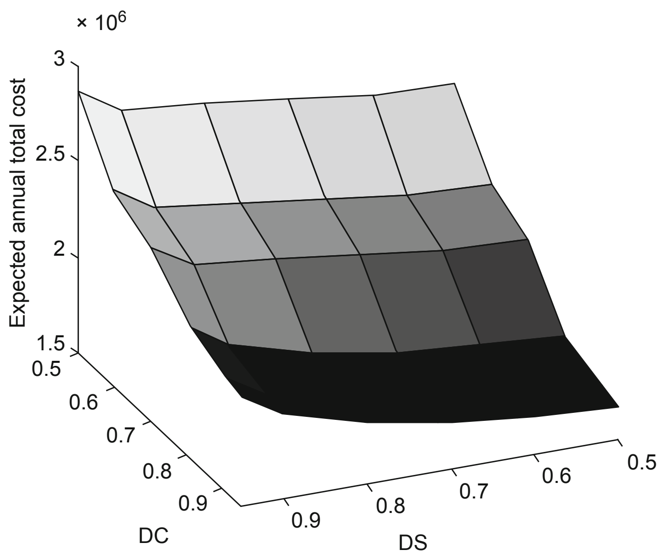

Figure 3.4.2 Impact of the DS and DC on the expected annual LC (Strategy 3)

Table 3.4.2 Impact of the proposed approaches on parameters of SLT

Strategy	**Min[a]**	**Max[a]**	μ^a	σ^a	**Percentage reduction μ**	**Percentage reduction σ**
Strategy 1 and 2	62	122	86	9.4	–	–
Strategy 3	52.1	101	71.6	7.8	17%	17%
Strategy 4	56	105	75.1	7.9	13%	16%
Strategy 5	56	87	71.7	5.3	17%	44%

Note: [a]All values refers to durations in days.

Table 3.4.3 Expected annual costs for each scenario (€*1000/year)

	S1	**S2**	**S3**	**S4**	**S5**
Transportation costs	22,22	22,22	27,95	23,82	25,74
Inventory holding costs	16,00	19,94	17,92	16,96	16,39
In-transit inventory costs	16,38	16,38	14,90	14,31	14,31
Out-of-stock cost	57,45	33,43	15,08	24,39	20,55
TOTAL	**112,05**	**91,97**	**75,85**	**79,21**	**76,71**

- The joint use of mitigation actions and contingency plans (Strategy 5) allows for a reduction in SLT variability of 44%.
- For the examined case study, improving the performance of SLT results in an improvement of the total logistics cost, making the strategy typically used (buffer safety stock) less convenient.
- The use of mitigation actions (Strategy 4), compared to Strategy 3, has a minor effect on stock-out cost.
- The efficiency of Strategies 3, 4 and 5 are similar in this case study.

Conclusions

This paper sought to address one of the areas of vulnerability that emerged reviewing the literature: supply lead time in a global sourcing context. A framework for supply chain risk management has been then developed. The goal of this was twofold: to evaluate the proposed approaches and to offer a model to support manufacturing or retail companies in the implementation of strategies intended to reduce their supply chain risk. The results on a case study confirm the effectiveness and efficiency of the proposed approaches to supply chain risk management on the one hand and highlight the relevance of their correct use by setting detailed rules and procedures on the other. Finally, the supply process improvement obtained in this case study, related to a reduction of the total expected logistics cost, does not necessarily entail an absolute efficiency of the proposed solutions, which we do not claim to be exhaustive. In fact, within some specific business contexts it might be more cost effective to assess and implement other risk reduction strategies.

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4
Supplier Management

4.1
A Computerised Vendor Rating System

Abby Ghobadian, Alan Stainer, J. Liu and Tibor Kiss

Introduction

The first element of a firm's "value added" chain is logistics. "Logistics management" is concerned with the supply, storage and movement of materials, personnel, equipment and finished goods within the organisation and between the organisation and its environment. Broadly, functions such as purchasing, materials management, distribution and maintenance fall within the logistics management area. An important element of "strategic logistic management" is "purchasing". This paper is primarily concerned with "purchasing", with a particular focus on "vendor rating".

A purchasing function can potentially influence both the efficiency and effectiveness of an organisation. In terms of efficiency, it has a direct effect on the company's profitability (through an increase of decrease in the purchase price) and the company's operations (lack of supply or quality problems bring the production process to a halt). In terms of effectiveness, purchasing can potentially play an active role in the design of new productions. There is no point in incorporating a given material in a new product if it is unavailable or available only at a high cost or risk (DTI, 1991). Moreover, the information provided by the purchasing is valuable in valuable in the formulation of corporate strategy or development of new products. In the highly competitive and global markets of the 1990s, the purchasing function should fulfil a strategic role and not solely assume an operational role (Kraljic, 1983).

In many industries, material and components cost constitute the major part of the products cost. Material costs could account for up to 70% of the cost of production. The recent public battle between GM and

VW for the services of Mr Lopez de Arriortua, head of GM's worldwide purchasing, is indicative of the importance attached to the purchasing function (Dickson et al., 1993). Lopez is widely credited with transforming GM Europe into one of the world's most profitable vehicle businesses. GM Europe enjoys one of the lowest cost bases of any European assembler. The improved efficiency of "purchasing" was a major contributory factor. Lopez's last task at GM was to substantially reduce its annual $50 billion expenditure on materials and components.

The above arguments indicate that the purchasing function is one of the key components of effective management. It has a significant impact on the following three aspects of business:

(a) **Finance** – Purchasing accounts for a significant part of a manufacturing organisation's total expenditure (DTI, 1991);
(b) **Operations** – Lack of performance on the part of purchasing could bring the production process to a halt (Houson and Dale, 1991); and
(c) **Competitiveness** – Purchasing potentially is a source of competitive advantage within a particular market (Sutton, 1989).

In this paper, the authors examine the components of the "purchasing" function, "vendor rating" process and "vendor rating" techniques. More importantly, the development of a program designed to facilitate "supplier evaluation" and "vendor rating" is discussed.

Purchasing function and sourcing

Purchasing may be defined as the "process by which organisations define their needs for goods and services, identify and compare the supplies available to them, negotiate with source of supply or in some other way arrive at agreed terms of trading, make contracts and place orders, and finally, receive the goods and services and pay for them" (Bailey, 1980).

The purchasing function is involved in the following three critical activities (Burt, 1989):

(a) Determination of what material or service is required including its quality, quantity and timeliness;
(b) Selection of a source capable of providing the right quality of goods or services at the right price and at the right time; and
(c) Contract management which comprises mutual understanding of buyer and supplier, motivation of supplier, monitoring of quality, requesting value analysis and assisting suppliers.

In broad terms, "sourcing" encompasses many of the issues identified under points (b) and (c) above. Formally, sourcing comprises the following activities (Bailey and Farmer, 1981):

(a) Identification and/or development of suitable sources of supply;
(b) Systematic investigation, evaluation and comparison of sources of supply;
(c) Sourcing decisions, that is to say, which supplier to buy from, number of suppliers for a given item, how to distribute the available business and on what terms to do business; and
(d) The relationship with preferred sources which are actually supplying goods and/or services and with potential sources which could be used in the future.

"Sourcing" is arguably one of the most important components of "purchasing and logistic management". This is because sourcing carries significant risks as well as potential benefits. Manufacturing companies spent as much as 60% of their sales revenue on purchased supplies (Burt, 1989). It is no exaggeration to state that purchased supplies are the source of half of the quality problems that a company suffers. Thus, the consequences of choosing a low performing supplier can be catastrophic. For example, production downtimes, customer defections and even bankruptcy may stem from a wrong sourcing policy.

Suppliers potentially are a valuable resource (Helper, 1991). Thus, the source selection must become not only a question of reducing risks but also a search for strengths. This point was grasped by the Japanese manufacturers some time ago. For example, the Japanese automakers have shown that a skilled and loyal supplier base can be a key source of competitive advantage. It is estimated that Japanese manufacturers' superior vendor relations resulted in a \$300 to \$600 reduction in manufacturing costs per car in the early 1980s.

Effective sourcing requires a set of procedures or operating policies on which the choice of vendor or the continuation of purchase from a vendor is based. The basic decision are three-fold. These are:

(a) **System Design**. This is concerned with the strategic decision of single or multiple sources of supply. Each of these have advantages and disadvantages. The management needs to balance the advantages and disadvantages of each policy for various groups of purchased items.

(b) **System Planning.** The evaluation of the capability of the potential supplier to supply the right goods, at the acceptable quality level, and at the right time constitutes the planning step. A systematic evaluation will enable the organisation to decide whether to purchase from the particular supplier or to include the vendor on an approved supplier list. These are often referred to as "vendor grading" or "supplier qualification".
(c) **System Control.** It is necessary to evaluate the past performance of the supplier. Such an evaluation will enable the organisation to systematically decide whether to re-purchase from a particular vendor. Moreover, monitoring the supplier performance will enable the organisation to draw up cooperation plans with the vendor. This process is referred to as "vendor rating".

The location of the purchasing function in an organisation depends on factors such as: organisational culture, nature of business, corporation's complexity, volume and value of purchased items, and importance of purchased materials and parts in terms of its likely impact on performance. The trend in both the USA and UK has been towards establishment of an independent purchasing function (National Association of Purchasing Management – USA, 1979; Farrington and Woodmansey, 1980). To summarise, purchasing is concerned with the procurement of materials and all the activities that procurement involves. Purchasing is now recognised as an area of business capable of improving both effectiveness and efficiency of most manufacturing organisations.

Vendor rating

"Vendor rating" is defined as "a systematic and periodic evaluation of vendor performance based on a certain range of supplier attributes. The system enables the purchasing function to move away from the "guts feeling of buyers" and towards a methodical approach free of personal emotions. Vendor rating is a control measure designed to evaluate the past performance of the supplier. The major difference between vendor evaluation and vendor rating is that the latter is concerned with determining the ability of the potential supplier to meet the organisation's requirements, while the former is concerned with the performance of existing suppliers.

The vendor rating is central to effective purchasing management. It indicates how well suppliers conform to the organisation's requirements

(Stevens, 1978). The vendor rating information is useful for several different reasons:

(a) trends can be systematically pinpointed;
(b) it aids the repurchasing decisions;
(c) it provides information valuable in supplier negotiations;
(d) it contributes to the establishment of cooperation plan with the suppliers;
(e) it provides the means to identify and warn sub-standard performers; and
(f) it helps the identification of outstanding performers.

BS 5750 requires the organisation to operate a formal system to assess the performance of the suppliers (Part 4 – Section 4.6.2). The major advantages of systematic vendor rating are discussed highlighted below (Stevens, 1978; Caplen, 1988; DTI, 1991).

(a) The suppliers' performance is measured against a common criteria. This enables the organisation to methodically compare the performance of various suppliers.
(b) It enables the purchaser to negotiate with suppliers using factual information rather than relying on opinions.
(c) High performing suppliers can be identified and rewarded. Marginal suppliers can be identified and warned, while poor suppliers can be identified and eliminated.
(d) It provides the basis for the establishment of closer link between the purchaser and supplier in additional it provides an opportunity to identify quality and service improvement opportunities.

The major disadvantages of the vendor rating are discussed below (Stevens, 1978; Barnett, 1985).

(a) It may be possible to include all the pertinent variables. Missing variables not may be equally important and skew the results.
(b) It may not be possible to include all of the suppliers, particularly in the case of the organisations with a large supplier base.
(c) The "output" is only as good as the "input" data.
(d) There is an element of subjectivity in any "vendor rating" system. In the case of weighted techniques, care must be taken to ensure that assigned weights reflect their true utility.

(e) The cost of operating a vendor rating system may outweigh its benefits.

Vendor rating techniques

There are a number of different approaches to vendor rating. These can be divided into two broad categories: (a) qualitative or subjective techniques and (b) quantitative or objective techniques. The most frequently used techniques in each category are briefly described in the following sections.

Qualitative techniques

Categorical plan is arguable the most commonly used qualitative technique. It is a subjective approach to vendor rating. Salient attributes are identified and typically rated on a four point scale very good (A) to very bad (D). The factors and grades are chosen either by an individual, group of buyers or, more typically, a cross functional team. The main disadvantages of this method are: (a) its high degree of subjectivity and (b) its lack of uniformity. The main advantages of this technique are: (a) its simplicity and (b) its low operational costs. For these reasons, the technique may appeal more to small organisations.

Quantitative techniques

There are two main quantitative techniques: (a) weighted point plans and (b) cost ratio plans. These are described in the following sections.

Weighted point plans

Weighted point technique can be used to either rate suppliers' overall performance or its performance for an individual product. Product performance rating (PPR) is given by the following formula:

$$PPR = WiFi_{n}^{i=1} \quad i = 1,\ldots,n$$

where *Fi* is the value of *i*th factor; *Wi* is the weight assigned to *i*th factor.

The supplier performance rating (SPR) index can be calculated by the following formula:

$$SPR = \sum Wxd\ (PPR)_{xj}^{j=1} \quad j = 1,2,3\ldots,n$$

Wxd is the weight assigned to class *d* material for producer *x;* (PPR)*xj* is the product performance rating for the *j*th term for the producer *x*.

Factors used fall under four broad categories: (a) purchased part quality and its impact on the process, (b) supply performance and its impact on the process, (c) price, (d) service.

Typical factors considered under the "quality and its impact on process" heading are identified below.

(a) $$\text{Degree of Quality Conformance} = \frac{\text{Units of Batches Accepted}}{\text{Units of Batches Received}} \times 100$$

(b) $$\text{Minor Non - Conformance} = \frac{\begin{array}{c}\text{(Total No of Items or Batches} \\ \text{Received – Items or Batches} \\ \text{With Minor Quality Problems)}\end{array}}{\begin{array}{c}\text{Total Number of Items or} \\ \text{Batches Received}\end{array}} \times 100$$

(c) $$\text{Wrong Items Dispatched} = \frac{\begin{array}{c}\text{(Total No Of Dispatches –} \\ \text{Quantity of Wrong Dispatches)}\end{array}}{\text{(Total No Of Dispatches)}} \times 100$$

(d) $$\text{Capacity Reduction} = \frac{\begin{array}{c}\text{(Total Time Available – Down Time} \\ \text{Due to Defective Material)}\end{array}}{\text{(Total Time Available)}} \times 100$$

(e) $$\text{Production Rate Reduction} = 100 - \frac{\begin{array}{c}\text{(Actual Production} \\ \text{Rate – Planned} \\ \text{Production Rate)}\end{array}}{\begin{array}{c}\text{(Actual Production} \\ \text{Rate)}\end{array}} \times 100$$

Factors usually considered under the "supply performance and its impact on process" are identified below.

(a) $$\text{Delivery Performance} = \frac{\text{No of On Time Deliveries}}{\text{Total No of Deliveries}} \times 100$$

(b) $$\text{Extent of Lateness} = 100 - \frac{\begin{array}{c}\text{(Actual Delivery Date –} \\ \text{Promised Delivery Date)}\end{array}}{\text{Actual Delivery Date}} \times 100$$

(c) $$\text{Extent of Early Deliveries} = 110 - \frac{\begin{array}{c}\text{(Promised Delivery Date} \\ \text{– Actual Delivery Date)}\end{array}}{\text{Promised Delivery Date}} \times 100$$

(d) Production Delays Resulting from Late Deliveries
(e) Stock Room Problems Resulting From Early Deliveries

(f) Extent of Order Shortages $= \dfrac{\text{Quantity of Items or Batches Delivered}}{\text{Quality of Items or Batches Ordered}} \times 100$

(g) Impact of Shortages or Incomplete Orders on production

Typical items considered under the "price" heading are identified below.

$$\text{Annualised Price Increase} = \frac{(\text{Current Price} - \text{Previous Price})}{\text{Previous Price}} \times 100$$

$$\text{Price Ratio} = \frac{\text{Lowest Net Unit Price from any Vendor}}{\text{Net Unit Price from the Vendor Under Consideration}} \times 100$$

Service Typically consists of the following factors.

(a) Flexibility – Ability to alter delivery dates and volumes, accept short noticed orders, etc.
(b) Willingness to Cooperate/Technical Contribution – The degree of involvement acceptable; willingness to collaborate on technical matters; etc.
(c) Accuracy of Documentations and Billing
(d) Accuracy of Labelling
(e) Notification of Problems/Communication

Cost ratio plans

"Cost ratio" is another way of objectively rating vendors. This model relies on evaluating the "real cost" of purchase by taking into account: quality; delivery performance; impact on the process; and unit price into account. Cost ratios are normally calculated for suppliers rather than individual products.

The technique consists of five steps. These are described briefly in the following sections.

Step 1 – Compute the supplier's net price for an item. Net price is the sum of quoted unit, price, transport, insurance and other costs less discounts.

Step 2 – Compute the total costs incurred due to quality non-conformance and express these as a percentage of total cost of purchases for the item under consideration.

Step 3 – Compute and express the costs incurred in expediting the item's delivery and other service costs as the percentage of item's total purchase cost.

Step 4 – Compute the net purchase price by multiplying the supplier's net unit price by the percentage cost increases computed in Steps 2 and 3.

Step 5 – Compare the net cost of the item for different suppliers.

The main advantage of this technique is the fact that supplier performance is calculated in monetary units. This is useful in negotiations with the vendors. The procedure is difficulty and time consuming to operate. It normally should be used in cases where the importance of the decision outweighs the costs.

Vendor rating program

Vendor rating is very time consuming and difficult to undertake in organisations with large number of suppliers. The clerical effort required means that vendor rating is only practicable with the aid of a computer. A flexible vendor rating program has been developed. The program gives the analyst the opportunity of tailor making the vendor rating process to the needs of the organisation. The analyst can choose one or both of the techniques described previously. In addition, there is a menu of factors, and the analyst can choose the appropriate factors and assign weights to the factors. Moreover, the program will allow the analyst to include factors outside those provided by the standard menu. As well as vendor rating, the program can be used in the vendor evaluation process. It provides standard questions for this purpose.

The program consists of three data files. These are vendor data, materials data and firm data. The program performs Prato analysis, costs analysis, vendor rating analysis and vendor evaluation. The results can be presented graphically. The program was developed "using object vision".

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4.2
Toyota Supplier System in Japan and the UK

Peter Hines

Introduction

This research program involved the benchmarking, verification visit, semi-structured interview and modelling of a group of 8 first tier and 13 second tier Toyota suppliers in Japan together with a similar grouping in the UK. The benchmarking questionnaires were sent to the participating companies approximately one month before a visit was made. The firms were requested to return the completed questionnaires before the visit date. This was the case in all but one company. Each questionnaire was then individually interrogated to ensure that errors had not occurred during completion. This was primarily achieved by entry onto a comprehensive spreadsheet with predetermined check questions and calculations. This is believed to have identified over 90% of any suspect or missing data at this pre-visit stage.

Subsequent to this analysis, a visit was made to each company site for the purposes of verification and qualitative semi-structured interview. During these half-day visits, remaining missing or suspect data was checked and verified. The verification also included discussion of each data set and a tour of the factory shop floor. In addition, a semi-structured interview (1.5 to 2.5 hours in length) was undertaken to ascertain how the results demonstrated on the questionnaire were achieved. In particular, time was spend understanding to what degree the Toyota Production System (TPS) was employed, when it had been employed, how it had been learned and how it had been disseminated to suppliers. Due to the range and detail of the techniques employed, it is believed that the resulting evidence and data displays a high degree of rigour and integrity.

To supplement the above approach, structured interviews were carried out with relevant trade associations, academics and researchers in Japan and the UK. This methodology was chosen to give adequate research triangulation between the approaches used to provide as far as possible a realistic appraisal of the existing situation.

Research limitations

In spite of the care taken with the survey, the research does suffer from two important limitations. These should be borne in mind by the reader, in particular in drawing conclusions from the work. The first of these is that the first tier firms in the UK and Japan can only be considered to be broadly similar. Although a strictly comparable paired research method (as employed by Andersen Consulting, 1992, 1994) was not employed due to research access and the differing research purposes involved, it is not believed that this greatly compromises the results. The reason being that although individual differences were present between firms, when these are aggregated, the range and depths of product and process complexities were broadly similar in the two first tier sets of data. However, some margin for error should be allowed for in interpretation.

The second major limitation of this work is that the selection criteria for suppliers may suggest a slight skew in favour of selecting a "better" group of Japanese suppliers than British suppliers among their respective peers. The reason for this is that the British first tier firms are the seven Toyota suppliers in Wales (a region in the UK) whereas the Japanese first tier sample are the board members of the Tokai Kyoho Kai. As a result, it may be anticipated that these latter firms are at least of average ability and expertise whereas the British set are perhaps only average within Toyota's supplier base in the UK. However, anecdotal evidence provided by another UK-based assembler has suggested that the seven UK suppliers are above average within their own supplier benchmarking scheme.

As a result of these two limitations, strict use of the data is not to be recommended although general conclusions may still be made.

Main findings

The main results of the research conclude that the Japanese first tier appeared to perform best in virtually every measure employed whether it was concerned with process results, internal excellence measurement or supply chain integration. With the exception of the new product development process, the Japanese second tier firms showed themselves to be broadly superior to the UK first tier and second tier. This will be demonstrated in the following section using various value stream mapping tools (Hines and Rich, 1997) before a discussion of the underlying factors is undertaken.

Supply chain responsiveness

As can be seen from Figure 4.2.1, the responsiveness of the Japanese supply chain far exceeds the UK case. The figure plots the cumulative inventory and lead time in both countries from the point of delivery of raw materials to second tier firms to the point of delivery to the assembler. In the Japanese case, this process takes five working days using a pull kanban system rather than the more traditional Western push

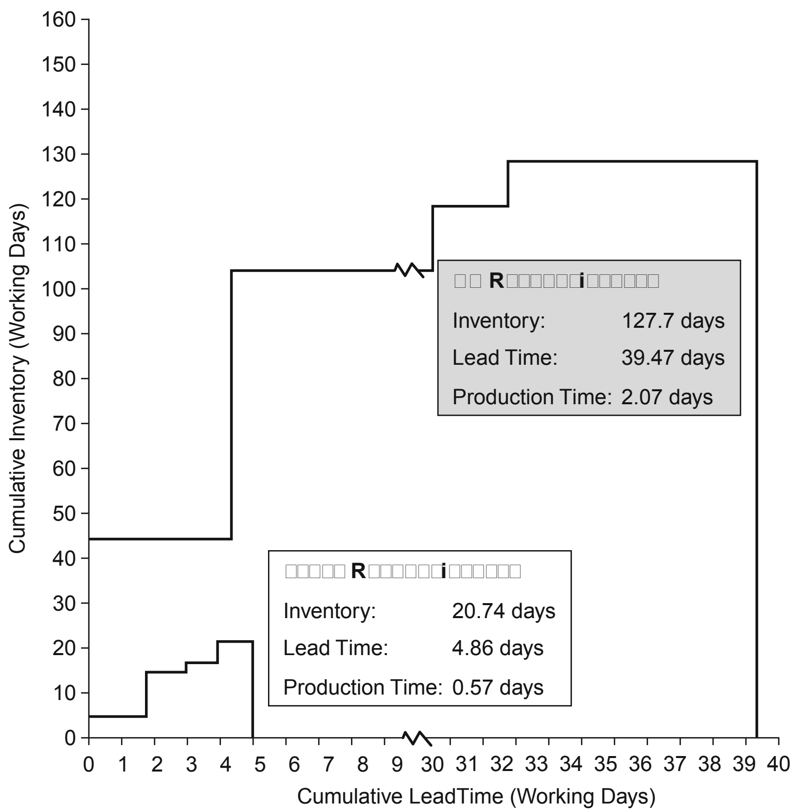


Figure 4.2.1 Supply chain responsiveness: UK and Japanese automotive industry

system involving 40 working days of lead time. In a similar way, the total inventory required in Japan for this portion of the supply chain (21 working days) is far lower than in the UK (127 working days).

Process abilities

As it is believed that key process deliverables are more important to customers than departmental excellence (Dimancescu et al., 1997), data was collected for both geographical areas focusing on key process deliverables. This was added to earlier data (Womack et al., 1990) to provide information at assembler, first, second and even third tier levels. Table 4.2.1 demonstrates that the gaps in quality, productivity (cost) and delivery performance are considerable at every tier. However, it is interesting to note that the quality and delivery performance gaps peak at the first tier while the productivity gap is widest at the second tier.

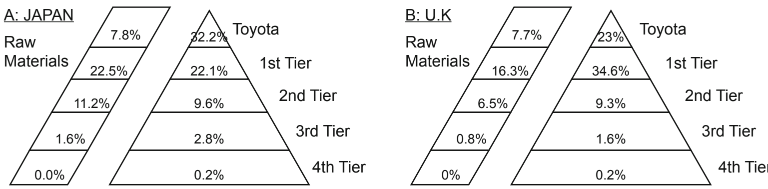
Value added in the supply chain

It is informative to compare the value adding profiles of the two country's automotive industries. Figure 4.2.2 segregates the raw material component of the final product outside the pyramid structure. This has been done because the principles, dynamics and style of relationships operating in the raw material value stream are very different from those operating within the parts and components value stream. Figure 4.2.2 demonstrates that there are a number of key similarities and differences between the two data sets. The first similarity is that the value added by assemblers between the two regions is very similar

Table 4.2.1 Comparative process control abilities in the Japanese and UK automotive industries

	Assembler*1	1st Tier	2nd Tier	3rd Tier
Quality				
Customer delivery defect rate	2.00	244.50	12.01	2.57
Productivity				
Value added per qualified employee*2	1.82	2.84	4.35	N/A
Delivery				
– Inventory level	10.00	14.34	4.33	N/A
– Late delivery	N/A	283.82	13.20	1.71

Note:
*1Based on data from Womack, Jones and Roos (1990) Japanese vs Western assemblers.
*2Qualified employee includes direct shop floor operators and supervisors/team leaders who spend the majority of their time as direct labour.



Value Adding by Category:

	Japan	UK
Raw Materials	43.1%	31.3%
Suppliers (Parts)	34.7%	45.7%
Assembler	22.2%	23.0%
	100.0%	100.0%

Figure 4.2.2 Value adding in the Toyota supplier system in Japan and UK supplier system

due to the emulation by UK-based firms of earlier Japanese preferences for outsourcing.

In contrast, the value (or more correctly cost added) added by parts suppliers is considerably higher in the UK (45.7% compared with 34.7% in Japan) with the value added by raw material firms (31.3% compared with 43.1%) considerably higher in Japan. The reasons for this will be discussed below.

Demand amplification

The last key area for discussion is the demand amplification within the different supply chains as shown in Figure 4.2.3. The variability is based on the difference between forecast orders one month before delivery and the actual quantity required. As can be seen, although variability does increase from the assembler back down the supply chain in Japan, the change is only from 2.2% up to 4.2% from the assembler's purchases, through the different decision points, to the second tier firm's purchases reflecting the near exact pull of product from even third tier firms.

In contrast in the UK variability from assemblers starts at 12.2%, which is dampened by the first tier by high inventory levels but greatly amplified at second and third tier levels. When a cost is apportioned to this variability, based on the cube of the variability (Stalk and Hout, 1990), then the cost of demand amplification can be seen to be disproportionately higher in the UK case than the negligible cost to the Toyota supply chain in Japan (Figure 4.2.3). The poor and declining productivity levels

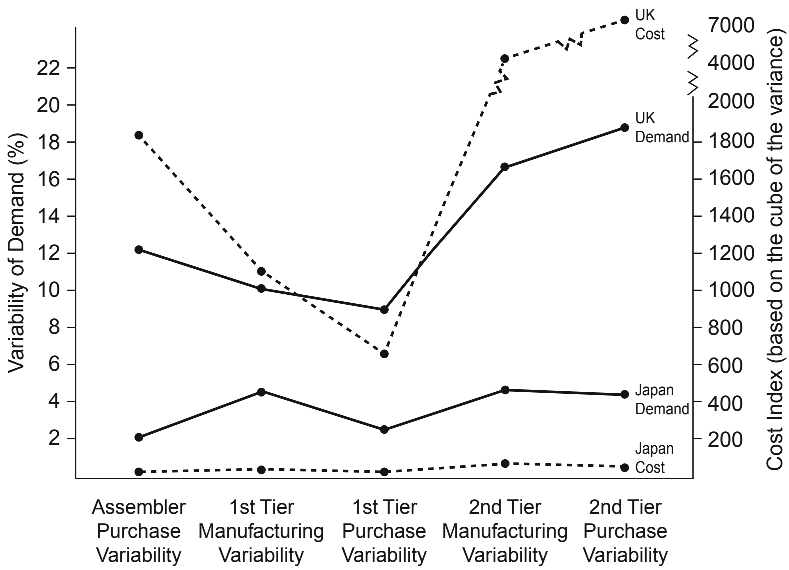


Figure 4.2.3 Demand amplification in UK and Japanese automotive industries

in the UK with lower component tiers discussed above can now be partly understood.

Discussion

Although a full discussion of the data requires more space than this paper allows, a few key points can be made. The first concerns the weighted productivity gap in the total supply chain between Japan and the UK. This is shown in Table 4.2.2 and is found by finding the total productivity gap weighted by the value added at each tier. As can be seen from these crude calculations, the Japanese supply chain, in totality, shows approximately a doubled productivity level to the UK case. This gap is verified when attention is directed to the very low relative prices of new Toyota cars in Japan relative to other general products.

A second point to note is that the very high productivity levels in the Japanese assembler and component firms (tiers 1–4) are not matched by similar gaps in the Japanese raw material firms. It is suggested here that this is because these firms have followed a Total Quality Control (TQC) approach that has succeeded in yielding high levels of quality. However, such firms have not emulated the Toyota Production System

Table 4.2.2 Competitive advantage in Toyota, Japan vs the UK automotive industry

	Japan value added	**Competitive gap**	**UK value added**	**Indexed competitive gap apportionment**
Assembler	22.2	1.82*1	40.4	18.0%
1st Tier	22.1	2.84	62.8	40.2%
2nd Tier	9.6	4.35	41.8	31.8%
3rd Tier	2.8	4.35*2	12.2	9.3%
4th Tier	0.2	4.35	0.9	0.7%
Raw Materials	43.1	1.00*3	43.1	0.0%
Total	100%	2.01%*4	201.2%	100%

Note:
*1Womack, Jones and Roos (1990).
*2Assumed same as 2nd Tier.
*3Based on various industry expert' viewpoints.
*4Weighted Competitive Gap.

and largely failed to integrate their key processes with those of Toyota or their other component making customers through activities within customers' *kyoryoku kai,* for example. It is contended here that such activity would have helped to remove inter- or intra-company waste as happened in the rest of the Toyota supply chain. The challenge then in Toyota's Japanese supply chain is to do this. The challenge in the UK is to make dramatic improvements in productivity, quality and delivery performance at the assembler and each component level in order to close the gaps with Japan. In addition, if the raw materials makers can be integrated into the supplier network in the UK then there may be a source of potential competitive advantage in that country even over Toyota's approach in Japan.

A third major point for discussion is the actual mechanisms used within the Japanese Toyota supply chain that clearly differentiate it from its UK counterpart. Based on personal observation and detail discussion with the firms involved it would appear four key elements have been brought together in Japan that are absent or at least only partially realised in the UK (Rich and Hines, 1997). These are the use of:

1. Policy Deployment (*hoshin kanri*) for internal strategic focusing and alignment
2. Cross Functional Management (e.g., quality, cost and delivery) in order to actualise the policies developed

3. Toyota Production System (TPS) to yield a standard management approach in the supply chain
4. Supplier integration particularly focusing around the use of the *kyoryoku kai* or supplier association which integrates each tier with the one above and below and allows for an external version of policy deployment, cross functional management and inter-company learning and development to be enacted (Hines, 1994).

Role of the first tier firms

It would also appear that the first tier firms play a key role in Toyota's Japanese supply chain. There are six areas in which these firms act as the pivotal part of the system. These areas are:

1. Role as a quality buffer

If a longitudinal cross section of the supplier system is taken (Figure 4.2.4), it can be clearly seen that not only are the first tier firms most adept at controlling their own defects but significantly act as a buffer for their customers by controlling the quality of their suppliers. They thus act as a quality filter. This is particularly the case in Japan as can be seen in Figure 4.2.4. This means that Toyota can produce excellent quality products even though its second, third and lower tier suppliers are not always so excellent in their quality performance.

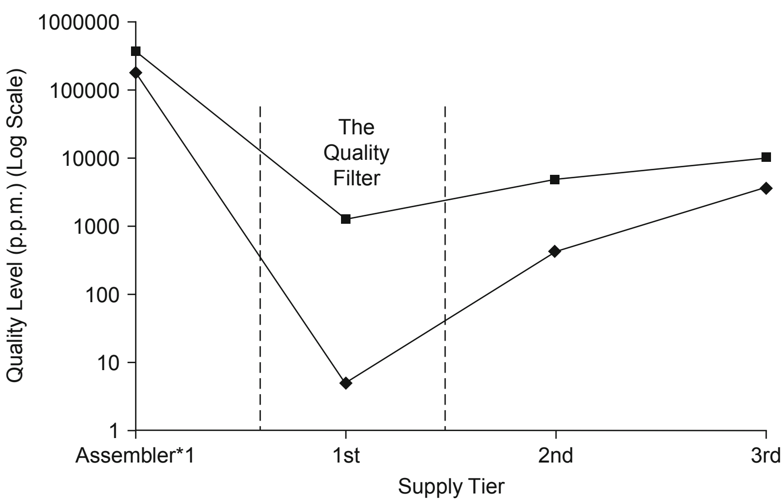


Figure 4.2.4 The quality filter concept

2. Role in gaining (productivity) competitive advantage

As can be seen from Table 4.2.2, the competitive gaps that exist in productivity give Toyota in Japan a keen advantage in all areas except their raw material supply. However, the advantage is not uniform in the supplier network and is greater at first tier than at assembler level (and may be even greater than the figures suggest due to Western assemblers closing the gap on Toyota in recent years). When these gaps are indexed according to the value adding at each level, it becomes clear that the advantage that Toyota gains in Japan is largely a result of their own productivity (18%), that of the first tier (40%) and that of the second tier (32%). However, the largest advantage lies at the first tier level.

3. Role as system developer

Due to the focusing that the first tier firms employ in the coordination and development of their suppliers in Japan, Toyota gains significant advantage from their second tier suppliers, many of whom they do not even know the names of. Thus, in addition to the advantage that the first tier firms exhibit themselves, they are also instrumental in unlocking another 32% directly from their suppliers (and indirectly another 10% from third and fourth tier firms). Thus, the first tier firms have, through their own and Toyota's work, developed a system which means that Toyota can lever their internal competitive advantage (largely gained by the prolonged and rigorous use of TPS) by at least a factor of five within their supplier network with the first tier acting as the key architects of this advantage through the use of methods such as the various *kyoryoku kai*.

4. Role as purchaser

The first tier suppliers are also the focal point of raw material purchasing as they, with the exception of the direct purchases by Toyota, directly buy not only their own raw material requirements but also the majority of raw materials on behalf of their (direct and indirect) suppliers. Such materials are supplied to the second and lower tier firms on a just in time basis but are in general supported by a stockholding in subsidiary companies of the first tier component manufacturers. Although no verifiable data was collected as to the performance of these firms, anecdotal evidence suggests that these stockholders achieve stock turns of around 12 per year, putting them in line with the best performers in the sector in the UK.

It would not be true to say that all raw material purchases made by second tier firms are made in this way. However, even when first tier firms are not actually buying on behalf of their suppliers, they tend to exert a large or even total influence over which raw material suppliers are used by their suppliers and indeed even the prices to be paid.

5. Role as designer

The majority of the detailed design work for components is not done by Toyota themselves but by their first tier suppliers. When comparing the design engineering hours for components made by parts suppliers in Japan and the UK, a low time input is given by Toyota in Japan (7% compared with 26% in the UK), a higher proportion at the first tier (88% compared with 69%) and a broadly similar figure at the second tier (5% compared with 4%). The first tier firms are thus key in both new product development as well as offline research and development. In this respect, Toyota has moved to being a concept designer and detailed design facilitators, keeping only a small percentage of detailed design to themselves.

6. Role as problem identifiers and solvers

The effective use of engineering and quality staff in supplier development by the Japanese first tier firms helps them to solve their own suppliers' problems in a very effective manner. However, it is important to note that not only is their very rapid usage of stock useful in itself for rapid cash turnover, but it critically helps identify the most important problems to be solved either in the first tier themselves or with their own supplier networks. Thus, the first tier acts as a facilitator of focused change not only for themselves but also for their direct and indirect supplier.

The role of the micro firm

Within the Toyota supplier network in Japan, there is only a small reliance on the micro firms that authors such as Piore and Sabel (1984, inter alia) have suggested as being a major area of competitive advantage in such supplier networks. However, the key to Toyota's success cannot lie within Piore and Sabel's economies of scope if such micro firms at the third and fourth tiers are only responsible for only 3% of the value adding processes, although due to their high productivity this does yield a 10% total productivity advantage in the complete Toyota supplier network.

Overseas application of the Toyota supplier system

In Japan, it would appear that Toyota perhaps should seek ways of addressing how TPS can be spread to, and competitive advantage gained from, the raw material industry and indeed even looking overseas for sources of steel and plastic. In addition, even greater attention could be focused at how they could assist the first tier firms to gain more competitive advantage from the second and lower tier firms. Although the Japanese second tier is in most cases superior to the UK first tier, there are still large gaps between the two tiers in Japan. This would, therefore, appear to be a significant area for attention. As evidenced by a recent Toyota annual report, appropriate actions in this area are already under way (Toyota Motor Corporation, 1994).

The implications for Toyota in the UK revolve around how they can survive without the source of over 80% of their competitive advantage. The answer to this is problematic but must surely lie in intensive supplier coordination and development of the first tier and major efforts to encourage these firms to spread this message on down the hierarchy. Recent evidence from the UK and the US suggests that this is precisely what they are doing with the application of the *kyoryoku kai* or supplier association approach (Hines, 1994).

Conclusion

The question raised, therefore, is why is the Japanese system superior? Evidence is presented in the paper to show that the key to this success lies to a large degree in the hands of the first tier firms who facilitate the supplier network excellence in terms of quality, productivity, design, delivery, purchasing and supplier development.

However, to regard the system as a direct result of the first tier would be to ignore the fundamental role in Japan of Toyota themselves. Indeed, it would appear that what has brought about the present situation is Toyota's ability in developing TPS and in integrating the policies and practices of their suppliers with their own. This would appear to have been done by the extension of internal policy deployment through their *Kyoho Kai* (or supplier association) into the supplier network and the active coordination and development of suppliers within the general remit of TPS.

It would be easy to conclude that Toyota had little potential for improvement in their Japanese supplier network, but this would simply not be true. Significant improvements may be forecast in Japan if attention can be directed at the raw material producing sector of Toyota's suppliers. In addition, through the localisation and development of TPS with European-based suppliers to Toyota, a similar high performing supplier network may be developed for the UK plant.

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4.3
Readiness for Supply Chain Collaboration and Supplier Integration – Findings from the Chinese Automotive Industry

Joachim Schadel, Martin Lockström, Roger Moser and Norma Harrison

Introduction

The efforts among automotive companies in China to find suitable domestic suppliers have to be seen as a response to local content requirements promulgated by the Chinese central government but also as part of the global sourcing strategy among the producers. Therefore, automotive companies, both original equipment manufacturers (OEMs) and their Western suppliers, are currently trying to integrate more domestic suppliers in their supply chains in China (Holweg et al., 2005). The automotive industry is suitable for further research of complex buyer-supplier interactions because it can also be considered a networked industry implying that it is virtually impossible for any firm alone to possess all the technical expertise and capabilities needed to develop and produce a complex product (Binder et al., 2007; Holweg and Pil, 2007).

The goal of this paper is to contribute to theory building of supplier integration in the specific context of the Chinese automotive industry by analysing empirical data gathered from a series of exemplary cases. The paper aims at answering the following research questions: How is supplier integration characterised in the Chinese automotive industry? What are antecedents to supplier integration in the Chinese automotive industry?

Literature review

The existing body of supply chain management research is replete with empirical studies on supplier selection, supplier relationship management, supply chain integration and management (Bowersox et al., 1999; Frohlich and Westbrook, 2001; Malhotra et al., 2008). Consequently, a new paradigm evolved among numerous scholars that positions the purchasing function in a company into a more strategic setting emphasising the importance of supplier management for the generation of competitive advantage (Watts et al., 1995; Narasimhan and Das, 2001; Möller and Törrönnen, 2003). The complexity of tasks in the automotive industry strongly suggests the implementation of collaborative concepts and approaches in such a networked industry (Tang and Qian, 2007). As supported by a vast amount of evidence, collaborative approaches result in improved product quality, shorter lead times and a higher responsiveness of the supply chain, lower cost and increased customer satisfaction (Bennett and O'Kane, 2006; Humphreys et al., 2007).

Hereby, it has been found that product modularisation reduces the complexity within the supply chain and plays a decisive role in particular in the automotive sector to facilitate supply chain linkages (Doran, 2003). It has been found as well that order-driven supply chains strengthen the need for stronger synchronisation of production planning processes (Holweg and Pil, 2007). Besides collaborative production planning (Bennett and O'Kane, 2006), collaborative product development (Takeishi, 2001) can be identified as a main form of collaborative relationships.

Supplier integration, supply chain integration and collaborative relationships

This paper adheres to several existing theories relating to *supply chain integration* (SCI), of which *supplier integration* (SI) is defined as a subset belonging to the upstream part of the supply chain. SCI is defined as series of activities intended to organise the material, information and cash flow across traditional functions within companies and across companies (Bowersox et al., 1999). This approach can be broken down into strategic, operational, flexible and financial aspects (Malhotra et al., 2008).

In congruency and adaptation to several concepts of collaborative buyer-supplier relationships in literature (Kraljic, 1983; Bensaou and Venkatraman, 1995), this term is defined in the context of this paper as relationships that are characterised by trust, interaction, mutual responsibility, mutual risks and benefits, autonomous problem solving capabilities of the involved partners and a proactive approach towards new challenges.

Methodology

Research design

Although there is some research on purchasing and supply management in China (Cai and Yang, 1999; Pyke et al., 2000), there is an apparent gap in the existing literature on these topics in the Chinese automotive industry. As the validity and reliability of frameworks developed based on empirical studies conducted in the West cannot be taken for granted (Hoskisson et al., 2000), combined with the overall lack of knowledge in this specific research context, an exploratory approach without prior assumptions or propositions was chosen. Therefore, an exploratory and inductive approach based on grounded theory was chosen for this study (Glaser and Strauss, 2006).

Sampling

As the purpose of the research was to capture the circumstances and conditions of an everyday and commonplace situation, a so-called *representative case* implying a holistic, multiple-case study approach was designed (Yin, 2003). The major rationale was to gain insight in the experiences of the average sourcing professional directly involved in the procurement of supplies in the Chinese automotive industry. As the purpose of the study was theory building, a theoretical sampling approach was deployed.

Data collection

Data was collected through semi-structured interviews in order to accomplish a certain degree of comparability while ensuring an unobstructed flow of narrations (Bryman, 2004). The informants involved in the study were purchasing, quality and supply chain managers from automotive companies. Two investigators were deployed for the interviews in order to "enhance the creative potential of the study" and to facilitate "convergent perceptions" (Eisenhardt, 1989). Each interview was conducted face-to-face, voice recorded (unless disapproved by the interviewee) and finally transcribed. Interviews were carried out in a sequential manner until a state of information saturation was accomplished (Glaser and Strauss, 2006), resulting in a total number of 30 interviews with automotive companies.

Instances of rivalling propositions were also investigated (Marshall and Rossman, 1995). Any such negative instance or rivalling proposition was questioned together with supervisors or managers in subsequent interviews. This was done in accordance with the consistency principle (Rubin and Rubin, 1995) that requires researchers to further investigate responses that appear inconsistent.

Analysis and results

Upon completion of each interview, the voice recordings were transcribed into a text format, resulting in 650 pages of textual material. In order to assure validity, four techniques as proposed by Maxwell (2006) were deployed. In the open coding step, the interview transcripts were analysed line by line breaking the data down into discrete parts (i.e., words, sentences and paragraphs) yielding 1,253 initial codes. Next, in the axial coding step, data were put back together in new ways by making connections between categories (Corbin and Strauss, 1990).

Supplier integration

The first construct that emerged out of the interview analysis was supplier integration (SI). The overall concept turned out to be similar with the common definitions in literature where buyers (i.e., OEMs/first tier suppliers) and their suppliers try to improve supply chain performance through joint activities in regard to information exchange, data transparency increase and production planning, etc. (Zhao et al., 2007; Malhotra, 2008).

Joint production planning. This is the first dimension of the SI construct and involves the planning and execution of supply chain-wide master plans (Pibernik and Sucky, 2006). Moreover, it contains tactical and short-term activities needed in order to ensure timely delivery of direct materials for production such as the development and sharing of master production plans or inventory levels and feedback on potential delivery delays or similar disruptions. These activities required the existence and transparency of accurate and relevant planning information within companies and synchronised exchange between supply chain echelons. It turned out in the interviews that this activity was mainly carried out manually or semi-automatically.

Furthermore, the level of integration of the material flow was investigated. It turned out that deliveries took place in some cases daily, but mostly in weekly or monthly lot sizes. It also turned out that advanced logistics and supply chain concepts, such as just in time (JIT) or vendor managed inventories (VMI), were possible in only a few cases. Continuous improvement processes, however, were implemented among half of the domestic suppliers.

Joint product development. This dimension of the supplier integration category proved to involve collaborative activities between the OEM and its key supplier(s) that were needed to bring new car models to the market at the lowest cost and as fast as possible (Binder et al., 2007). Early supplier involvement (ESI) and value analysis (VA) were major activities of this category. The actual joint product development activities proved to take place at three distinct levels, namely (1) process-related product modifications which occurred most often and refer to changes of the technical specifications due to different production processes and techniques without changing the overall product characteristics and functional requirements, (2) product-related changes in order to better adapt to the needs of local customers, for example, elongated car bodies with more back seat leg space and (3) new product development capability.

Communication technologies and patterns. This dimension of supplier integration involved the means through which communication between buyers and suppliers take place on a daily basis. The automotive companies in the West rely on a high level of electronic information exchange through the use of online supplier portals, e-sourcing tools and EDI for the information exchange between buyers and suppliers. In the Chinese automotive industry, this information exchange turned out to take place at a more basic level with frequent use of telephone, fax and email.

Strategic planning. This dimension of supplier integration involved all kinds of long-term planning such as capacity, demand or product planning as well as sharing of new ideas and alignment of long objectives. Based on the analysis, the decisive factor is the maturity of the buyer-supplier relationship. Automotive companies that have done business with domestic suppliers for a long-term period also tended to involve them more often in long-term planning. However, it was evident that the stronger supply chain partner (i.e., the foreign buyer) usually dictated the activities.

Organisational integration. This dimension involved all kinds of joint investments (financial and non-financial) in joint infrastructure (physical and non-physical). According to our results, major activities included process development and continuous improvement in order to optimise the organisational interface between the buyer and supplier. Another identified key activity was supplier development programs where cross functional teams consisting of buyers, logistics experts, quality engineers and production managers were sent to a supplier's facilities to improve production processes and train staff and management. It also turned out that most buyers have some sort of contingency plans in place as part of the contract with a supplier in case unforeseen events or problems would occur.

Collaborative supplier capabilities

After examining the concept of supplier integration in the Chinese automotive industry, interviewees were asked to elaborate on factors that facilitate and drive supplier integration in the Chinese automotive industry.

Process management capability. The first dimension of collaborative supplier capabilities that emerged from our data was process management capability. It appeared to be one of the most important ones as most respondents claimed that it enables producers to effectively achieve adequate quality, delivery, productivity and, at the end, also cost levels. According to the respondents, this capability has to be shown in basically any activity of the supply, development, production and delivery process. Consequently, reliable and stable processes seem to be a prerequisite for supplier integration in the automotive industry.

Performance management capability. Another common SI driver highlighted in 12 cases was the frequent difficulty of managing production and delivery performance (Kaplan and Norton, 1992). Despite a high willingness to learn (indicated in eight cases) and to invest in improvement activities the experience was that a lack of targets, performance indicators and action plans, lead to instable results and gradually drifts away from pre-defined levels. Other stated reasons for this phenomenon were high staff turnover rates, a lack of organisational learning and broken information feedback loops within the Chinese companies.

Communication/Autonomous problem solving capability. One of the most frequently occurring challenges concerning supplier integration in the Chinese automotive industry (22/30 cases) was the difficulty in effectively communicating with suppliers. This was the case especially concerning problem identification where most suppliers were described to be very reactive. Twenty-one of the 30 cases indicated this capability to be of essential importance further stressing this inhibiting factor for supplier integration. In general, this problem led to situations where buyers had to spend considerable resources on supplier monitoring and inspection on a continuous basis in order to discover potential problems at an early stage.

Planning capability. Partly interlinked with the process management capability, the planning capability within a company and across companies was named as a prerequisite to manage processes across the supply chain in a reliable and stable manner (indicated 15/30 cases). Many of the suppliers were said to lack experience in collaborative production and development activities.

Evidently, accurate and relevant planning information regarding orders, inventories, capacities, etc. were often reported to be missing. In most cases, missing information systems or the lack of a systematic approach were suggested as possible reasons for this situation.

Engineering/Innovation capability. This capability was emphasised as one of the key drivers for strategic partnerships with suppliers in 21 of the cases. Despite a high degree of openness and willingness to learn and develop the level of innovations stemming from domestic suppliers still proved to be very low. The research results did not reveal a single case where genuine product development took place. The few instances where joint R&D activities happened turned out to be limited to product modifications primarily on the initiative and guidance of the buyer. As most of the interviewees indicated the ability to develop a component on the basis of functional requirements as a prerequisite for supplier integration the level of difficulty is apparent.

The above discussion leads to the following proposition:

P1. The aggregate level of collaborative supplier capabilities has a positive impact on supplier integration.

Supplier collaboration readiness

Following the discussion about the importance and impact from collaborative supplier capabilities on supplier integration, the next question is indeed how such supplier capabilities can be developed and maintained.

Quality mindset/Customer orientation. In instances where successful buyer-supplier interaction had taken place it was evident that a quality mindset permeated the supplier organisation from top to bottom. Examples of such values and beliefs were a perceived importance of quality, zero tolerance for defects, paying attention to details in operations, continuous improvement and an acknowledged importance of the customer.

Top management support. According to the data, it seems difficult to build and nurture the same kind of thinking throughout the organisation unless supported by senior management. Collectively, these values and beliefs can be summarised as top management mindset.

Strategic alignment. The results also showed that those suppliers that were involved in successful collaborative projects with their customers were also highly motivated. This motivation was manifested in several ways. First, highly motivated suppliers turned out to have a high willingness to follow – that is, they seemed to have realised the benefits of making necessary changes and adaptations to their strategy, processes and organisation in order to make their customer relationships work.

Willingness to learn/improve. In parallel with the strategic orientation among successful collaborative supplier-buyer relationships, those suppliers also showed a great interest in learning and improving. The willingness to learn and improve also seemed to be coupled with the supplier mindset in a sense that suppliers must have acknowledged the need for improving performance in order to invest time and money in training and improvement activities.

Long-term orientation. Product development in the automotive industry is a costly and lengthy process. Thus, it is no surprise that well integrated suppliers had adopted a long-term view where expenses today were perceived as investments in future benefits. This factor proved to be one of the more common problems when dealing with domestic suppliers in China. They often tend to prioritise short-term profit over long-term objectives such as overseas expansion, technology leadership, excellent customer service and quality excellence.

Trust. In buyer-supplier relations characterised by a high degree of supplier integration the data shows that a high level of trust from the supplier's side was prevalent. In contrast, in those instances where the level of trust was low, suppliers were not willing to take the financial risk implied from engaging in new automotive development projects, investments in new equipment/machinery and staff training activities.

The elements identified above might be aggregated to a conceptual construct called *supplier collaboration readiness*. Without top management support, willingness to learn and improve, the right strategic orientation and a trust in a non-opportunistic relationship it is not possible to develop and maintain the required supplier capabilities. The second proposition is therefore defined as follows:

> *P2. Supplier collaboration readiness has a positive impact on the level of collaborative supplier capabilities.*

Buyer leadership

Another aspect that emerged out of the coding of the transcribed interviews was the role of leadership. Most recent leadership research has primarily focused on "influencing a group of people to achieve a common goal" within one's own organisation (Northouse, 1997) by virtue of formal power and authority (French and Raven, 1959). The data analysis of this study indicates that leadership might in fact also span across firm boundaries.

The empirical data also suggests that there exists a set of behaviours related to leadership. The relevant aspect in our study proved to be the leadership behaviours towards the supplier organisations. Almost all decision-makers from buying organisations involved in collaborative supplier activities tended to apply a sort of situational leadership style (Hersey and Blanchard, 1969) depending on the relationship atmosphere and urgency of the matter.

It turned out that leaders who allegedly had managed to facilitate a high degree of collaborative readiness among the suppliers had taken a systematic approach. They did not only focus their efforts on one function but rather targeted the senior management among their suppliers and actively worked at a very personal level to convince these managers to adopt values, beliefs, make strategic adaptations, investments in new machinery/equipment, etc. in line with the strategic orientation of their own company.

The third proposition is defined as follows:

> *P3. Buyer leadership effectiveness has a positive impact on supplier readiness.*

Continuous supplier development

Another construct that emerged during the axial coding of the interview data turned out to be *continuous supplier development*. Conceptually, the construct involves activities from organising relevant training for the supplier at various levels (e.g., FMEA, APQP, TQM, etc.) to consulting activities at the supplier's facilities.

The fact that supplier development is a common and acknowledged practice in the automotive industry is no news. However, the results indicate a more idiosyncratic side of the concept. In fact, it seems that supplier development activities must take place on a *continuous basis*. Most respondents agreed that it was seldom enough to invest once into some supplier development activities for a specific supplier. In many of the cases, supplier performance started to become volatile and drift away from target levels as soon as supplier development activities were stopped. The fourth proposition thus is as follows:

P4. The level of continuous supplier development has a positive impact on the level of collaborative supplier capabilities.

Internal constraints

The data coding also revealed that the challenges concerning supplier integration in the Chinese automotive industry are not only related to the domestic suppliers. In fact, many cases indicated that some of the biggest bottlenecks were related to internal issues. One of the most prevalent internal challenges was identified as unrealistic headquarters expectations. The discrepancy between expectations was also manifested through insufficient provision of resources for local operations in terms of staffing and financing. Moreover, a common lack of on-site testing facilities resulted in lengthy sample inspections cycles which causes frustrations among the domestic suppliers and hinders the buying firms to position themselves as "valued customers". Based on the above discussion, the fifth proposition is defined as follows:

P5. The level of internal constraints is negatively moderating the relationship between buyer leadership effectiveness and supplier readiness.

Cultural distance

This study does not deliberately investigate the impact from specific cultural characteristics such as power distance, masculinity, uncertainty avoidance, individualism, etc. (e.g., Hofstede, 1980; Javidan et al., 2006). Regardless of any conceptual culture frameworks elaborated in the literature, cultural distance is almost always manifested in differences in interpersonal communication. Also, the ways business relationships are built in China vary differently from the West. Clearly, the coding revealed culture to be an influencing factor. It turned out that cultural differences and a lack of cultural understanding in many cases hinder supply managers from effectively doing their job because it makes actions and counter-actions of the supplier more difficult to anticipate. Therefore, the sixth proposition is stated as follows:

P6. The level of cultural distance is negatively moderating the relationship between buyer leadership effectiveness and supplier readiness.

Collectively, the six propositions form a causal framework identifying important antecedents to supplier integration in the Chinese

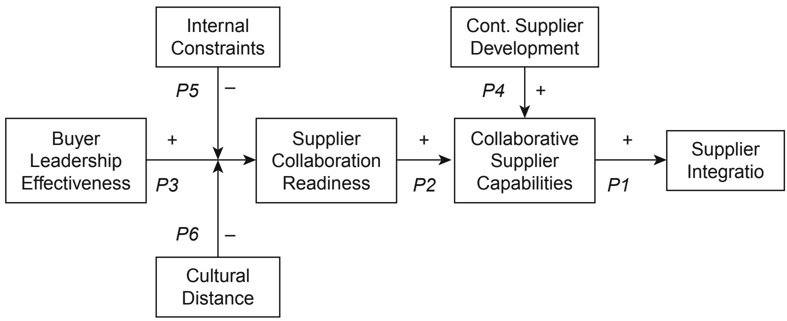

Figure 4.3.1 Conceptual framework of antecedents to supplier integration

automotive industry. An overview of the conceptual framework is depicted in Figure 4.3.1.

Conclusions

The developed conceptual framework is based on an extensive analysis of recent and current supplier integration practices in the Chinese automotive industry. The study results contribute specifically by adding a specific perspective on supplier integration analysing the antecedents of supplier integration in the Chinese automotive industry. Elements such as buyer leadership effectiveness might not be as relevant in a Western context but seem to be of importance in this specific context. The data analysis has revealed that there seldom exist concepts such as "one face to the customer or supplier" as each sourcing or product development project is executed by cross functional teams from both sides with representatives from purchasing, production, logistics, product development, etc. Furthermore, a so-called leader in this context does not seem to be limited to formal leaders; the data analysis, in fact, suggests that leadership seemed to exist at all hierarchical levels and all functions involved in the collaborative activities from the buyer's side.

It has also become clear from the data analysis that the local purchasing department in China serves as an interface and important linkage between the local suppliers and the internal customers located outside of China emphasising the limiting aspects of internal constraints and cultural distance.

Finally, the results contribute to a better understanding which elements might be necessary in a Chinese context to achieve a satisfactory level of supplier integration.

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4.4
Business Process Management and Supply Chain Collaboration: Critical Comparison of Four Thai Case Studies

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Introduction

Internal and external business process collaboration is vital for effective supply chain (SC) management. Building relationships between companies can lead to their competitive advantage, resulting in organisational performance improvement than when working individually (Cao and Zhang, 2011). The earlier phase in our research empirically tested the interrelationships between business process management (BPM), supply chain collaboration (SCC), collaborative advantage and organisational performance. This study is a step further and aims to illuminate the findings from the large-scale survey data analyses. This was achieved by gathering practitioners' opinions to provide an in-depth and detailed understanding of the meanings, actions and experiences of practitioners in their specific contextual situations.

The following section provides a brief review of the relevant literature on the relationships between BPM, SCC, collaborative advantage and organisational performance. This is followed by a summary of the large-scale survey results. The research methodology is subsequently presented. The case studies analysis is explained next. Finally, key research findings, managerial implications and conclusions are highlighted.

Literature review

BPM is defined as a process-oriented organisational approach, used to design, analyse and improve business processes that results in increased organisational performance (Chang, 2006). It uses various methods, techniques and technology to support changes in business process and encourages employees to become more involved in the workplace (van der Aalst et al., 2003). Crossing individual organisational boundaries, SCC is defined as when two or more companies in an SC work closely in delivering products to end customers, to optimise profits for the SC members and create competitive advantage (Simatupang and Sridharan, 2008). Ultimately, the benefits from working collaboratively with SC partners can be explained in terms of collaborative advantage and organisational performance. Collaborative advantage can be defined as strategic benefits achieved over competitors in the marketplace that could not have been achieved without working through the SC partnership (Malhotra et al., 2005; Cao and Zhang, 2011). Organisational performance is defined as how well an organisation fulfils both financial and its market-oriented goals (Li et al., 2006). Previous research has suggested that both BPM and SCC are important for improving performance and competitiveness, yet these two approaches have usually been studied separately (e.g., Zacharia et al., 2009; Nyaga et al., 2010). The scope of business processes is often defined within organisational boundaries, rather than being linked to SC partners. Additionally, there is evidence suggesting that SC relationships are dependent on organisational, competitive and relationship-specific attributes (e.g., Sila, 2007; Tang and Rai, 2012). However, there is also a lack of empirical research elaborating on the impact of context dependent factors have on the interrelationship between the competitive and performance linkages, on both the individual operation and the SC.

An earlier stage in our research empirically tested the interrelationships between BPM, SCC, collaborative advantage and organisational performance. The moderating effects of the contextual factors of firm size (medium and large firms), industry type (automotive and electronics industries), closeness (supplier and customer) and relationship length (short- and long-term relationships) were also included. The hypotheses were developed and tested by using the Partial Least Squares approach to Structural Equation Modelling (PLS-SEM). A range of Thai manufacturing firms were surveyed and 204 completed questionnaires were analysed. The results confirmed that (a) there is a positive relationship between BPM and organisational performance, (b) BPM is also a driver of SCC, (c) the effect of BPM on organisational performance is partially mediated by SCC, (d) firms which collaborate with SC partners are better positioned to achieve collaborative advantage, (e) the effect of SCC on organisational performance is partially mediated by collaborative advantage and (f) there are no significant differences in firm size, industry type, closeness and relationship length on the relationships between BPM, SCC, collaborative advantage and organisational performance.

This study is a step further, the aim was to capture instances of the practitioners' views on the relationships between BPM, SCC, collaborative advantage and organisational performance, and develop understanding on the underlying factors guiding these interrelationships.

Methodology

This study employed the case study approach as a follow-up to the large-scale survey (Yin, 2014) to gain a deeper understanding of the empirical results. Some level of triangulation above the company level was achieved, namely industry and firm size, considering the focus of the research is on the manufacturing industry in Thailand. Four case companies were selected, which presented different types of firms in terms of size (medium and large) and industry (automotive and electronics industries). All selected companies had participated in the previous quantitative phase. The size distinction was based on the official Thai definition: a medium-sized firm having 51–200 employees and a large-sized firm employing more than 200 people (The Ministry of Industry Thailand, 2013). The selected case studies allowed for a comparison of similarities and differences between firm size, industry type, closeness and relationship length. An interview protocol was developed, based on the results of the large-scale survey, to ensure that all issues required were addressed. Semi-structured interviews were employed in order to understand the practitioners' opinions and to give them the opportunity to elaborate on their opinions and to highlight specific issues of the proposed model, resulting in more in-depth evidence from key practitioners. The first interview served as a pilot to allow for improvements in the interview protocol. The average duration for the interviews, which took place over the telephone in February 2014, was one-and-a-half hours.

For the case study analysis, the main themes were developed to elaborate on the quantitative results. These themes are: (i) the link between BPM and organisational performance, (ii) the link between BPM and SCC and (iii) the contextual factors and benefits achieved from working collaboratively with SC partners. Based on the data collection in this phase, the company's background and the key findings from the cross-case analysis related to the investigated issues are presented in the following section.

Case studies analysis

Regarding the company background, *Case EL* is a large electronics company with a capital investment of 810 million Thai baht, employing 2,200 people. It is a wholly owned Japanese company, which has achieved sustainable growth and operates in various countries. It produces elevators, escalators and moving walk ways for export and the domestic market. The interview participant from this company was the SC Manager. *Case AL is* also a large wholly owned Japanese company, which produces automotive and motor vehicle batteries. The company has a registered capital investment of 240 million Thai baht and 600 employees. The interview participant from this company was the production manager. *Case EM* is a medium-sized example from the electronics industry. It is a joint venture, with 94.33% Japanese and 5.67% Thai ownership. Its registered capital investment is 30 million Thai baht and employs a total of 98 employees. The company produces electrical component inverters, switch boxes and wire harnesses for air conditioners. The production manager participated in the interviews. *Case AM* was selected to represent a medium-sized company in the automotive industry. The company is wholly owned Japanese company and was established in Thailand with a capital investment of 20 million Thai baht, employing over 100 employees. Automotive parts are produced both for the domestic market and for export. The information was provided by the factory manager. All of these four case companies have achieved ISO 9001 certification which emphasise process management.

The link between BPM and organisational performance

The four cases provided four common characteristics of BPM practices namely, long-term planning, information technology (IT), process improvement, and top management support and employee involvement. *Long-term planning* needs to be based on customer requirements and should cover aspects of production planning, promotional events and supplier development. This plan has to be jointly developed with the SC partners. For instance, the production manager from AL suggested that: "The company has set a long-term policy, which is for three years. However, at the end of each year there is a review of the situation, and if necessary there is a change to or an improvement to the plan. The company has jointly developed production forecasts with its suppliers." Thus, the firm and its main suppliers use the same production forecast plans. IT is important to accomplish the business plan and to improve operational processes, and IT is used to share information both within an organisation, from top management to employees, and with their SC partners. For instance, it was suggested that: “The use of IT is very important to accomplish this plan, and information sharing includes both top management and all the employees” (EL).

The four cases have used various *process improvement* techniques such as total quality management (TQM), Lean Manufacturing and Kaizen to improve their business processes. The managers pointed out that their process improvement techniques were often the same techniques as their SC partners (AL, EM and AM). The use of process improvement techniques also leads to more employee involvement; for instance, it was suggested that the use of Kaizen provides opportunities for employees to contribute any suggestions they may have for work improvements (EL). *Top management support* is very important for successful BPM practices, as participants in all the four cases suggested that their BPM practices were fully supported and led by top management. Additionally, good relationships between top management, managers and employees have been developed. For instance, one company provides a “President box”, for employees to contact the president of the company directly (EL). Additionally, employees are involved in decision-making; it was reported that: “Top management has to set policies that should lead to improvements. However, before the policies have been set, there is an internal meeting, including managers of each department, where they discuss any problems. Also, employees can give any suggestions they have to their manager” (AL). Regarding training and skills development, it was explained that: “We have sent employees to train in Japan to learn new technology and innovations, so they can come back to improve our products” (EL). Thus, employees have opportunities to learn new technology to improve products to meet customer requirements.

The four participants explained that BPM practices had helped to improve their organisational performance, both financial and non-financial. In terms of financial performance, all of the four cases emphasised that sales growth and cost reduction were the most important dimensions. Sales growth and cost reduction referred to the improvement of production processes, the policies adopted to reduce costs and the reduction of waste. The manager explained that: “In terms of cost reductions, the company has set targets for cost reductions, improved sales growth and improved product quality, in each department” (EM). Regarding non-financial performance, two cases focused on overall competitive position and core competencies (EL, AL). Case AL, for example, has a strategy in place in which a team has been settled to analyse and develop strategy to be able to compete in the marketplace. For all cases, quality is an important issue (EL, AL, EM and AM). For instance, the SC Manager from EL indicated that: "Quality is the first priority for our operations". The four companies have continued to carry out quality improvement activities such as record problems and the improvements and preventive measures, in response to quality non-conformity and the monitoring of progress. Waste reduction was also important for all cases.

The link between BPM and SCC

From our investigation, BPM practices help various collaborative activities, which we have divided into four types: information sharing and communication, joint activities, sharing common goals and sharing costs, risks and benefits. The analysis provided evidence of the importance of *information sharing and communication* within a firm and with SC partners. For instance, in the case of EL, an enterprise resource planning (ERP) system is used to share information within the company and with its SC partners. Technical and non-technical information is also shared with suppliers (AL). Relevant knowledge, regarding collaborative activities and process improvements, are shared between a firm, suppliers and customers (EL, AL, EM and AM). For instance, knowledge regarding process improvement techniques and knowledge that can be used to reduce costs in production process are being shared. Also, all cases indicated the importance of open and clear communication, both formal and informal, with suppliers and customers. All cases have some form of *joint activities* with their SC partners. For instance, jointly planning demand forecasts, resolving forecast errors and jointly working out solutions of any problems within an SC. Regular meeting with suppliers and customer are held to jointly plan and jointly solve problems and to update any changes and improvements in terms of production planning, process improvement and technology. For instance, case AL has set up a team to work closely with its suppliers, to improve and develop the relationships and grow together. It is important for working collaboratively with SC partners that *mutual benefits* are highlighted (EL, AL, EM and AM). Thus, the production manager in case AM stated that: "if there is no agreement about goals and objectives from working collaboratively, this could create problems rather than benefits within the chain". Thus, a firm, suppliers and customers need to develop and grow together (EL, AL, EM and AM). A firm has also co-developed systems by setting and sharing Key Performance Indicators (KPIs) together with its suppliers

(AL). Taking into account the joint activities and the sharing of mutual benefits between a firm and its SC partners, the case studies results show that all cases have some form of sharing *cost, risk and benefit* with their SC partners.

The four cases illustrate that an intra-organisational focus (on BPM) is a prerequisite for inter-organisational activities (SCC). The managers suggested that working collaboratively with SC partners would pay back to the company in terms of benefits along the SC, and this can help to improve the firm performance (EL, AL, EM and AM). The production manager from case AL suggested that: "To collaborate successfully with SC partners; firstly, we have to improve and develop both human resources and technology. Secondly, we have to drive the growth of our suppliers at the same time as our company. Thirdly, we have to follow the 'voice of the customer' as much as we can, in order to meet customer requirements and to achieve customer satisfaction. Finally, these three will be paid back to the company in terms of mutual benefits along the SC and this must help to improve our firm's performance."

Contextual factors and the relationships benefits

The case companies explained the mutually beneficial outcomes of BPM practices and working collaboratively with SC partners in terms of collaborative advantage and organisational performance. Regarding, collaborative advantage, the initial terms from these four case studies are time to market, quality and the meeting of customers' requirements. The production manager in AL explained that: "Time to market and quality are essential because we produce automotive parts, which means that if the car is sold then we will automatically hit the market. The others are product variety, meeting customers' requirements, the effective use of technology and innovation and the sharing of system controls with customers, which we can use in our own company." The results from the case studies also illustrate that working collaboratively with SC partners improves both financial and non-financial organisational performance (EL, AL, EM and AM). In terms of financial performance, it is improved in terms of cost reduction, sales growth and return on investment. Additionally, in terms of non-financial performance, it is improved in terms of quality, overall competitive positions and waste reduction. For instance, The SC Manager indicated that: "This has created a win-win situation for the company, customers and suppliers. The collaboration has resulted in the suppliers knowing that they will receive orders from the company, as long as they maintain certain standards, and everyone benefits from working collaboratively."

The results also indicate that large firms work more closely with suppliers, whereas the medium firms are work more closely with their customers. The results show that regardless of firm size similar collaborative advantage can be achieved. However, firm size is important when the priorities of collaborative advantage are taken into account. The two large firms focus more on time to market and quality, while the medium-sized firms concentrate more on quality and meeting customer requirements. The results indicate that product innovation and the effective use of technology are the main focus in the large firms and that they are actively improving their technology and their employees' skills to facilitate these outcomes.

All of the four companies suggested that the closeness of relationships is usually based on long-term partnerships, so trust with both suppliers and customers have been developed. Additionally, whether the company is working closely with suppliers or customers, they require joint working; for example, it is important to have joint meetings to develop policy, joint decision-making, joint problem solving, joint planning of demand forecasts and jointly working together to reduce lead time with suppliers. In relation to the importance of close relationships with SC partners, two practitioners explained that: "The use of technology and the use of joint activities such as forecasting with suppliers are vital. Also, the company visits suppliers and attempts to solve production problems together" (EL) and "The activities with close suppliers cover developing policy and technology together, sharing information and sharing knowledge such as product design" (AL).

As regards industry type, the results show that the electronics and automotive industries are similar in the way they collaborate with SC partners. Both electronics and automotive industries provide similar results in terms of benefits achieved from working collaboratively with their SC partners. However, the two automotive companies focus more on improving product variety. It was explained that: "We need to develop technology to support the new automotive models [...]. The company sees innovation as a way to improve our products, so they have a longer life [...] we have to improve our employees' skills, so we can use new skills to improve current products and to provide innovative products" (AL).

Regarding the relationship length, the results show that the four cases have been working collaboratively with their closest SC partners since they started the business. All participants suggested that long-term relationships provide fewer problems, more flexibility, and that trust has been developed, so communication can be both formal and informal. For example, the SC Manager in EL suggested that: "The close relationships and the fact that the companies have been working together for a long time, has resulted in the suppliers opening a warehouse in Singapore in order to support their customers in Asia. This means that the lead time has been reduced because the company can now place orders in Singapore instead of Switzerland". Additionally, the production manager in AM stated that: "Communication is easier than when it's a short-term relationship [...] we rely on each other more." In contrast, dealing with short-term relationships is more complex. The participants indicated that: "With suppliers who we have had shorter relationships with, we need to spend more time; for example, we often need more communication to explain specific requirements, as suppliers will work based on our requirements" (AL). Although, the results reveal that short-term SC relationships can create difficulties, they do not have an impact on the benefits achieved in collaborative advantage and organisational performance. The managers highlighted that: "Actually, the length of the relationship does not cause any problems, in terms of benefits, but short-term relationships make the collaboration process more complicated than with long-term relationships" (AL) and "Relationship length has not caused any problems because we are continuously improving our systems. However, it is not about relationship length, it is more about how to improve our business, so we are able to compete in the market better than our competitors" (EM). Thus, short-term SC relationships can create difficulties, but they do not have an impact on the benefits achieved in terms of collaborative advantage and organisational performance.

The key findings

The results from the case studies have provided the key common characteristics of BPM namely, long-term planning, IT, process improvement, and top management support and employee involvement. These common characteristics can assist a firm to improve organisational performance, both financial (e.g., sales growth and cost reduction) and non-financial (e.g., quality and waste reduction) performance. It has been established that intra-organisational focus (BPM) is essential for inter-organisational activities (SCC) in terms of information sharing and communication, joint activities, sharing common goals and sharing costs, risks and benefits. A firm and its SC partners need to develop and grow together and work to enhance mutual benefits. The results revealed that BPM not only directly improves organisational performance, but it also assists in collaborative activities which in turn help to improve internal capabilities.

The case studies illustrate that the benefits achieved from working collaboratively with SC partners, in terms of collaborative advantage and organisational performance. They also illustrate practices and approaches across diverse firm sizes, industry types, closeness and relationship lengths. Different firm sizes support collaborative efforts with proportional financial and managerial resources; however, firms develop an appropriate strategy based on common goals with their SC partners to share their, limited occasionally, resources in an effective way to achieve collaborative advantage and improve organisational performance. Additionally, they apply different business strategies. For example, considering our case sample, medium firms tend to focus on cost reduction and sale growth, whereas large firms not only focus on cost reduction and sale growth, but also on their overall competitive position.

The large-scale survey results, from the earlier phase found that a firm working closely with either upstream or downstream SC members can achieve benefits in terms of collaborative advantage and organisational performance. A greater understanding provided from the case studies that firms of different sizes from both the electronics and the automotive industries have chosen to work closely with their SC partners differently. The larger firms are working more closely with their suppliers, while the closest relationships for medium firms are with their customers. The closest partnerships are characterised as being of a long-term nature including building of trust and jointly working closely together in various activities, such as jointly planning, decision-making and sharing knowledge over time. Regarding the relationship length, long-term relationships between a firm and SC partners result in working collaboratively with fewer problems, enhanced flexibility and open communication. Nevertheless, the case study analysis shows that short-term relationships can be difficult (e.g., communication and setting policy and conditions), but they do not have any impact on the benefits achieved in terms of collaborative advantage and organisational performance. Hence, collaborative relationships, whether long or short term, both result in mutual benefits and improved organisational performance.

Relevance/contribution

Regarding its theoretical implication, the paper provides a deeper understanding in terms of how and why BPM and SCC interrelate to drive collaborative advantage and organisational performance. A detailed understanding of each contextual factor in terms of firm size, industry type, closeness and relationship length was gained to understand and elaborate the quantitative findings. Also, the important manufacturing sectors, namely the automotive and electronics industries in a developing economy, Thailand, were addressed in this study. In terms of practical implications, this study elaborates on the joint role and impact of BPM and SCC. The lessons drawn from the case studies incorporate practical mechanisms of BPM and SCC approaches that are critical to offering benefits in terms of collaborative advantage and organisational performance. From the results, managers should consider these four contextual factors have a minor impact. This means that BPM practices based on the four common features: long-term planning, IT, process improvement and top management support and employee involvement and working collaboratively with SC partners can lead to benefits in terms of collaborative advantage and organisational performance even when firms have different characteristics. Managers should consider allocating sufficient efforts in terms of resources and employee skills to convince SC partners to implement more collaborative activities. Furthermore, managers should consider collaborating in information sharing and communication, joint activities and the sharing of common goals, costs, risks and benefits, which will enable firms to effectively leverage their capabilities and to accomplish the desired benefits in terms of collaborative advantage and organisational performance.

Conclusions and future research

This paper aims to gain a deeper understanding of the large-scale survey results by returning to the participants for a second round of qualitative data collection. Therefore, the reasons behind the results of the relationships between BPM, SCC, collaborative advantage and organisational performance were explained in this paper. The main issues of: (i) the link between BPM and organisational performance, (ii) the link between BPM and SCC and (iii) the contextual factors and benefits achieved from working collaboratively with SC partners were gained to understand and expand the quantitative findings.

It is acknowledged that there are limitations of the study. Firstly, the data collection was based on a few individual firms. The future research could consider extending this research by collecting and examining these relationships by using a wider sample to compare the differences and similarities to gain a comprehensive understanding within each industry type. Secondly, the data collection was based on one key respondent per company. Future research may consider using a broader range of respondents from different positions regarding the company practice on BPM, collaborate with its SC partners and the benefits achieved. Lastly, the study is scoped at specific industry types and limited on the considerations of the contextual factors. Therefore, future research could consider other industry sectors and other contextual factors (e.g., type of ownership) in order to identify the relationships between BPM, SCC, collaborative advantage and organisational performance.

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5
Retail Logistics

5.1

Customer Segmentation Based on Buying and Returning Behaviour: Supporting Differentiated Service Delivery in Fashion E-Commerce

Klas Hjort, Björn Lantz, Dag Ericsson and John Gattorna

Introduction

In shifting market conditions, the choice of supply chain strategies is critical when competing to serve customers (Gattorna, 2010). It is accepted in theory that the "one size fits all" approach to supply chain design is no longer valid (Christopher et al., 2006; Gattorna, 2010; Ericsson, 2011; Godsell et al., 2011). Still organisations, even in the highly competitive e-commerce market, utilise a "one size fits all" strategy to create and deliver value to their consumers, thereby implicitly assuming that consumers' demands and buying behaviour are homogeneous, and therefore, there is no profitable reason to differentiate delivery in terms of service.

However, e-commerce consumers' buying behaviour is not homogenous, especially in the fast-moving consumer goods (FMCG) business. FMCG organisations compete not only in products and price, but also in a large variety of services. For example, accessibility and speedy delivery are critical determinants for success. Returns management (RM) is clearly a part of the parcel, and, if handled properly, it can decrease costs, while simultaneously increasing revenue and serving as a means of competition. The total offer is called the "value package" and consists of the physical product plus the services surrounding it. Some of these services are the order qualifiers, and some are the order winners (Ericsson, 2011).

If customer groups exist with different service requirements, then it makes sense to try to match these with differentiated supply chain strategies (Godsell et al., 2011). Gattorna (2010) argues that organisations, or rather supply chains, need not only to understand the competitive forces, they need also to understand their customers' buying behaviour. Furthermore, they need to understand how to use the knowledge internally to offer and deliver suitable value propositions. In e-commerce this has implications on service delivery as well as the sourcing of products and thus on how we design the supply chains. In designing supply chains, Godsell et al. (2006) express a need to replace the focus from the product to the end customer and specifically on the end customer's buying behaviour. Traditionally, there are two different schools of thought in supply chain design (Godsell et al., 2011). The first theory is the lean-agile supply chain design, which is product driven. The second school of thought is that strategic alignment is driven by customer buying behaviour. Both schools take a supply chain approach; thus, neither theory focuses on the consumer or the end user as is done in this research.

Supply chains are omnipresent (Gattorna, 2010), and e-commerce organisations exist in many supply chains or supply networks. As noted earlier, it is accepted that the "one size fits all" approach to supply chain design is no longer valid, and the suggested number of parallel supply chains varies and is naturally context dependent. It depends upon diverse variables such as demand uncertainties, product characteristics, replenishment lead times, etc. Traditionally, literature describes supply chain design from a manufacturer's perspective, trying to link the supply side with the demand side, often with a product focus (see Croxton et al., 2001; Christopher et al., 2006). In e-commerce, the focus would naturally shift to the e-commerce organisation, which changes the focus from manufacturing towards sourcing of and delivery of finished goods. However, as e-commerce organisations grow, they are likely to try to design and produce their own products and brands in search of greater margins, which shifts the focus back towards manufacturing or at least a combination of sourcing and manufacturing. This exemplifies the need for at least two supply chains, probably even more. In e-commerce, the critical focal point is to match the demand from consumers with an appropriate set up of sourcing, final distribution and returns-handling activities. If demand variations for different products exist, it is probably useful to apply diverse sourcing strategies in order to match demand uncertainties with responsive supply strategies. Gattorna (2010) argues that in a typical supply chain three to four dominating customer buying behaviours exist that need to be understood in detail. Further, these dominating behaviours cover approximately 80% of the customers, and the same dominating patterns fit other markets as well.

Christopher et al. (2011) explain the need for combining both product characteristics and market considerations when designing supply chain capabilities and selecting supply chain pipelines. In the selection of pipeline types, there are eight theoretical types to choose from depending on whether products are standard or special, demand is stable or volatile and lastly if the replenishment lead time is short or long (Christopher et al., 2006). According to Christopher et al. (2006), standard products tend to be more stable in demand with longer life cycles, while special products tend to be the opposite, that is, erratic demand and shorter life cycles. Therefore, there is a connection between demand predictability and product characteristics, which reduces the amount of theoretical pipeline types to four (Christopher et al., 2006, p. 282). Depending on product demand and supply characteristics, Christopher addresses a lean, agile or a combination of the two, that is, a *leagile* approach (see Christopher et al., 2006, p. 283).

In many markets, especially the e-commerce market where several organisations are competing, that is, selling the same brand or similar products with little or no difference in price, it is difficult to maintain a competitive edge trough the product itself (Christopher, 2005). Therefore, the service level and the delivery service as such becomes a critical determinant for market success. The e-commerce supply chain often appears, in theory and practice, as a one-dimensional chain. However, in reality, it is a spaghetti bowl of interrelated activities or processes sourcing thousands of SKUs, receiving, storing, picking, packing and distributing them to the end user and later receiving and handling consumer returns. In the e-commerce business, especially in fashion, delivery from stock to consumers makes it difficult to apply the lean/agile approach for the final distribution. However, customers buying and returning behaviour might affect the profitability if it is not matched with a suitable delivery and return strategy.

In the fashion e-commerce business, a trend towards more liberalised delivery and return conditions as a way to cope with competition inside the industry has become evident. Additionally, these lenient return policies attract new consumers from the traditional retail chains. Consequently, return policies are a part of marketing practice (Autry, 2005), and therefore, returns management (RM) is surely a part of the value creation process. RM is the part of supply chain management that includes returns, reverse logistics, gatekeeping and avoidance (Rogers et al., 2002, p. 5). Mollenkopf et al. (2011) investigate the marketing/logistics relationship relative to RM. They found that the effectiveness of RM was enhanced when firms coordinated their strategic and operational activities. Clearly, RM needs to be efficient; in some cases, however, it seems that it is also a part of the value creation not only the value recovery. Stock and Mulki (2009) emphasises that product returns will continue to be a part of business operations, and literature indicates that competition is increasing and consumer demands are surely following this development. Therefore, there is a need to align RM within the supply chain strategy where the whole supply chain needs to operate efficiently and effectively and returns are no exception (Stock and Mulki, 2009).

The aim of the changes in delivery and return conditions is to attract and create loyal and repetitive customers, thereby increasing sales. However, a liberal return policy increases returns (Wood, 2001). There is, however, no direct correlation between increasing sales and maximising profitability. Differences in service requirements might affect both sales and profitability. When utilising a "one size fits all" strategy correctly, one would expect to find a uniform response or behaviour from consumers, that is, no grouping when analysing consumers' loyalty in terms of repetitiveness and profitability in terms of contribution margin. This study set out to characterise customer segments in terms of buying and returning behaviour as a starting point for grouping customers and their response to a "one size fits all" approach. If there are considerable differences in how customers behave, then one ought to investigate these differences in more detail and analyse how it might reflect upon product characteristics and the sourcing of finished goods. Gattorna (2010) indicates that the most critical point to start with is the customers' buying behaviour, especially in the e-commerce business focusing on sourcing of finished goods and delivering from stock. Segmentation as such is a well-established concept (Gattorna, 2010; Christopher et al., 2011), but ways to segment are quite widespread. (For reviews of traditional segmentation techniques see Bonoma and Shapiro, 1984; Cooil et al., 2008). Identified segments, regardless of the technique used, indicate a need for a differentiated product and service delivery, thus abandoning the old and out-dated "one size fits all" approach.

Designing the matching supply chain should mirror the demand side requirements, and in e-commerce this means delivering the appropriate product and service to the consumer/end user. If differences exist in how customers respond to a "one size fits all" strategy, then it is logical to increase the understanding of customers buying behaviour. Gattorna (2010, pp. 62–63) presents five different ways to perform the behavioural segmentation. These methods would likely fit, although they are quite time consuming. Often literature presents business techniques developed for customers. In the rapidly evolving business to consumers (B2C) e-commerce, the fifth method where Gattorna (2010) creates consumer insight using point of sales (POS) data and uses sophisticated data mining techniques could be used. However, e-commerce business maintains a vast amount of transactional data that could be used to segment the consumers based on their behaviour. It could be used to segment consumers based on their buying and returning behaviour measuring their net contribution. A "one size fits all" supply chain strategy inherently assumes that there is one large segment of customers in the market with the same requirements and demands for products and services. It is assumed that a homogenous customer group with the same requirements and demands share a similar buying behaviour.

Organisations perform a vast number of different activities and procedures, such as the delivery and return processes. These activities drive costs that affect the price charged for products and services. In addition, these activities mean different things to different consumers, that is, they are more or less important. Therefore, performing activities better or more efficiently might result in a competitive advantage (Porter, 1996). Performing different activities than competitors might also result in a competitive advantage; however, this is not necessarily cost dependent as it might deliver a value advantage. According to Porter (1996), differentiation arises from a choice of activities and from how organisations perform them. In the rapidly growing e-commerce business, especially in fashion, the competition is quite fierce. Depending on what products e-commerce consumers are purchasing, the delivery and return policies might be more or less critical. Non-adopters or new customers might therefore hesitate to purchase products where fit and size problems are apparent, such as shoes or certain non-flexible garments. Certain companies in the shoe business (Zappos.com, Brandos.se, Hippo.se) are truly generous and offer all customers (Zappos only domestic customers) both free delivery and free returns. This is an indication that these companies see the delivery and return conditions as critical to their business. However, even here the strategy is "one size fits all" and they are therefore likely to over service some customers (Gattorna, 2010). Over servicing is costly and will affect profitability, and customers who misuse this service will increase costs that will have to be paid by all customers returning or not. Misuse occurs when the liberal delivery and return policies affect a consumer's buying behaviour, that is, ordering more than one size, etc. when returns are free. In the global retail industry, companies are likely to see the surrounding complexity but attack it with an operational sledgehammer (Gattorna, 2010). It might be easier and cheaper to deliver only one service level to all customers; however, it is not the most profitable way, as it will undoubtedly under or over service some customer groups.

Traditionally organisations have seen commercial product returns as a nuisance (Blackburn et al., 2004; Guide and Van Wassenhove, 2006) and a necessary evil, a painful process, a cost centre and an area of potential customer dissatisfaction (Stock et al., 2006). Organisations have realised that effective RM can provide a number of benefits, such as improved customer service, effective inventory management and product dispositioning (Norek, 2002; Rogers et al., 2002; Stock et al., 2006; Mollenkopf et al., 2007a, 2007b; Frankel et al., 2010; Mollenkopf, 2010). If organisations view returns as a cost driver rather than a competitive edge, they miss the potential value it could add to them and their customers (Mollenkopf et al., 2007a). From a consumer's perspective, online purchases represents a certain level of risk (Mollenkopf et al., 2007b) relating to product quality, size and fit issues. The customer has to await the delivery and the execution of service delivery as well. Mollenkopf et al. (2007b) argue that a well-executed handling of returns could act as a service recovery opportunity, where the customer evaluates the ongoing service delivery during a particular purchase experience. According to Andreassen (2000), service recovery affects customer loyalty. This also follows the arguments of Harrison and van Hoek (2008) that service performance is important, as customers' perception of delivered products and services is what creates loyal customers. Thus, the importance of RM should not be underestimated in distance sales. RM has started to gain a strategic role in organisations (see Rogers and Tibben-Lembke, 1999). It is time to position RM in its proper place in the supply chain strategy.

This paper views segmenting customers based on their buying behaviour as the starting point and driver for supply chain strategies. Globalisation has reduced consumers' behavioural homogeneity within countries and increased commonalities across countries (Broderick et al., 2007). This facilitates a development of global strategies targeting similar segments in different countries. In a consumer context, behavioural homogeneity deals with the decision-making processes that lead to a purchase decision, and it is used to predict and explain market segment responsiveness (Broderick et al., 2007). Hoyer (1984) investigated consumer decision processes regarding repeat purchases, and Broderick et al. (2007) used this in their study of consumer behaviour. They performed a survey using questions such as "How often do you purchase?" to analyse behavioural homogeneity. Asking questions regarding future purchase and/or historical return behaviour will likely present bias, as one can evaluate how questions and answers are interpreted as well as the accuracy of the responses. It is possible that respondents say one thing and then do another (Alreck et al., 2009). Further, there are also problems when trying to foresee the future and/or remembering the past. Observing customers' behaviour online presents other methodological issues, especially post purchase behaviour, as certain decisions might involve a continuous rather than a discrete processing (Hoyer, 1984), that is, whether or not to return a purchased item. Any data tend to be an historical snapshot of a phenomenon under study. In this case, consumers are a moving target in a continuous change due to increased competition and an increased focus on service delivery. Kim and Kim (2004) investigated customers' purchase intentions for clothing and expressed that their conclusions might not hold for long given the rapid development in e-commerce. In the fast-moving global e-commerce business, it is probably difficult to predict and/or explain consumer behaviour using any type of data. However, customer (consumer) insight can be created using transactional data, and according to Gattorna (2010), using behavioural data alongside transactional data makes it possible to better predict customer behaviour. Transactional data including purchase and return behaviour can therefore be useful when segmenting customers. Utilising actual purchase and return data to uncover how customers behave regarding delivery and return policies, reduces certain methodological issues regarding data collection, that is, perceptions about the future or remembrances of the past. The data as such follows a buying behaviour over time (not a snapshot) and should, therefore, result in fewer validity problems as it measures and follows (if data is updated) a real behaviour, not intentions or perceptions.

In designing supply chain strategies, the literature describes, from a manufacturer perspective, that "one size fits all" is no longer valid, and further, that organisations or rather supply chains need to align with consumers' buying behaviour (Gattorna, 2010). Stock and Mulki (2009) argue for the importance of RM within supply chains, as returns are likely to continue to be a part of business operations. Consumer returns are a central part of e-commerce market operations. The overarching hypotheses for this paper are firstly, that the "one size fits all" strategy does not fit in the fashion e-commerce market either (Christopher et al., 2006; Gattorna, 2010; Ericsson, 2011; Godsell et al., 2011). Secondly, RM is a central part of the supply chain (Autry, 2005; Stock and Mulki, 2009; Mollenkopf et al., 2011) and should be aligned in the design of supply chain strategies. Therefore, the purpose of this paper is twofold: firstly, to empirically test and support whether a "one size fits all" strategy really fits all in the fashion e-commerce business. Secondly, this study aims to evaluate whether consumer returns are a central part in the creation of profitability, and if so, the role of RM in the overall supply chain strategy.

Research design, method and measurement

Designing supply chain and organisational strategies in the fast-moving consumer goods business, especially within fashion e-commerce, requires a profound understanding of customer behaviour and requirements. Therefore, the development of supply chain strategies needs to be both context specific and close to the competitive environment; therefore, it is relevant with a single case design for testing the well-known "one size does not fit all" theory. To test the overarching hypotheses presented in the previous section, we need to select a case organisation, determine a unit of analysis and collect and analyse data. The selected case organisation Nelly.com was selected mainly because they fit the purpose to test specific theories, that is, they do not segment customers or differentiate what they offer customers in terms of products or services. Further, the organisation was willing to support the research with transactional data to test the theory on an organisational and customer level. For the quantitative analysis, Nelly.com exported transactional data from their ERP system. The data contained all (256,233) customer orders for a period of two years (2008–2009) covering their four markets in Denmark, Finland, Norway and Sweden. As the analysis was performed on a customer level, the authors performed detailed calculations to reveal each customer's order sales figures, return figures, contribution margin, etc. Thereafter, each customer was analysed in terms of total sales, average sales per order, total contribution margin, average contribution margin, total number of orders and total number of returns. The organisation's operations manager was interviewed on site during the research and supplied the researchers with vital information regarding freight costs, return freight costs and costs related to the handling of orders and returns.

To test the hypotheses in terms of construct validity, the financial contribution of customers was categorised according to their buying and return habits. Customers were categorised as either repeat or non-repeat customers, depending on whether they made only one purchase or several purchases during the period. They were also categorised as either returners or non-returners, depending on whether they returned at least one item during the period or not. Using this perspective, four different types of customers emerged, and they were categorised as Type A, Type B, Type C and Type D (see Figure 5.1.1).

Differences in contribution per order and contribution per customer and year among the four types of customers were described on a country basis and were further analysed with two-way ANOVAs.

Results

Contribution per order

Table 5.1.1 presents descriptive statistics regarding the contribution per order for all four countries.

Two-way ANOVAs were conducted on the data for all countries to explore the observed differences in contribution per order more in detail. Table 5.1.2 presents the ANOVA for the Swedish subsample (the significant patterns are again identical for all four countries).

Repeat customers and non-returners generate a significantly higher contribution per order (F = 1441, p < 0.001 and F = 2755, p < 0.001 respectively). There is also a significant interaction effect between the factors (F = 1443, p < 0.001). For non-returners, the contribution per order is not significantly different depending on whether they are repeat customers or not. Returners, on the other hand, generate significantly higher contribution per order if they also are repeat customers.

		Return Habits (RH)	
		Non-returner (0)	Returner (1)
Buying Habits (BH)	Non-repeat Customer (0)	Type A	Type B
	Repeat Customer (1)	Type C	Type D

Figure 5.1.1 The four types of customers

Table 5.1.1 Contribution per order

			SWE			NOR			DK			FIN		
		RH	**Mean**	**SD**	*n**	**Mean**	**SD**	*n**	**Mean**	**SD**	*n**	**Mean**	**SD**	*n**
BH	0	0	327	356	80	559	523	23	438	414	15	376	385	12
		1	157	339	19	349	637	4	238	417	3	220	362	4
		Total	295	359	98	525	549	27	406	421	18	339	386	16
	1	0	327	272	29	571	413	8	440	313	4	385	309	4
		1	300	317	37	513	430	7	392	324	3	338	291	5
		Total	312	298	66	544	422	14	418	319	7	358	300	9
	Total	0	327	336	109	562	497	30	439	396	19	378	368	16
		1	253	331	56	448	528	11	318	380	6	287	329	9
		Total	302	336	165	532	508	42	409	396	25	346	358	25

Table 5.1.2 ANOVA on contribution per order in Sweden

Source	Type III sum of squares	d*f*	Mean square	*F*	Sig.	Partial Eta squared
Corrected Model	456861012	3	152287004	1383	< 0.001	0.025
Intercept	9640321806	1	9640321806	87525	< 0.001	0.347
Buy habit	158668911	1	158668911	1441	< 0.001	0.009
Return habit	303417785	1	303417785	2755	< 0.001	0.016
Buy habit * Return habit	158949373	1	158949373	1443	< 0.001	0.009
Error	18127084710	164577	110143			
Total	33575189056	164581				
Corrected Total	18583945722	164580				

Total contribution per customer and year

Table 5.1.3 presents descriptive statistics regarding total contribution per customer and year for all four countries. Note that the values for non-repeat customers are the same as in Table 5.1.3.

Two-way ANOVAs were conducted on the data for all countries to explore the observed differences in total contribution per customer and year more in detail. Table 5.1.4 presents the ANOVA for the Swedish subsample (the significant patterns are again identical for all four countries).

The fact that repeat customers generate a significantly higher total contribution per customer and year ($F = 26160$, $p < 0.001$) is not surprising, to say the least. More interesting is the fact that returners generate a significantly higher total contribution per customer and year than non-returners ($F = 449$, $p < 0.001$). The interaction between the factors is also significant ($F = 2750$, $p < 0.001$). For non-repeat customers, the total contribution per customer and year is significantly lower if they also are returners. For repeat customers, however, the total contribution per customer and year is significantly higher if they also are returners.

Table 5.1.3 Total contribution per customer and year

BH		SWE			NOR			DK			FIN		
	RH	**Mean**	**SD**	*n**	**Mean**	**SD**	*n**	**Mean**	**SD**	*n**	**Mean**	**SD**	*n**
0	0	327	356	80	559	523	23	438	414	15	376	385	12
	1	157	339	19	349	637	4	238	417	3	220	362	4
	Total	295	359	98	525	549	27	406	421	18	339	386	16
1	0	921	944	29	1599	1495	8	1152	996	4	1021	946	4
	1	1321	1747	37	2090	2450	7	1337	1486	3	1250	1270	5
	Total	1147	1467	66	1828	2012	14	1237	1249	7	1150	1145	9
Total	0	484	630	109	824	989	30	579	644	19	532	636	16
	1	936	1542	56	1405	2127	11	807	1237	6	807	1111	9
	Total	637	1056	165	979	1412	42	635	835	25	629	845	25

Table 5.1.4 ANOVA on total contribution per customer and year in Sweden

Source	Type III Sum of Squares	d*f*	Mean Square	*F*	Sig.	Partial Eta squared
Corrected Model	31762561573	3	10587520524	11475	<0.001	0.173
Intercept	58055895333	1	58055895333	62922	<0.001	0.277
Buying habits	24136466847	1	24136466847	26160	<0.001	0.137
Return habits	413915532	1	413915532	449	<0.001	0.003
Buying habits * Return habits	2537269709	1	2537269709	2750	<0.001	0.016
Error	151849456970	164577	922665			
Total	250478290897	164581				
Corrected total	183612018543	164580				

Discussion and conclusions

Gattorna (2010) highlights the importance of understanding the dominating buying behaviour in a supply chain. This study tested whether the "one size fits all" strategy results in a homogenous behaviour in fashion e-commerce. The grouping of customers (see Figure 5.1.1) performed in this paper is not a segmentation as such; however, it surely indicates a heterogeneous buying behaviour thus requesting further qualitative research regarding a differentiated service delivery. The results from the quantitative analysis show an interesting pattern which supports both Gattorna's (2010) theory that the dominating behaviour found in one market appears in the others as well. Further, the findings also support the theory about reduced behavioural homogeneity within countries and increased commonalities across countries (Broderick et al., 2007) as the analysis did find a heterogeneous pattern within markets and matching patterns among markets. The research design used does not allow for discussion as to whether the behaviour has changed over time as suggested by (Broderick et al., 2007); it only acknowledges the matching patterns.

The increasing competition of channels versus channels rather than companies versus companies puts the highlight on all types of relations between and among entities in the supply chain. Relationships grow deeper and more profound and develop into new areas. RM is one of the emerging and important new areas. It is important in all the consecutive dyads in the chain, but it is of particular vital interest in the link between the retailer and the consumer. RM is of great importance for building strong and lasting relations in most dyads, but ultimately, it is decisive in gaining competitive advantage and profitability. RMs role as order winner has not been studied explicitly previously, but this study shows that using purchasing and return data as bases for segmentation can improve performance considerably.

Most e-business companies have a wealth of data concerning returns. However, it can be stated that even though they are drowning in data, they are starving for information. This means that they need a guideline for how to analyse existing data and how to collect valuable information.

Experiments with different tariffs for transportation and returns show that consumer behaviour is influenced by differentiated costs. The question is how to use this in a systematic segmentation model. This research shows one possible approach is to use return data as a vital part of the model and complement it with purposefully collected data concerning buying behaviour (Ericsson, 2011). This fits quite well with the evolving demand chain approach with its focus on consumer behaviour, insight and alignment of marketing, sales and logistics activities.

It also goes hand in hand with the development of retailing with increasing co-creation and reliance on social media. The term co-creation is not new, however, but it is now receiving more attention as companies endeavour to differentiate themselves from the competition. Where in the past value was created by companies in the chain, value today is co-created at multiple points of interaction. Not only the physical product, but also the services in the value package can be co-created. RM is one of the most promising areas for co-creation!

To summarise these research findings and relate the results to the overarching hypotheses and research purpose, the authors conclude that there is conclusive support for both hypotheses. The behavioural model described in this pattern shows that customers behave in a heterogeneous way and this indicates that the "one size fits all" theory is obsolete as the literature indicates (Christopher et al., 2006; Gattorna, 2010; Ericsson, 2011; Godsell et al., 2011). The results also support previous findings that RM is an important part of the supply chain (Norek, 2002; Rogers et al., 2002; Stock et al., 2006; Mollenkopf et al., 2007a, 2007b; Frankel et al., 2010; Mollenkopf, 2010), as consumer returns are an important part of e-commerce customer behaviour and therefore important both to the case organisation and its partners, including the customers. Further, Mollenkopf (2007b) highlights the risks involved in e-commerce and the importance of RM in the service recovery process.

This research empirically supports the importance of RM in the service recovery in fashion e-commerce, as quite a large group of customers are systematically returning. However, companies using a "one size fits all approach" are focusing solely on RM efficiency and therefore missing the opportunity to create a competitive edge. They are missing the potential value it could add to the organisation and their customers (Mollenkopf et al., 2007a) as well as their supply chain partners. A differentiated return service might attract new customers (non-adopters) and better support the customer groups with diverging patterns or returns identified in this paper as RM. Clearly, this is a part of the value creation, at least to certain customers.

We are all hardwired with a range of values as humans, and we all have different expectations towards products and services. So, therefore there is an interaction between product/service categories and buying behaviour, but it is the buying behaviour that determines demand patterns (Gattorna, 2010) and therefore how we should engineer our supply chains, forward and reverse (RM). And it is the range of buying behaviours which determine the number of supply chains in the end-with a bit of approximation to make the whole thing workable.

Future research

The findings reported in this study show how customers behave and that there clearly is a heterogeneous response from customers on the "one size fits all" strategy. It is important though to stress that the segmentation is but a starting point for aligning resources of the firm (Gattorna, 2010) and the supply chain. Future research should include qualitative research that creates a detailed understanding of why customers behave differently, it is important to investigate their values, and how to, from a supply chain perspective, design and deliver matching value propositions.

E-commerce is an extremely competitive marketplace (Kim and Kim, 2004). Therefore, the demand predictability is troublesome, and customers returning goods increase the uncertainty and variability of demand. Early indications of demand, in season, might turn out differently and change the pattern when returns arrive later in time. This might have implications on how we source and replenish products. Therefore, future research needs to address the behaviour pattern described in this paper in combination with different product categories. This means testing Gattorna's (2010) dynamic alignment approach in e-commerce aligning customers/market, strategy, internal cultural capability, and leadership style.

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5.2
The Retailer's Stock-Keeping Unit Allocation Problem

Balram Avittathur and Janat Shah

Introduction

Increase in competition is witnessing the twin trends of product price erosion and product proliferation. Retailers cater to the price sensitive customer by providing standard low-priced products. They also cater to the customer segments that are willing to pay a premium for customisation by offering customised extensions of the standard product. While the profit margin for a standard product is generally low and the profit depends on volumes, its customised extensions carry higher profit margins. However, the standard product typically has longer shelf life while its customised extensions are promoted as flavours of the season and have short shelf lives. Examples of this are (i) breakfast cereal (standard product) with flavours for different climatic seasons, (ii) chocolate (standard product) with extensions for different occasions like vacation and festivals and (iii) sportswear (standard product) with flavours for different game seasons/occasions like basketball season, cricket World-Cup and Olympic Games. Increase in customised extensions results in increase in demand uncertainty and higher inaccuracy in forecasting demand for individual stock-keeping units (SKUs). This in turn implies higher possibility of stock-outs or oversupply.

Retailers of products with limited shelf life are faced with the dilemma of stocking the right mix of standard product and its customised extensions or SKUs. On the one hand, stocking only a standard product ensures logistics that can be managed easily and efficiently, lower manufacturing cost, and stable demand with minimal stock-out or oversupply. The profit is volume driven and there are lesser losses owing to stock-out or oversupply. On the other hand, stocking only customised products implies higher margins, higher logistics complexity owing to high variety, higher manufacturing costs and higher losses owing to stock-out and oversupply. In this paper, we attempt to derive the optimal allocation of a standard product and its customised SKUs that would maximise the retailer's profit.

The above problem belongs to a class of problems known as newsboy problem or single period inventory model. Over the last decade, several researchers have worked on multiple-product single inventory problem. Refer to Khouja (1999) for an excellent survey on capacitated multiple-product single inventory problem. We build our model as an extension of the work done by Khouja, Mehrez and Rabinowitz (1996). The problems are modelled in §2. The proposed solution methodologies with numeric examples for both problems are also described in this section. Discussions and conclusions are in §3.

The problems and solution methodologies

In the newsboy problem, an optimal stock of product is built in the beginning of the period from which the demand for that period is met. However, the newsboy cannot replenish the stock during the period in case the demand is more than the opening stock. Hence, the demand that is excess of the opening stock is lost sales for the newsboy. Also, the newsboy has to clear the stock left at the end of the period, owing to demand being less than the opening stock, at a salvage or clearance price.

Notations

Subscripts, parameters and variables:

I = $\{i|i = 1, \ldots, p\}$
= set of customised extensions of standard product
c unit cost of procuring and retailing a standard product
r unit retail (un-discounted) price of standard product
m unit clearance price of standard product, $m \leq c$
c_i unit cost of procuring and retailing a customised product i, $c_i \geq c \; \forall \; i$
We assume that the retailer can predict aggregate demand accurately, though, it is not the case with the customised products.
r_i unit retail (un-discounted) price of customised product i, $r_i \geq r \; \forall \; i$ and $r_i - c_i \geq r - c \; \forall \; i$
F_i fixed cost per period for retailing customised product i
m_i unit clearance price of customised product i, $m_i \leq c_i$
M a very large number

D aggregate demand of standard product and its customised extensions for period in question (model period).

x_i demand of customised product i at retail price r_i in model period, described by an independent discrete distribution such that $\sum_i x_i \leq D$.

J $= \{j | j = 0, 1, 2, \ldots, n\}$
= set of integral numbers that represents $(n + 1)$ possibilities of discrete demand for each customised product i at retail price r_i in model period.

P (j^i) probability that demand in model period of customised product i is equal to j

It may be noted that n is chosen such that $\sum_{j=0}^{n} P(j^i)$ is very close to 1.00 (e.g., 0.99) for all i. It is obvious from above definitions that $n \leq D$.

Decision variables:

s optimal stock-level of standard product for model period

y_i = 1, if customised product i is retailed in model period
= 0, otherwise

s_i optimal stock-level of customised product i in model period

Derived variables:

Following are variables that are derived on the basis of parameters and variables defined above.

X aggregate sale in model period of all customised products at respective retail (un-discounted) prices, $X = \sum_i \min(x_i, s_i)$. This implies that $X \leq \sum_i s_i$.

x demand in model period of standard product (residual of customised SKU demands) at retail price r. This is dependent on aggregate demand and aggregate sale of customised products such that $x = D - X$
The earlier definition of D implies that demand for standard product will at most be equal to D. Hence, s will have D as the upper bound.

$P(x)$ probability that demand in model period of standard product is equal to x

It may be noted that it is analytically complex to determine the demand distribution of x for $p \geq 2$ problem and, hence, the optimal solution. We formulate the problem separately for $p = 1$ and $p = 2$.

One customised product, one standard product problem

The different combinations of customised and standard products sales for this problem are as follows:

Event	Customised Product	Standard Product
$x_1 \le s_1$	x_1	$D - x_1$
$x_1 > s_1$	s_1	$D - s_1$

Formulation

Maximise

$$\prod = \sum_{j^1=0}^{s_1} \left\{ \begin{array}{l} (r_1 - c_1)j^1 - (c_1 - m_1)(s_1 - j^1) + (r - c)\min(s, D - j^1) \\ -(c - m)\max(0, s - [D - j^1]) \end{array} \right\} P(j^1) + \sum_{j^1=s_1+1}^{n} \left\{ \begin{array}{l} (r_1 - c_1)s_1 + (r - c)\min(s, D - s_1) \\ -(c - m)\max(0, s - [D - s_1]) \end{array} \right\} P(j^1) - F_1 y_1 \quad (1)$$

Subject to:

$$s_1 \le M\, y_1 \quad (2)$$

$$s, s_1 \ge 0 \quad (3)$$

$$y_1 \in (0,1) \quad (4)$$

Constraint (2) indicates that customised product will be stocked only if the retailer decides to retail the same. The constraint denoted by (3) indicates non-negativity of the stock-level decision variables and constraint denoted by (4) indicates that the decision regarding whether to retail customised product is a binary variable.

Two customised products, one standard product problem

The different combinations of customised and standard products sales for this problem are as follows:

Event	Customised Product 1	Customised Product 2	Standard Product
$x_1 \le s_1$, $x_2 \le s_2$	x_1	x_2	$D - x_1 - x_2$
$x_1 \le s_1$, $x_2 > s_2$	x_1	s_2	$D - x_1 - s_2$
$x_1 > s_1$, $x_2 \le s_2$	s_1	x_2	$D - s_1 - x_2$
$x_1 > s_1$, $x_2 > s_2$	s_1	s_2	$D - s_1 - s_2$

Formulation

Maximise

$$\prod = \sum_{j^1=0}^{s_1} \left(\begin{array}{l} \sum_{j^2=0}^{s_2} \left\{ \begin{array}{l} (r_1 - c_1)j^1 - (c_1 - m_1)(s_1 - j^1) \\ +(r_2 - c_2)j^2 - (c_2 - m_2)(s_2 - j^2) \\ +(r - c)\min(s, D - j^1 - j^2) \\ -(c - m)\max(0, s - [D - j^1 - j^2]) \end{array} \right\} P(j^2) \\ + \sum_{j^2=s_2+1}^{n} \left\{ \begin{array}{l} (r_1 - c_1)j^1 - (c_1 - m_1)(s_1 - j^1) \\ +(r_2 - c_2)s_2 \\ +(r - c)\min(s, D - j^1 - s_2) \\ -(c - m)\max(0, s - [D - j^1 - s_2]) \end{array} \right\} P(j^2) \end{array} \right) P(j^1)$$

$$+ \sum_{j^1=s_1+1}^{n} \left(\begin{array}{l} \sum_{j^2=0}^{s_2} \left\{ \begin{array}{l} (r_1 - c_1)s_1 + (r_2 - c_2)j^2 \\ -(c_2 - m_2)(s_2 - j^2) \\ +(r - c)\min(s, D - s_1 - j^2) \\ -(c - m)\max(0, s - [D - s_1 - j^2]) \end{array} \right\} P(j^2) \\ + \sum_{j^2=s_2+1}^{n} \left\{ \begin{array}{l} (r_1 - c_1)s_1 + (r_2 - c_2)s_2 \\ +(r - c)\min(s, D - s_1 - s_2) \\ -(c - m)\max(0, s - [D - s_1 - s_2]) \end{array} \right\} P(j^2) \end{array} \right) P(j^1)$$

$$- F_1 y_1 - F_2 y_2 \qquad (5)$$

Subject to:

$$s_i \le M\, y_i \quad \forall\, i \qquad (6)$$

$$s,\ s_i \ge 0 \qquad (7)$$

$$y_i \in (0,1) \qquad (8)$$

The constraints in this formulation are similar to the earlier formulation.

The above formulations are an adaptation of the multi-product newsboy problem (Hadley and Whitin, 1963). For the customised product i, when demand x_i is less than the stock-level, s_i, a unit profit of $(r_i - c_i)$ is realised on quantity x_i and an unit loss of $(c_i - m_i)$ is incurred on quantity $(s_i - x_i)$. When demand x_i is greater than or equal to the stock-level, a unit profit of $(r_i - c_i)$ is realised on quantity s_i. The unsatisfied demand, $(x_i - s_i)$, is met by sale of standard product, subject to availability. A heuristics approach is proposed for solving both the problems. Though complex, the heuristic approach for problem with $p = 2$ can be extended to problem with $p > 2$. Using numerical examples, we compare the heuristics with the optimal solutions. We attempt to gauge the heuristic accuracy through these comparisons.

The solution methodology for both problems comprises of the following steps: (1) determining initial values of s_i, $s_i^{'}$; (2) determining y_i values and final values of s_i; and (3) determining value of s.

Determining initial values of s_i for both problems

The heuristic approach for determining initial value of s_i, $s_i^{'}$, is same for both the problems. It is as described below:

Cost of under-stocking customised product, $i = (r_i - c_i) - (r - c)$ (9)

Cost of overstocking customised product, $i = c_i - m_i$ (10)

Referring to Martinich (1997), for discrete demand distribution,

$$s_i^{'} = \{smallest\ j \mid \sum_{j=0}^{s_i} P(j^i) \geq [(r_i - c_i) - (r - c)] / [(r_i - m_i) - (r - c)]\} \quad (11)$$

Determine whether to retail customised product i or not (y_i values) for both problems

By our definitions, the profit margin for any of the customised product is greater than that of the standard product. However, each customised product has a fixed cost of retailing, F_i, which is incurred when customised product i is retailed. This implies that a customised product should be retailed only if the marginal profit owing to retailing it is greater than the fixed cost that is incurred in retailing it.

Let Π_i be the maximum profit for a one standard product one customised product problem where i is the customised product. The marginal profit owing to retailing the customised product i is equal to $\Pi_i - (r - c)D$. Then,

$$y_i = 0 \text{ and } s_i = 0, \text{ if } \Pi_i - (r - c)D < 0, \quad (12a)$$

$$y_i = 1 \text{ and } s_i = s_i^{'}, \text{ otherwise} \quad (12b)$$

Determining value of s

One customised product, one standard product problem

For the one standard product one customised product problem, it is easy to determine the probability distribution of demand per period of standard product at retail price r, x. In this problem, if Equation (12a) is true, then retailer retails only the standard product. As aggregate demand is accurately predictable, it is sufficient for him to stock D units of the standard product. However, when Equation (12b) is true, then probability distribution of x can be expressed as follows:

$$P\,(x = D - j^1) = P\,(j^1) \tag{13a}$$

$$P(x = D - s_1) = \Sigma_{j^1 = s_1}^{n} P(j^1) \tag{13b}$$

Also,

$$\text{Cost of under-stocking standard product} = r - c \tag{14}$$

$$\text{Cost of overstocking standard product} = c - m \tag{15}$$

If h is an index of integral numbers that represent different possibilities of x, then

$$s = \left\{ smallest\ h \mid \sum_{h=D-s_1}^{D} P(h) \geq (r-c)/(r-m) \right\} \tag{16}$$

Two customised products, one standard product problem

In this problem, only those customised products for which $s_i \geq b_i$ are retailed. The optimal stock-level of customised product i is determined using Equation (11). If neither of the customised products is retailed, the retailer stocks D units of standard product as aggregate demand can be predicted accurately. If only one of the two customised products is retailed, this problem transforms into one standard product one customised product problem, the solution methodology for which is already described above. When both customised products are retailed and their demands distributions are independent of each other, the probability distribution of x is computed from the probabilities of different combinations of x_1 and x_2 values as described earlier.

If h is an index of integral numbers that represent different possibilities of x, then

$$s = \{smallest\ h \mid \Sigma_{h=D-s_1-s_2}^{D} P(h) \geq (r-c)/(r-m)\} \tag{17}$$

Nume rical example

Consider a retailer whose aggregate demand in a particular period is 16 units as per accurate forecast he has. Let the discrete demand for customised product follow a Poisson distribution with mean described by λ_1. Also, let $r_1 - c_1$ and $r - c$ be 20 and 15, respectively. The $c_1 - m_1$ and $c - m$ values are derived from ten simulation critical fractile values shown in the table below. The results using an optimal solution methodology and the above suggested heuristic solution methodology for two fixed cost per period of retailing, 0 and 10, are as shown in Table 5.2.1. The optimal solution is determined by solving the problem as a mixed integer programming problem (MIP).

Table 5.2.1 One customised product problem

		$\lambda_1 = 4$							$\lambda_1 = 6$						
		Optimal solution			**Heuristic solution**				**Optimal solution**			**Heuristic solution**			
Critical fractile	F_1	s_1	s	Π_{max}	s_1	s	Π_{max}	**Diff**$_\Pi$	s_1	s	Π_{max}	s_1	s	Π_{max}	**Diff**$_\Pi$
0.1	0	1	15	243.81	2	14	242.86	0.95	3	13	249.68	3	13	249.68	0.00
0.2	0	2	14	245.60	2	14	245.60	0.00	3	13	251.73	4	12	250.68	1.05
0.3	0	2	14	246.52	3	13	243.98	2.54	4	12	252.62	5	11	248.59	4.03
0.4	0	2	14	246.98	3	13	245.43	1.55	4	12	253.59	5	11	250.75	2.84
0.5	0	2	14	247.25	4	13	244.13	3.12	4	12	254.17	6	12	250.52	3.65
0.6	0	3	14	247.91	4	14	247.41	0.50	5	12	254.80	6	12	254.24	0.56
0.7	0	4	14	249.92	5	14	249.64	0.28	6	13	257.35	7	13	257.18	0.17
0.8	0	5	15	252.65	6	15	252.48	0.17	8	13	260.85	8	13	260.85	0.00
0.9	0	6	15	255.96	7	15	255.96	0.00	9	14	265.00	9	14	265.00	0.00
0.1	10	0	16	240.00	0	16	240.00	0.00	0	16	240.00	0	16	240.00	0.00
0.2	10	0	16	240.00	0	16	240.00	0.00	3	13	241.73	4	12	240.68	1.05
0.3	10	0	16	240.00	0	16	240.00	0.00	4	12	242.62	0	16	240.00	2.62
0.4	10	0	16	240.00	0	16	240.00	0.00	4	12	243.59	5	11	240.75	2.84
0.5	10	0	16	240.00	0	16	240.00	0.00	4	12	244.17	6	12	240.52	3.65
0.6	10	0	16	240.00	0	16	240.00	0.00	5	12	244.80	6	12	244.24	0.56
0.7	10	0	16	240.00	0	16	240.00	0.00	6	13	247.35	7	13	247.18	0.17
0.8	10	5	15	242.65	6	15	242.48	0.17	8	13	250.85	8	13	250.85	0.00
0.9	10	6	15	245.96	7	15	245.96	0.00	9	14	255.00	9	14	255.00	0.00

For the same aggregate demand, consider a two customised products scenario with λ_1 and λ_2 equal to 6 and 4, respectively. Let, $r_1 - c_1$, $r_2 - c_2$ and $r - c$ be 20, 20 and 15, respectively. The $c_1 - m_1$, $c_2 - m_2$ and $c - m$ values are derived from ten simulation critical fractile values shown in the Table 5.2.2. The results using an optimal solution methodology (solving problem as an MIP) and the above suggested heuristic solution methodology for two fixed cost per period of retailing, 0 and 10, are as shown in the Table 5.2.2.

Of the 60 simulations in Table 5.2.1 and Table 5.2.2, the highest maximum profit difference between optimal solution and heuristic solution is 6.09 (Table 5.2.2, $F_i = 0$, Critical Fractile = 0.3). This works out to an error of 2.35%. The average error for the 60 simulations works out to 0.45%. Hence, it is reasonable to conclude that the proposed heuristic generates solutions that are close to optimal solution.

Discussion and conclusions

From the numeric examples shown in previous section, it can be seen that the fixed cost of retailing customised SKU is a crucial factor in deciding whether the SKU should be retailed or not. It is important that this is also considered by the retailer and not just the higher profit margins that generally accompany the customised SKUs.

The formulation and the results clearly indicate that the stock-level of customised SKU will depend on the cost of under-stocking and cost of overstocking the SKU. As we saw in the formulation, the cost of under-stocking a customised SKU depends not only on the profit margin of the customised SKU but also on the profit margin of the standard SKU. Hence, customisation decisions should factor the fixed cost of retailing of customised SKUs as well as the increase in profit margin owing to creation of the customised SKU. When fixed cost of retailing a customised SKU is high and the incremental profit margin of the same is negligible, it does not make sense to retail customised SKUs.

The formulation and examples also reveal another issue. In many retail situations, it is common to see only customised SKUs being retailed. In such situations, if a customer does not get the customised SKU he/she seeks, he/she has no option but to forsake the purchase. However, when there is one standard product available, customers who do not get the SKU of their choice can opt for that. For the retailer, a lost sale gets converted into a low-margin sale. It also implies that where a standard product is not available currently, introduction of one could be an ideal strategy for the retailer that would enable them to weed out slow moving

Table 5.2.2 Two customised product problems

Critical fractile	$F_i = 0$										$F_i = 10$								
	Optimal solution				Heuristic solution						Optimal solution				Heuristic solution				
	s_1	s_2	s	Π_{max}	s_1	s_2	s	Π_{max}	Diff_{Π}		s_1	s_2	s	Π_{max}	s_1	s_2	s	Π_{max}	Diff_{Π}
0.1	3	1	12	253.49	3	2	11	252.54	0.95		0	0	16	240.00	0	0	16	240.00	0.00
0.2	3	2	11	257.33	4	2	10	256.28	1.05		3	0	13	241.73	4	0	12	240.68	1.05
0.3	4	2	10	259.14	5	3	9	253.05	6.09		4	0	12	242.62	0	0	16	240.00	2.62
0.4	4	2	10	260.57	5	3	9	258.93	1.64		4	0	12	243.59	5	0	11	240.75	2.84
0.5	4	3	10	262.54	6	4	9	260.79	1.75		4	0	12	244.17	6	0	12	240.52	3.65
0.6	5	3	10	266.03	6	4	9	266.24	0.00		5	3	10	246.03	6	0	12	244.24	1.79
0.7	6	4	10	270.70	7	5	10	270.35	0.35		6	4	10	250.70	7	0	13	247.18	3.52
0.8	8	5	10	275.83	8	6	10	275.67	0.16		8	5	10	255.83	8	6	10	255.67	0.16
0.9	9	6	11	281.99	9	7	11	281.99	0.00	w	9	6	11	261.99	9	7	11	261.99	0.00

customised SKUs and provide a hedge against high demand uncertainty of individual SKUs.

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5.3
Exploring Supply Chain Relationships and Information Exchange in UK Grocery Supply Chains: Some Preliminary Findings

Mark Barratt

Literature review

Despite the concept of supply chain management having existed since the early 1980s (Oliver and Webber, 1982; Houlihan, 1984, 1985), there is still significant confusion as to the meaning of the concept and particularly as to how to implement it (Kearney, 1994; Neuman and Samuels, 1996). Such confusion is further enhanced by the multitude of terminology and definitions (New, 1996; McGuffog, 1997) arising from the academic and practitioner literature.

One aspect of the SCM concept is clear, in order to coordinate the supply chain as a whole, cooperative relationships based upon mutual dependency (Atkin, 1993) must be developed between the organisations in the chain. Such relationships must replace the more traditional adversarial relationships which have fostered a "silo" or "trench warfare" mentality resulting in extremely inefficient and ineffective supply chains (McGuffog, 1997). There is clear evidence that some organisations have recognised this and are attempting to implement such an approach within the management of their supply chains (Kearney, 1994), however, there would appear to be a bias towards the formation of relationships with customers at the expense of relationships with suppliers (Kearney, 1994). It is not clear as to the reasons for this apparent bias.

Limited empirical work has been undertaken in modelling and studying supply chain relationships. Most research carried out in this area has focused on one relationship or a single level of the supply chain, such as buyer/seller, shipper/carrier, and so on (Ellram, 1991; Harland, 1996). Such research appears to ignore the systemic view of supply chain philosophy; moreover, the traditional "pipeline" view of the supply chain needs to be replaced with that of the "inter-business network" (Harland, 1996; Juga, 1996). Many of the definitions of SCM lend themselves to the representation of the supply chain as either a network (Christopher, 1992; Juga, 1996) or that of the external supply chain (Houlihan, 1985; Stevens, 1989; Davis, 1993). However, much of the existing research in to supply chains is in the form of internal supply chains (Oliver and Webber, 1982) or dyadic relationships (Cooper and Ellram 1993). Thus, there is a distinct need for research into supply chains as networks of relationships between organisations. This view is supported by Harland (1996) who suggests that "as there is a move towards network relationships, the need for research in external supply chains and networks will increase".

It is also clear from the literature that organisations must share demand and cost information if competitive advantages are to be achieved (Kearney, 1994; Christopher, 1997). If organisations continue with the

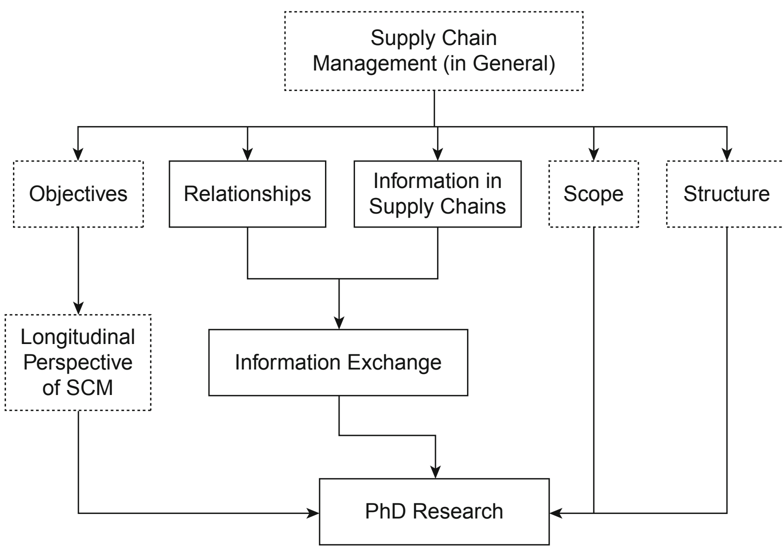

Figure 5.3.1 Research themes

practice of charging for forecast or demand data (Kearney, 1994), then the ideal of cooperative relationships is not likely to be achieved. It has also been suggested that information sharing is not open and extensive but restricted and selective (Ogbonna and Wilkinson, 1996). There is a distinction between own-label suppliers, whose relationships with retailers in many cases appear to be increasingly close, and branded manufacturers, with whom the relationship remains selectively distant (Ogbonna and Wilkinson, 1996). Christopher (1997) suggests that the way forward is a re-orientation of the supply chain towards cooperation through shared information.

From the literature review, a number of research themes emerged, which were to form the focus of the research. The themes identified were as detailed in Figure 5.3.1. For the purposes of this paper only, findings pertaining to the supply chain relationships and information in the supply chain themes will be presented. Supply chain relationships are considered by the literature as critical to supply chain integration. Many authors (e.g., Kearney, 1994; Christopher, 1997) suggest that information exchange is key to obtaining competitive advantage.

Research methodology

In a subject area that has traditionally borrowed theoretical insight from other disciplines rather than developing its own theories, the research undertaken here is part of a wider exploratory study, whose aim is to develop theoretical propositions concerning the implementation of cooperative supply chain relationships based upon information exchange. The chosen research methodology for this paper is that of the case study. A number of authors have highlighted the growing interest in the management discipline in the use of case study based research (Eisenhardt, 1989; Ellram, 1996). Ellram (1996) goes on to suggest that empirical research can include either quantitative analysis, qualitative analysis or a mixture of both. She also suggests that qualitative results are frequently expressed verbally, often to create an understanding of relationships or complex interactions. Ellram (1996) suggests that case studies focus on holistic situations (i.e., a supply chain) in real life settings and tend to have set boundaries of interest, such as an organisation, a particular industry or particular type of operation. Yin (1981) suggests that a case study method is often chosen because the researcher wants to know how the context of the phenomenon of interest affects the outcomes.

A number of authors (Hogarth-Scott and Parkinson, 1993; Ellram, 1996; Juga, 1996) support the use of the case study method in logistics and supply chain management research. Going beyond Yin's (1981) initial criteria, the case study method is deemed to be particularly appropriate in a supply chain management context for the following reasons: Firstly, the difficulty in distinguishing between a phenomena (*a cooperative supply chain relationship)* and its context (*the UK retail grocery sector)* (Yin, 1981). It is argued by the author that the sector is made up of a myriad of relationships between organisations, that when considered collectively, form the UK retail grocery sector. Secondly, the immaturity of the field of logistics and supply management.

Pilot study research findings

The pilot was undertaken to compare the findings of the literature review, as summarised above, with the current thoughts and views of a cross section of practitioners from various roles and positions in the UK retail grocery sector. The pilot was also used to raise further issues for consideration in the subsequent main part of the author's study. As the context of the research is supply chains within the UK grocery sector, it was decided by the author to approach organisations with varying roles and positions in such supply chains. Interviews were undertaken with the following types of organisations: four retailers; five grocery manufacturers; two raw material suppliers; two logistics providers; one packaging supplier; one farmer, one IT service provider and five supply chain consultants. The preliminary findings from the pilot study follow.

Status of relationships

There are signs that while many relationships are still adversarial in their nature, there is a degree of migration towards more cooperative types of relationships. A number of the manufacturers interviewed are now reporting more cooperative relationships with retailing counterparts.

Relationship objectives

Objectives appear to be mainly financial, but are also focused upon improving service levels and developing a greater understanding of activities in the supply chain.

Relationship benefits include: growing the business, total supply chain cost reduction, improved knowledge of how the supply chain operates, improved service levels, reduction of inventory, improved standardisation of processes, systems, etc. and, most importantly, improved communication.

Types and basis of relationships are mutual, strategic, broader (wider relationship interface), positive, communicative, longer term, process alignment, information based. Relationships are based upon mutuality, trust, understanding, focused (by category), value adding and empowering.

Relationship problems include severe lack of understanding of needs (supplier, customer and consumer), technical (lack of standardised integrated systems), culture, lack of shared objectives, control (poor understanding of supply chain specific performance measures).

Cooperation and key success factors are sharing (exchange of personnel), teams (multi-disciplinary), recognition (that relationships can take on many forms), organisational (inter-board participation). Understanding common process requirements, mutuality, strategic (in terms of longer term), commonality, financial benefit, consumer focused, innovative, open, senior management.

Several key areas relating to information in supply were identified, and these are summarised as follows:

The role of information

Accurate timely information (as opposed to data) can remove significant inventory costs from the supply chain. Critical to the functioning of the integrated supply chain, information also enables enhanced decision-making providing greater certainty.

Why share information?

Sharing information offers increased visibility across the supply chain and enables participating organisations to synchronise their activities and improve their responsiveness.

Benefits of information exchange

Exchanging information across the supply chain offers benefits that include, informed decision-making resulting from improved visibility, automation of order processing, inventory minimisation together with improved responsiveness (in terms of service and promotions) and on-shelf product availability.

What information to exchange

Demand information (consolidated at regional distribution centre level) on as close to a real time basis, product information including inventory levels, promotional information, forecast information, new product information.

How information is exchanged

Information should be shared electronically, via Internet based intranet/extranet systems. There are still signs that information is communicated via faxes and telephones due to the lack of system integration. Retailers and manufacturers are already adopting this medium of information exchange.

Barriers to information exchange

Many barriers to information exchange exist. These include: information standards (one manufacturer was faced with dealing with three separate Internet based systems used by retailer customers), organisational (information is still regarded as a source of power) and individual mindsets (there is a lack of people with the ability to understand the implications usage's of information exchange), commercial sensitivity, cost (although the Internet is providing a cheaper alternative), ability to collect, share and process information and understanding of the role of information and the need to exchange such information across the supply chain.

Conclusions

A number of organisations, including retailers and manufacturers, recognise the need to develop cooperative relationships throughout their supply chains. However, these organisations accept that the development of such relationships means a significant upheaval within their organisations. Such upheaval is due to the need to develop an organisational supply chain view, which is contrary the traditional working practices of most employees in organisations. All of the retailers interviewed are developing relationships, albeit with a limited number of suppliers, based upon the sharing of information (via the Internet), shared resources, mutual commitment and an awareness that a longer term view of supply chain management must be adopted if it is to be successful.

There are two distinct views regarding the role of information. In the retail and manufacturing organisations interviewed, information regarding consumer demand is seen as vital to reducing total supply chain costs. In organisations much further removed from the consumer, the role of information is not so clearly understood. This may be due to the fact that the concept of supply chain management is not so clearly understood or appreciated. An ongoing mistrust of large retailers may also be grounds for the lack of willingness to enter relationships with such organisations or to exchange information, which may in fact be beneficial to both organisations.

The next phase of the author's study is a case study of an entire supply chain, beginning with a retailer and including manufacturer, raw material suppliers, packaging suppliers, logistics providers and IT service providers. All interfaces between the organisations (both internally and externally) will be examined, together with an examination of the impact of information exchange upon the supply chain as a whole.

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6
ICT and Decision Support

6.1
Traceability Information Management System for Composite Production Process

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Introduction

Much attention is now being paid to traceability systems which provide information on the production and distribution history of a product, especially in the food industry. Since the purpose of the system is focused on consumer service, the system is generally independent of a main management system, and therefore, the obtained traceability information is not applicable to the solution of production and distribution management problems. For example, dispatching the order information of parts, which is necessary to the traceability system, has generally been managed in MRP modules. Furthermore, sharing rigid inventory information of an individual product, which is easily obtained from the traceability system, can enlarge and extend the performance of supply chain management (SCM) systems. Horikawa et al. (2005) proposed a traceability information system which cooperates with ERP. The system comprises three-layered modules, namely physical logistics layer, ERP layer and independent data management layer. Traceability is realised with an information exchange among the three layers. This structure has the advantage over other applications at practical level as it replaces some modules to more suitable components such as more commonly available ERP package.

They developed a prototype traceability system and applied eight weeks of experimental order data of processed seafood. Through the experiment, they confirm that the system can calculate both trace-forwarding and trace-back information. The prototype system, however, did not support composite production process completely, where the blanching process was regarded as an assembly process. Radio frequency identification (RFID) tags were utilised to help identify each item. However, identification was realised only with the tag serial number. This caused the inconvenient task of having to identify each item at the material handling process level.

This paper is a companion of Horikawa et al. (2005). We extend MRP modules for composite production process and propose an additional sales order acceptance procedure. As most of the products, especially in the processed food industry, have a composite production process, supporting the process makes the application area wider. An additional sales order acceptance procedure is utilised in surplus parts consumption for the sales division at the company, where surplus parts naturally occur as a result of the blanching process.

Three-layered traceability system

The proposed system comprises three independent layers: physical logistics layer, ERP layer, and independent data management layer. See Figure 6.1.1.

Our proposed system is characterised with the following six properties (see bullet points).

- Supporting both trace-back and trace-forwarding:

Trace-back is known as searching and obtaining the traceability history from products to material. Trace-forwarding is known as searching and obtaining the history from material to products. The proposed system supports both trace-back and trace-forwarding. The function of trace-back is expected to achieve consumer's needs. Function of trace-forwarding is expected to correspond with some troubles in supply chain and reduce damages.

- Targeting complete supply chain

The proposed system prepared data interchange functions over the supply chain to achieve traceability for the complete supply chain. Functions and modules executing inter-company data transfer are centred in the independent data management layer. In other words, all traceability information is accumulated at the independent data

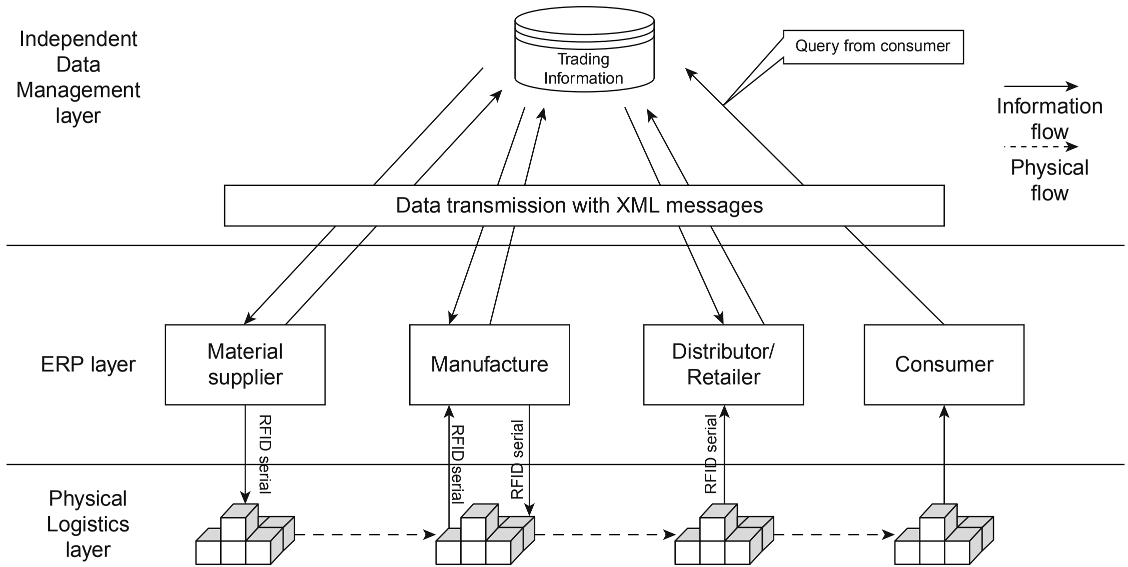

Figure 6.1.1 Three-layered traceability system

management layer. Therefore, the information is regulated and released at the layer according to releasing policy of each company. As releasing more detailed information contributes to better products value added information, positive tendency to open the information is expected.

- Introducing small unit management

Unit of managing stocks is determined to each works order, not by each item. As a result, the lot for material and parts is set to be small. At picking and shipping processes, each product has to be identified with its corresponding works order. This identification process is expected to have almost the same effect with inventory. This provides visualisation of inventory in supply chain management.

- Cooperating with enterprise resource planning system

The proposed system utilises enterprise resource planning system as development base. Some functions to realise traceability, for example, data interchange with another layer, are designed, developed and added. This reduces initial cost of introducing traceability system especially on changeover for information system.

- Orientating manufacturing process

Nowadays, most foods are consumed as processed food. Supporting the manufacturing process becomes a key point in widely introducing the food traceability system. The proposed system is focused on the manufacturing process, which is an important process in the supply chain since appearance and characteristics of items are going to be changed.

Recent industrial products also have the same problem in that the identification of the material and production process becomes difficult. Gaining information on parts used in a certain product becomes an important tool as far as responsibility of product quality is concerned.

- Supporting composite production process

In the processed food industry, the production process becomes the composite process in which the blanching process and the assembly process are executed in a same production line. The proposed traceability system supports this composite process. The system is also designed and implemented to apply only the blanching process or only the assembly process. This characteristic makes the application area of the system wide. We also propose an additional sales order acceptance procedure which is utilised to reduce naturally obtained surplus parts stocks.

- Traceability information processing

Traceability in the supply chain can be realised with a flow of information among these three layers. The ERP layer deals with the main core of business information, such as order, purchase, production, shipment, etc. at each stage of the supply chain. These functions are usually realised by ERP package software. Based on the management information, for example, production schedule, from the ERP layer, information of each material and product is managed at the physical logistics layer. Essential and necessary information for traceability is collected and processed at this layer and is transmitted to another layer.

At the independent data management layer, entire information is gathered both from the ERP layer and the physical logistics layer. Management information including planning and purchasing is obtained from the ERP layer, while records of physical movement and shipment is obtained from the physical logistics layer. Traceability information is processed and provided to consumers at this layer. This layer also provides EDI function and tracking information to material suppliers, manufacturers and distributors. The transmitted information is described in XML messages as standard data interchange message format. Functions of this layer will be applicable to B2B e-commerce technology. Because of its independency, it is preferable to be implemented by an application service provider (ASP).

Our approach is characterised with data interchange which is not realised within a single layer yet but realised with an inter-layer information exchange. Sorting information to be transmitted to another layer and defining boundaries of information sharing tend to create an important design issue.

Table 6.1.1 Necessary information transmitted from ERP layer to independent data management layer

Sale information	Order number, Customer, Order items, Quantity, Due date
Purchasing information	Order number, Partner, Order items, Quantity, Due date
Production information	Works order, Parts list, Process, Quality Control information
Delivery information	Delivery number, Customer, Delivery items, Delivery date

Composite production process

In general, raw materials are disassembled and processed into several parts. The parts, which are manufactured from several different raw materials, are assembled into one product. The former process to obtain parts is referred to as the blanching process. The latter is referred to the assembly process. We define the composite process as a production process comprised of both the blanching process and the assembly process. Most of products have a composite process during their manufacturing process. There is a practical problem for the blanching process to extend the methodologies such as MRP. The proportion of every part or substance involved in raw material is naturally determined. And the proportion is usually different from that of the customer's demand. Therefore, to satisfy demand of a certain part, undesired material stock for the other product would be generated. For example, a food manufacturer provides croquettes with a crab craw. A crab craw and some crabmeat are necessary to produce one croquette. Two craws can be obtained from a crab. To satisfy demand of the croquette, they have to purchase the required number of crabs. If demand of surplus crabmeat is less, the manufacturer is obliged to accept crabmeat as undesired stock.

Figure 6.1.2 shows an instance of composite production process. *Material A* is processed into *part a*, *part b* and *part c* through blanching

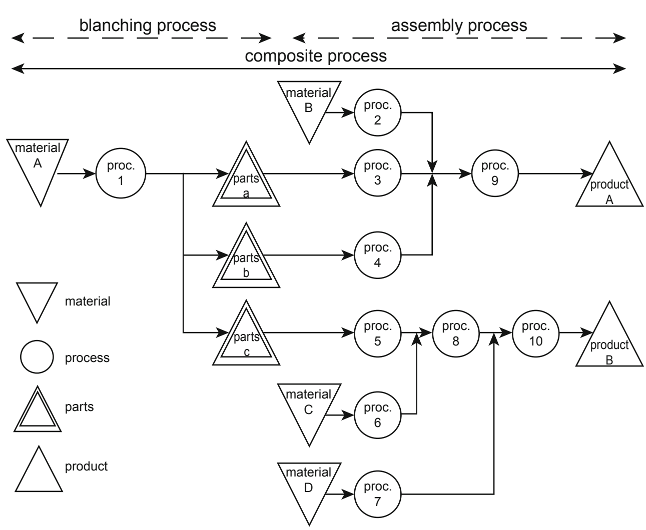

Figure 6.1.2 An example of composite production process

process 1. *Part a*, *part b* and *material B* are assembled into *product A* through assembly *process 2*, *3*, *4* and *9*. Product b is also assembled with *part c*, *material C* and *D*.

Additional sales order accepting

As a natural outcome of the blanching process, undesired material/parts stocks are obtained. We call it surplus stock. It is important to consume these stocks in a profitable way. Kikuchi et al. (2004) proposed implosion and explosion MRP for the composite process. Our approach is based on and is extended to this. In the approach, under cooperative work between the sales division and manufacturing divisions, we suggest reconsidering the procedure for accepting additional sales orders. The system provides an alert about undesired stock in the future by forecasting surplus stocks at an early stage of production planning. It also provides recommended consumption products for the sales division. The function is implemented as a new decision support system (DSS) because general ERP packages do not support this. Relation between process and information around the DSS is summarised in Figure 6.1.3. The figure shows single iteration of additional sales order acceptance procedure.

- MPS and explosion MRP

A master production schedule (MPS) is issued for regular sales orders. Consequently, material requirement planning (MRP) is executed. This MRP is referred to explosion MRP in this paper to distinguish from the proposed implosion MRP. These procedures are general procedures of the MRP system. According to the outcome of MRP, purchasing orders and works orders are scheduled in this stage.

- Implosion MRP for excess inventory

Amount of surplus stock is calculated based on the outcomes of MRP at the manufacturing division. A list of the producible product from surplus stock and material on hand is calculated with implosion MRP.

- Additional sales order acceptance

The sales division obtains the list and asks customers for additional sales orders. If they place the order, then necessary materials are assigned to the order. Implosion MRP is executed to update surplus stock for

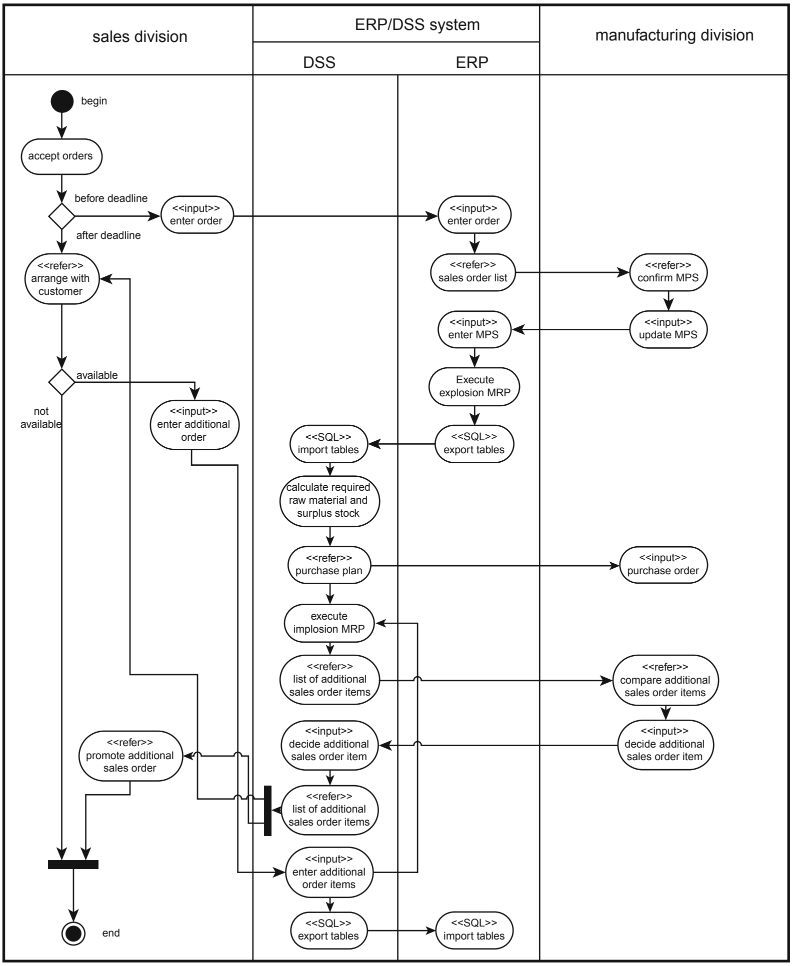

Figure 6.1.3 Relations between sales division and manufacturing division

additional sales orders. A new sales order also affects MPS, purchasing orders and works orders. The accumulating changes are reflected in the ERP package during certain rational time intervals.

- Termination of DSS

DSS terminates if all surplus stocks are assigned or the remaining time is over. DSS then prepares for the next term.

Prototype system

We have developed a prototype traceability system for a seafood supply chain. The supply chain comprises four material providers, one manufacturer and three distributors. The supply chain provides six frozen seafood products: crab shell gratin, crab leg croquette, crab fries, gratin with shrimp and scallop, etc. These products are made from material crab, shrimp and scallop with the recipes from an actual existing seafood processing company.

Environment of experimental system

The implemented system consists of two IA-based servers, several PCs and 2 RFID scanners. Each device is connected with ether net local area network, LAN. One server represents an ASP server and the other an ERP server. Management of XML-DB and traceability applications are processed on the ASP server, while an ERP package, including a relational data base and add-on applications, is executed on the ERP server. All applications are implemented as web-based, and users' requests are inputted to client PCs on the LAN. Companies are identified with different DB objects at the same ERP server. Two RFID scanners, WELCAT EFG-400–01, are directly connected with ether net LAN. Further details of the experiment environment are shown in Table 6.1.2.

Implemented experimental system

All developed applications except for software of controlling RFID scanners are implemented with web applications. Figure 6.1.4 shows a screen shot of an experimental system which shows a list of surplus stocks. From Table 6.1.2, the operator recognises the item number and excess amount by date. Figure 6.1.5 shows the calculation process of implosion MRP. Figure 6.1.6 shows the final recommended product which consumes surplus stocks with available number and date.

Table 6.1.2 Details of experiment environment

Server	**Application**	
ASP layer	Web Server	Apache 1.3
	XML-DB	Tamino 2.3.1.4
ERP layer	ERP	EFACS E/8 Ver.8.5
	DBMS	MS-SQL 2000
	Web Server	Apache 1.4
	Servlet Container	JBOSS

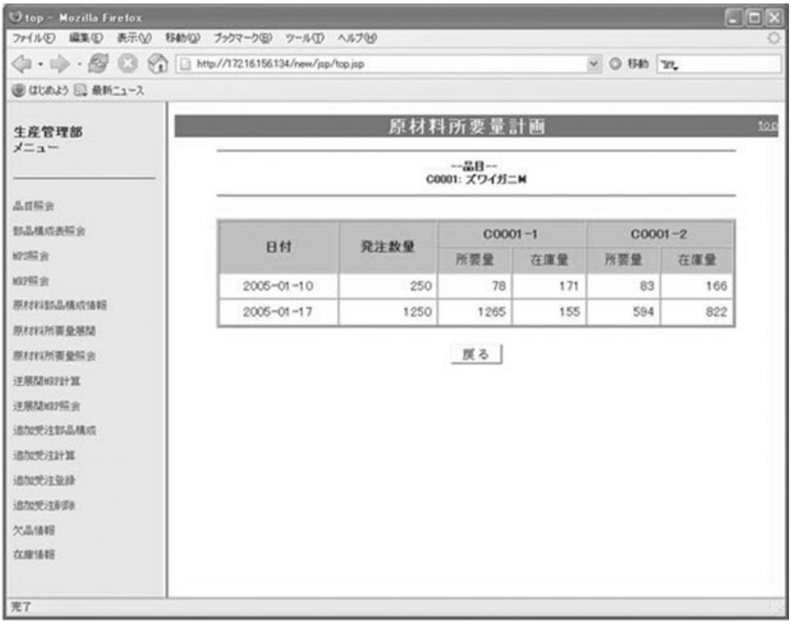

Figure 6.1.4 A list of surplus stocks

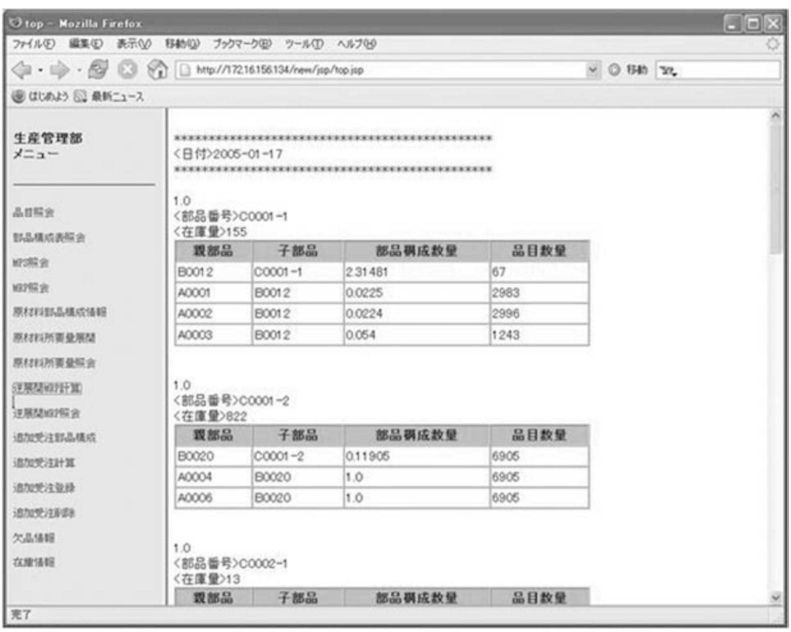

Figure 6.1.5 Process of implosion MRP

Figure 6.1.6 A list of available additional sales orders

Conclusion

In this paper, we have extended the proposed traceability system to composite production process and the proposed additional sales order acceptance procedure. To support the composite process, we implement implosion and explosion MRP module. Composite process naturally causes surplus stocks. The proposed additional sales order acceptance procedure and implemented modules are expected to reduce the stock and improve efficiency of manufacturing function. We are planning to evaluate the proposed procedure and implemented system for evaluation with practical condition and data.

Regulation of releasing information at the independent data management layer is not implemented completely. Development of this function is a recent theme of research projects. In our prototype system, we have tested only one ERP package. Connectivity with different ERP packages in our traceability system is an important research theme. At this moment, Electronic Data Interchange functions are simply implemented to refer order item and amount via Internet. An extension of this function is also an important developing theme.

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6.2

Flexible Mass Customisation: Managing Its Information Logistics Using Adaptive Cooperative Multi-agent Systems

Ingo J. Timm, Peer-Oliver Woelk, Peter Knirsch, Hans-Kurt Tönshoff and Otthein Herzog

Introduction

Since the last decade, the consideration of customer demands is of increasing importance for manufacturing enterprises. This situation provides a great opportunity to small and medium-sized enterprises (SME) to improve their competitiveness within the global economy. Due to their proximity to the customer, flat management structures and the resulting flexibility, SMEs are able to implement an efficient consumer response (ECR). However, modern industrial products are often characterised by a high complexity of design, functionality, necessary manufacturing and assembly processes. The complexity of modern products may overextend the available skills, knowledge and capacities of a single SME, or it may force this SME to spend great efforts in research and development activities to meet the customer's requirements.

The problem of overextension is well known in the global economy, and in consequence, enterprises are cooperating to manufacture complex industrial products in a distributed fashion. However, cooperating companies stay independent (autonomous) within these co-operations and therefore are able to remain flexible or agile. Facing the rapid change of customers' requirements, these cooperative relationships are not necessarily static during the production processes; and structural changes within these networks are quite normal. In consequence, this leads to "temporal logistics networks" as defined by Knirsch and Timm (1999).

The implementation of efficient consumer response within temporal logistics networks enables mass customisation in a very flexible manner even for small and medium-sized enterprises.

Mass customisation

Mass customisation is best defined as a transition process, which focuses on individualisation of mass-market goods and services to satisfy specific customer needs, at an affordable and reasonable price (Pine and Davis, 1999). The impact of mass customisation on individual industrial products and their design, manufacturing and assembly processes can be found, for example, in small lot sizes, increased diversity of variants and customer specific production of semi-processed material.

Looking at the information being shared within these logistics networks, two bottlenecks within the information flows can be identified. On the one hand, the amount and quality of information is increasing in a dizziness causing pace. But on the other hand, the information flow can be divided into two major flows: one focusing on the technological details of the product and another one carrying economical or administrative information, for example, due dates, priorities, costs, etc. The separated information flows correspond to strong borderlines that exist between process planning, production control and scheduling systems. In individual enterprises, this is caused by an extreme specialisation and the independent historical system evolution. The traditional approach of separating planning activities (e.g., process planning) from implementing activities (e.g., production control and scheduling) results in a gap between the involved systems, which has to be overcome using manpower. It implies loss of time, information and, in consequence, loss of quality and a prolonged time to market. In the framework of temporal logistics networks, this situation contradicts the idea of efficient and flexible mass customisation.

Cooperative multi-agent systems

Since the early 1990s, cooperative multi-agent systems and intelligent agents are of increasing concern within software engineering of large-scale distributed systems. In the last years, multi-agent systems have become a leading edge technology.

Multi-agent systems consists of distributed computational entities, the so-called agents. They are comparable to objects but are capable of sensing their environment and reacting according to the situation they perceive. Agents are goal-oriented, that is, they get tasks and then pursue them. In contrast to objects, intelligent agents are autonomous in their behaviour. They are pursuing goals but are able to choose the concrete realisation of the goal or choose the next goal to pursue. The autonomy is restricted to the scope granted by the instructing entity. To enable an intelligent agent with such a behaviour mental states and an explicit knowledge representation is integrated (Weiß, 1999).

Agents which are situated in an appropriate environment are able to cooperate. So agents in cooperative multi-agent systems have to deal with limited resources. Working concurrently with other agents and restricted resources leads to the need of coordination skills like social behaviour, that is, they must be able to communicate and cooperate to reach their goals. Therefore, the most important feature of a cooperative multi-agent systems is the communication between its agents. The communication language determines the expressive power and therefore the problem solving abilities and the efficiency. Furthermore, they must have knowledge of themselves and the existence and competence of other agents. This enables them to act in open systems. In particular, they need the capability to recognise agents entering or leaving the system. Internally, agents have their own views of their environment, and they need to adapt to and learn from changes that occur at runtime.

Integrated agent-based process planning and production scheduling

In order to bridge the gap between information systems in industrial production there is a strong need for new approaches integrating both worlds of planning and implementing activities. Innovative fundamental concepts and methods for management and control of integrated information logistics, of production scheduling and of process planning are being developed within the "Integrated Agent-Based Process Planning and Production Scheduling – IntaPS" research project (Tönshoff et al., 2001).

The new approach of this research project focuses on improvements of information logistics in the area of production engineering. The "IntaPS" system is based on a modular architecture. This architecture consists of two essential components, which link information systems of earlier stages of the product development process like CAD systems (Computer Aided Design) or PDM systems (Product Data Management) and the shop floor. These connecting components are decentralised planning units on shop floor level, which are realised by a multi-agent system, on the one hand, and centralised components for rough level process planning on the other hand (see Figure 6.2.1). These two basic

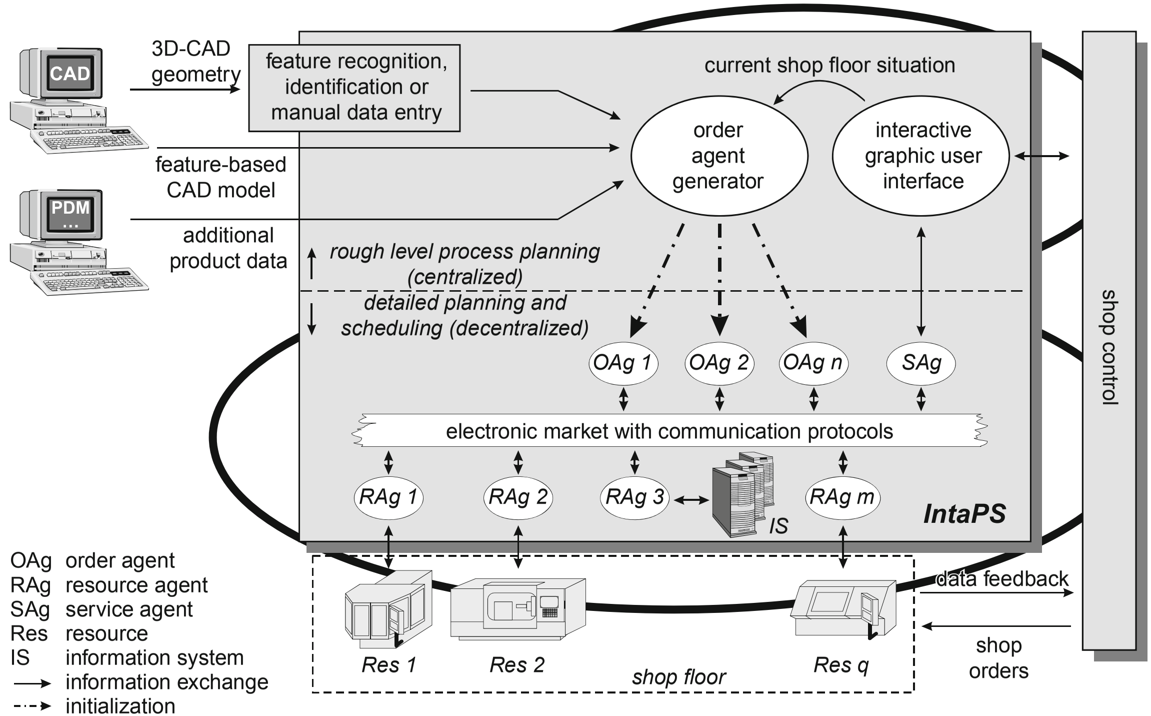

Figure 6.2.1 IntaPS architecture

components are supplemented by existing information systems (e.g., for feedback of captured production data to the shop control).

The first essential system component of the proposed architecture is a set of decentralised planning units on the shop floor level, which will be realised by a system of cooperative agents. The cooperative agents act very close to the shop floor and have access to recent production data at any time. These agents may be subdivided into resource agents, order agents and service agents. The "IntaPS" project is implementing a prototype of this system architecture.

Agent-mediated mass customisation

Since "IntaPS" focuses on intra-enterprise information logistics only, there is further need of an integrating approach for implementation of information interchange between cooperating companies. Here, problems of data privacy and security arise when two or more independent companies are interconnected. Only uncritical data needed for the common processes should be exchanged. In addition, owing to heterogeneous information systems, there is a problem in automatic negotiation within industry-wide cooperation relations. This problem is enforced by missing or inadequate standardisations for data exchange and various, partially contradictory definitions of used concepts. To address this problem and enable flexible and temporal logistics networks, we propose an adaptive cooperative multi-agent approach. This approach is based on intelligent agents, which are representing enterprises or profit centres within enterprises for the automated cooperation in temporal logistic networks. Agent representing entire enterprises are usually modelled and realised as multi-agent systems (see hierarchical agent systems). The multi-agent system is providing a framework for cooperation within short-term relationships as needed for temporal logistics networks. Therefore, our focus lays on sophisticated coordination skills like complex negotiation abilities and adaptive social behaviour.

Considering the emergent behaviour of the cooperative multi-agent system, it should result from the agents' interaction. On the one hand, the cooperation and coordination is following local optimisation criteria (profit maximisation) and, on the other hand, it has to take into account a joint optimisation criteria (optimisation regarding to mass customisation). Thus, as communication is one of the main methodologies for achieving emergent behaviour of the overall system, an adequate selection and configuration of communication protocols is required. The agents collaborating have to be able to adapt their protocols according to the dialogue partners, their own state, the multi-agent system's state and the experience of prior communications. To address this problem, we propose an approach of adaptive communication protocols (Timm et al., 2001). It is based on a probabilistic methodology, that is, dynamic belief networks. The analysis and design of these protocols is done with minimum effort: required protocol structures are defined and initial communication protocols are generated. The integration of open and adaptive communication protocols within this framework leads to the term "adaptive co-operative multi-agent system".

These agents are linked to enterprise resource planning (ERP) systems. They manage information transfer partially automatically using semantically well-defined communication. An essential step for the success of this approach in the framework of real industrial scenarios is to provide an open specification of the agents. Thus, the system architecture for agent-mediated mass customisation is based on the standardisation efforts of the Foundation for Intelligent Physical Agents (FIPA) committee (FIPA, 2000). FIPA defines the crucial elements of agents, agent systems and agent platforms prohibiting the establishment of new and mutual incompatible systems. On a conceptual basis, the project will be realising a new cooperation within mass customisation based on an electronic marketplace, where each participating partner is handled identically. Even resources or ERP systems can be integrated in this marketplace directly. The application of the FIPA reference architecture to this conceptual model will lead to a design of an agent system as illustrated in Figure 6.2.2. The basic concepts of this design is that each enterprise is represented by an agent platform. This agent platform will be connected to each agent platform within the system using the agent communication language (ACL). The enterprises can decide on their own which resources will be integrated within the platform. Consequently, if an enterprise uses an efficient ERP system, this system can be linked to the agent platform using an intelligent agent. This enables planning and scheduling on the basis of the ERP system as well as a partner matching and negotiating process on the basis of complex interaction using an ACL.

Figure 6.2.2 demonstrates the advantages of this approach in a straight forward way: agents are the interfaces of the possibly heterogeneous system architecture. Therefore, composing large systems in this way is just a matter of the communication of the single agents. There are no other dependencies between parts of different enterprises, and hence, such a system is inherently modular, flexible and extensible.

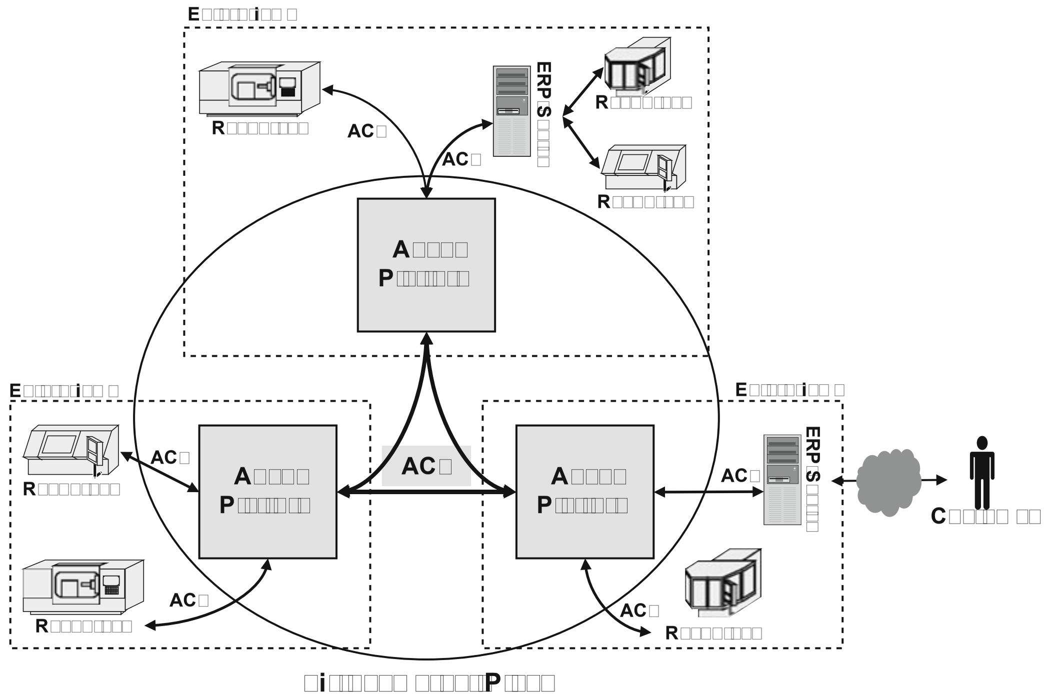

Figure 6.2.2 Multi-agent system architecture

The application of cooperative multi-agent system and intelligent agents seems to be very promising, but is also opening up risks for the safety and security of enterprises and the robustness of the (distributed) production. The security issues associated with agents fall into three major groups: integrity attacks, privacy attacks and denial of service attacks. A malicious agent may try to modify or delete information in the environment in unauthorised ways. The second form of attack consists of information theft or leakage: a hostile agent may try to get internal information from a cooperating enterprise. The third form of attack consists of denial of service, where the agent attempts to interfere with the normal operation (e.g., production process) of an enterprise. Therefore, it is necessary to establish adequate security mechanisms or restrict the multi-agent system to trusted cooperation partners only. Recent research deals with the first issue, but for the implementation of multi-agent systems in today's production processes, it seems to be necessary to apply the latter security approach and to restrict multi-agent systems to trustful participants, whose commitment is accompanied by external contracts.

Conclusion

In this paper, we discussed the application of adaptive cooperative multi-agent systems to temporal logistics networks of SMEs to facilitate flexible mass customisation. Aspects as confidentiality, robustness, information interchange and adaptive behaviour are considered with respect to the practical significance of our approach. In the last section, we presented a new architecture for agent-mediated mass customisation. The design of this architecture follows the prior discussed aspects with respect to openness and flexibility.

The IntaPS architecture is in the implementation process and will be applied to a realistic scenario in the domain of turbomachinery until end of this year. The results and lessons learned in this intra-business information logistics management are used for the extension of the approach to macro logistics level. The presented architecture will lead to another prototype on the basis of IntaPS, which is capable of inter-business coordination.

Acknowledgements

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7
Transport and Distribution

7.1
The Determinants of Containerised Grain Shipping

Ted T. C. Lirn and Jung-De Wang

Introduction

Increasing globalisation and lowering ocean freight help each nation focus on producing commodities of its specialty. With high quality but low paid labour, Asian nations have manufactured delicate industrial products and sold them to the EU and the US. North America has large arable lands that are suitable for planting agriculture (e.g., grains) with large farming machinery. The harvest grains can then be exported to the Asian nations. The major grains trade in the cross Pacific Ocean route could include soya bean, corn and wheat. The rapid increase of dry bulker freight between 2002 and 2008 forced the grain importers and shippers to ship their grain cargo by dry containers. It is estimated the containerisation ratio was around 80% in 2008. The grain containers could be used to control the freight cost for grain importers, and the grain cargoes can be transported on a door-to-door basis. It increases the importers' competitiveness because of its door-to-door service ability, its low ocean freight and small parcel size, reducing grain silo storage time and avoiding high inventory cost occurred by lengthy in-transit time. In short, the total logistics cost of imported grain cargoes can be reduced by using the container shipping service. Historical data reveal that only around 50% of containers exported from Asia to North America can find backhaul cargoes because many empty containers were trapped in North America in the 1990s. The development of exported grain cargoes from the US to Asia by containers reduces the cargo flow imbalance phenomenon across the Pacific Ocean. In addition to Taiwan, many Asian nations, including China, Korea and Japan have also employed dry containers to import their grain cargoes. There are several pros and cons by using containers to move grain cargoes:

> Pros: small batch size, easy to pick up, quality control and tracking ability.
>
> Cons: limited accessibility of empty containers in the farms, congestion in the container yards, deterioration in cargo loss ratio and low utilisation on grain silo.

This research employs the AHP technique to design the questionnaire, and several face-to-face interviews are made to find out the critical factors influencing grain shippers' and importers' mode choice behaviour. Fuzzy technique is also used to measure the degree of performance of bulk carriers and container carriers when the grain cargo movement is concerned. These two shipping modes' performance on the 12 decision-making sub-criteria is also discussed. Research purposes of this study include the following points: to find the impact of the containerised grain shipping on the dry bulker operators, to understand grain importers' transportation mode choice behaviour and to review factors that might influence imported grain cargo damage ratio and improve them.

Industry review

Scrapped metal, scrap paper and cotton used to be the major containerised cargoes imported to Taiwan by ocean carriers. However, soybean, corn, wheat and barley have become one of the most important containerised cargoes carried by the ocean carriers from 2006 to 2008. Taiwan is ranked as the ninth major cereal importer and is the destination for more than 3% of world cereal export (see Table 7.1.1).

Containerised grain cargoes are not stored in quayside grain silos, thus their volume is not publicly recorded. Importers can make more income with the information asymmetry advantage to control the retailing grain price in Taiwan. However, the market value and quality of inappropriately stored grains might be decreased if the heavy containerised grain cargoes sit idly in container yards for several days (see Table 7.1.2).

Grains are produced worldwide and their suppliers could originate in the US, Canada, Australia, Argentina and the EU (Lyons, 2000). The

Table 7.1.1 Major cereal importing nations and their world market share (000 tons)

Grain / Country/Region	Year				Share of world total (%)
	2002	**2003**	**2004**	**Average 2002–2004**	
Japan	26,605	26,537	25,943	26,326	11
EU	19,738	13,654	13,604	15,665	7
Mexico	14,092	13,352	12,977	13,474	6
Korea	13,389	12,925	12,103	12,806	5
Egypt	10,322	8,119	6,815	8,419	4
Brazil	7,809	8,820	6,317	7,649	3
Algeria	8,611	6,901	7,014	7,508	3
Indonesia	7,754	6,971	6,464	7,508	3
Taiwan	***6,576***	***6,599***	***6,361***	***6,512***	***3***
Iran	6,551	5,199	3,985	5,245	2
World average	245,196	232,846	232,193	236,745	100

Source: FAO (2007) The State of Agricultural Commodity Markets 2006, Food and Agriculture Organisation of the United Nations.

Table 7.1.2 Estimated impact of the grain quality on its market price

Grain / Quality	Corn	Soybean
Protein (increase 1%)	Increase USD 2.50/mt	Increase USD 3.00/mt
Fat content (increase 1%)	Increase USD 2.50/mt	Increase USD 2.50/mt
Humidity (increase 1%)	Reduce USD 1.50/mt	Reduce USD 2.80/mt

Note: The humidity of is 12.0%–13.7% for corn and is 11.0%–12.7% for soybean.

Source: Compiled from Soon (2005).

top ten cereal importing nations are also evenly situated in different continents (see Table 7.1.1). The five American ports, including Seattle, Long Beach, Los Angeles, Tacoma and Norfolk exported 69,050 TEUs of containerised grain in 1999 and 2000 (Vachal and Reichert, 2001). According to USDA (2007), 3% American export grain cargoes were moved in containers in 2006 (among the 3%, 34% of the cargo was corn, 22% of them were sorghum and 20% of them were wheat). Comparing with the data in October 2006 (Figure 7.1.1), the containerised grain cargo export volume increased by 78% in October 2007 (USDA, 2007).

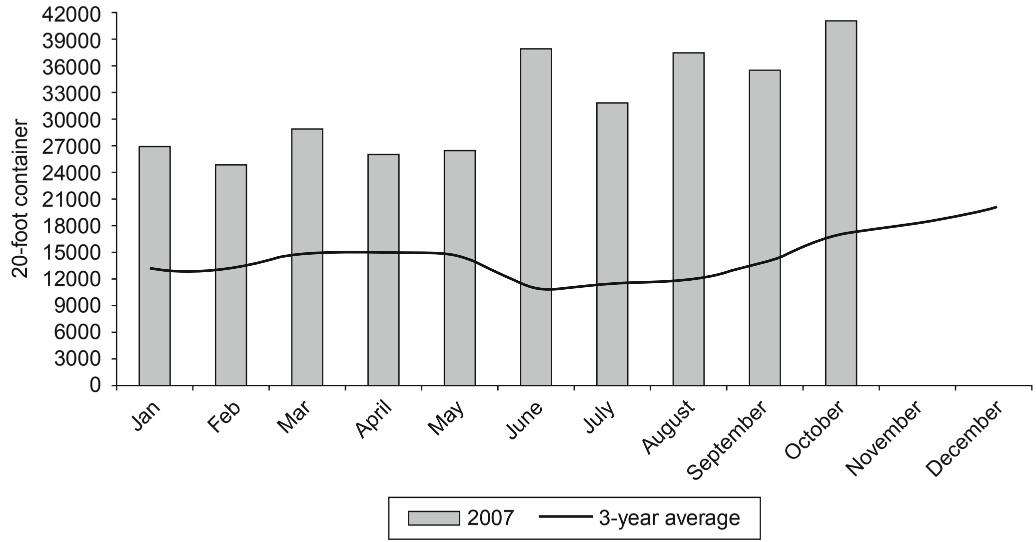

Figure 7.1.1 Number of containerised grain cargo export volume (in terms of TEUs)

Source: compiled from American USDA (USDA, 2007) and Port Import Export Reporting Service (PIERS), Journal of Commerce (from January 2007 to October 2007).

Transport mode choice behaviour

There is much literature about passengers' transportation mode choice, but little focusing on freight transportation mode choice decision-making. In the ocean freight transportation industry, according to the author's knowledge, extant literature on shippers' and importers' mode choice behaviour is very limited (Meixell and Norbis, 2008; Haugen and Hervik, 2004; Pedersen and Gray, 1998; Evers, Harper and Needham, 1996; Vachal and Reichert, 2001; Train and Wison, 2007; Shinghal and Fowkes, 2002; Vannieuwenhuyse et al., 2003; D'este, 1992; see Table 7.1.3).

Research methodology

This research employs the analytic hierarchy process (AHP) technique, and the authors have interviewed major grain importers to find the determinants influencing their transport mode choice behaviour regarding their use of container carriers versus bulk carriers to move their grain cargo. Fuzzy theory is used to calculate the overall performance of the two transport alternatives; fuzzy theory can also be used to deal with the importers' subjective, inaccurate and ambiguous perception problems in the AHP model.

AHP technique

AHP technique is a multi-criteria decision-making tool, and it is applied to improve the decision-making quality under a situation with multiple mutual conflicting goals and decision-making criteria. AHP is firstly proposed by Thomas L. Saaty in 1971 (Saaty, 1980), and this technique is widely applied to solve various decision-making dilemmas. It systemises and simplifies a complex situation; variables are deconstructed into several hierarchies, and variables in the same hierarchy are pairwisely compared to obtain the degree of importance of each variable. Finally, the overall performance of each alternative can also be found. Normally, there are eight steps in the AHP technique: define the research issues, confirm the factors with influencing power, build the hierarchy structure (i.e., goals, objectives, dimensions, sub-criteria and alternatives), set up the pairwisely comparison matrix, calculate the eigenvalue, examine the consistency index and consistency ratio, and find the priority weight for each alternative and choose the best alternative. There are four advantages to using the AHP technique: (1) simplify the complex issue by hierarchies, (2) understand and control the decision-making variables,

Table 7.1.3 Criteria influencing shippers' decision-making behaviour

Criteria \ Authors	Meixell and Norbis (2008)	Pedersen and Gray (1998)	Haugen and Hervik (2004)	Vanneieuwenhuyse et al. (2003)	Evers et al. (1996)	Kent and Parker (1999)	Vachal and Reichert (2001)	Train and Winson (2007)	Shinghal and Fowkes ,2002	D'este (1992)
Transport capacity	✓			✓						
International growth	✓									
Economies of scale & scope	✓		✓							
Cargoes quality	✓							✓		
Environment & energy issues	✓									
Transport cost /Freight rate		✓		✓		✓	✓			✓
Speed		✓		✓						✓
Reliability		✓		✓	✓	✓				
Cargo damage ratio		✓			✓					✓
Flexibility				✓		✓				
Safety & security				✓				✓		✓
Service network density				✓			✓			
Law & regulation				✓						

Inventory cost	✓						
Corporate image	✓						
Tracking ability	✓						
Availability of the transport mode in the origin & destination		✓	✓				
Cargo handling facility		✓	✓				
Compatibility of cargoes & transport vehicles		✓	✓				
Direct transport service		✓					
Service frequency		✓	✓			✓	✓
Cargo batch size		✓					
Easiness of pickup & delivery		✓					
In-transit time		✓	✓		✓		
Inventory holding cost		✓					
Cargo damage claim procedure		✓					
Communication/tracking/control		✓	✓		✓		
After sale service		✓			✓		
Overall service quality		✓			✓		
Distance to the inter-modal facilities				✓			
Seasonal demand factors				✓			
Grain market value				✓			
Dedicated CFS							✓
Free time (demurrage/detention)							✓
B/L release speed							✓
Punctuality & delay record							✓

Source: Compiled by this research.

(3) use inaccurate preference measurement and (4) employ the consistency ratio to examine the degree of agreement among experts. Several drawbacks of the AHP technique are also reported: imperfect preference transitivity, the scale from 1–9 is confusing, large perception variance between group members, requirements on the independency between variables in the same hierarchy is frequently violated in the real world.

Fuzzy theory and linguistic variable

Semantic wordings are mostly imprecise and Zadeh firstly proposed the fuzzy theory in 1965 (Zadeh, 1965). Fuzzy logic is a precise logic of imprecision and approximate reasoning (Zadeh, 2008). If an element cannot be clearly defined its membership to a variable in the set of (0, 1), then Zadeh defined the membership of the element to the variable is between 0 and1, it is a fuzzy set. Membership function, $\mu_A(x)$, can be employed to decide to what extent the variable x is belonged to set A. The fuzzy membership function can be defined as follow: $\mu_A(x) \in (0, 1), x \in X$

Triangular fuzzy set is used to discriminate the degree of membership of a specified semantic wording. Triangular fuzzy set (T) can be define as below (see Figure 7.1.2).

$T = (l, u, r)$, and $l \leq u \leq r$, its membership function is defined as below,

$$\mu_A(x) = \begin{cases} \dfrac{x-l}{u-l} & I \leq x \leq u \\ \dfrac{r-x}{r-u} & u \leq x \leq r \\ 0 & other \end{cases}$$

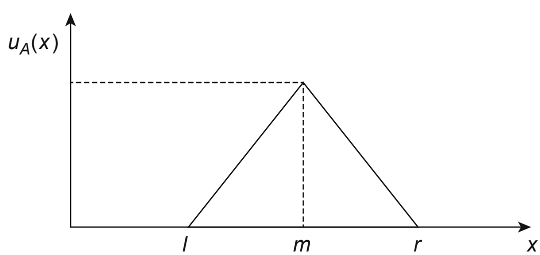

Figure 7.1.2 Exhibition of triangular fuzzy function

Source: Buckley (1985).

Linguistic variable

Natural languages are mostly imprecise because in a natural language almost everything is a matter of degree (Zadeh, 2008). Linguistic variable is defined as within a certain limit; a fuzzy set is used to measure the degree of performance given by the natural language, to change the natural language into a logic description, so it can then be calculated (Feng and Chiu, 2004). Zadeh (1972) suggests use linguistic variables to process variables that are difficult to be quantified.

This research intends to measure the Taiwan consignees' degree of preference on using the container carriers' and dry bulk carriers' services to ship their imported grain cargoes. Five linguistic wordings are employed in the survey, including very unsatisfactory, unsatisfactory, fair, satisfactory and very satisfactory. A TFN (triangular fuzzy number) technique is used to define the memberships and values to each of the five linguistic wordings (see Figure 7.1.3).

Fuzzy AHP (FAHP) technique

The multi-alternatives and multi-criteria used to build up the AHP model have different degrees of importance and performance to each of

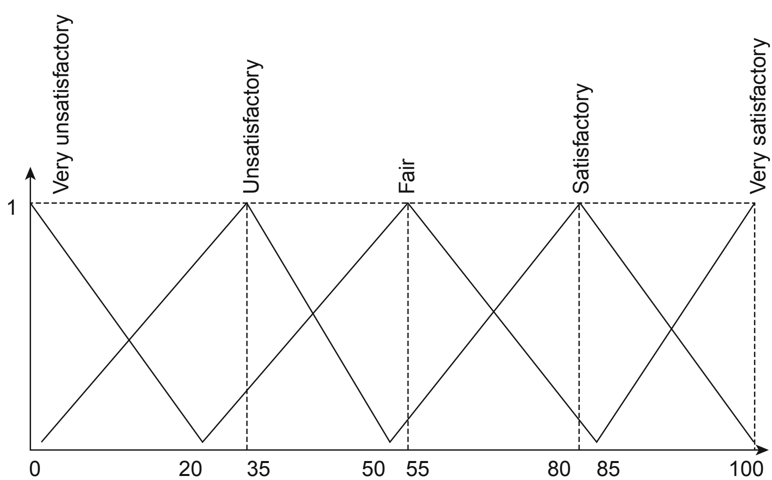

Figure 7.1.3 Five linguistics variable and their membership function from the survey

Source: this research.

the different group surveyed (i.e., grain importers). Linguistic variables are used to measure their perception on the degree of each alternative's performance on each of the decision-making criterion. Very satisfactory, satisfactory, fair, unsatisfactory and very unsatisfactory are the five linguistic wordings employed in this research survey, and different TFN is given by each of the respondents to reveal their subjective judgement on the performance of the two transport alternatives.

Let E_{ij}^{k} be the decision-maker *k*'s perception on the performance of *i* alternative to *j* criterion, *j* is a criterion in the *S* set. Then $E_{ij}^{k} = (LE_{ij}^{k},\ ME_{ij}^{k},\ UE_{ij}^{k}),\ j \in S$.

As every surveyee's perception on definition of the semantic wordings is different, each of the linguistic wordings has different TFN to each surveyee. Thus, geometric mean value of this used to aggregate n surveyees' responses and to represent the n surveyees' aggregated perception. According to Buckley (1985), let E_{ij} represents all decision-makers' degree of satisfaction on *i* alternative's performance in *j* criterion, and E_{ij} is a geometric mean of n respondents' perception (a TFN). Then

$$E_{ij} = \frac{1}{n}(E_{ij}^{1} + E_{ij}^{2} + \cdots + E_{ij}^{N}) = \left(\frac{\sum_{k=1}^{n} LE_{ij}^{k}}{n}, \frac{\sum_{k=1}^{n} ME_{ij}^{k}}{n}, \frac{\sum_{k=1}^{n} UE_{ij}^{k}}{n}\right) = (LE_{ij}, ME_{ij}, UE_{ij})$$

E_{ij} is then used to multiply the degree of importance of *j* criterion found in the AHP model. Then all decision-makers' perception on the weighted performance of *i* alternative on *j* criterion can be calculated as follow:

$$R_{ij} = E_{ij} * w_j = \left(LE_{ij} * w_j, ME_{ij} * w_j, UE_{ij} * w_j\right), j \in S$$

Finally an alternatives' overall performance, R_{ij}, can be represented by a fuzzy set which is an aggregation of R_{ij}, $j = 1, 2, \ldots, m$.

$$R_i = \left(\sum_{j=1}^{m} LE_{ij} * w_j, \sum_{j=1}^{m} ME_{ij} * w_j, \sum_{j=1}^{m} UE_{ij} * w_j\right) = (LR_i, MR_i, UR_i)$$

According to Tsaur et al. (1997), the gravity centre technique can be employed to defuzzify the TFN set by the following formula, and the crispy value of the performance of each alternative can be obtained. Finally, the most satisfactory transport alternative perceived by the grain importers can be concluded.

$$BNP = \frac{[(UR_i - LR_i) + (MR_i - LR_i)]}{3} + LR_i$$

Criteria selection and sampling

At least 14 criteria are found to be reported by three previous reports and are selected to design the Likert scale questionnaire for the pilot survey in this research (see Table 7.1.3). Ninety-one copies of questionnaires are dispatched and 26 copies of them are responded to. Criteria with importance less than the mean of the 14 criteria were removed, and 12 criteria are remained to design the AHP questionnaire survey. The 12 criteria are further categorised into three dimensions: cost dimension, cargoes and quality control dimension, and vehicles service attribute dimension (see Figure 7.1.4). The AHP round survey is then carried out, followed by several face-to-face in-depth interviews with the grain importers. Finally, the importance and performance of each alternative and each criterion can be found.

Research findings

The responded AHP round questionnaires are first checked with their consistency ratios and it is found that all responses have their consistency ratios below the 0.1 threshold value. From Figure 7.1.4, overall cost dimension has the highest importance with the importance weight 0.6. This is evidenced by the shippers/consignees that employ more containers to move their grain cargoes across the ocean when the BDI was high in 2007. Cargo and quality control dimension has an importance weight of 0.281. The vehicles service attributes dimension has the least degree of importance (0.119). Looking into the importance of each sub-criterion, the "grain market value" has an importance weight of 0.274, which indicates grain shippers and importers perceive this criterion as the most important factor influencing their freight transport mode choice decision. Other important sub-criteria include the cargo holding cost (0.125), freight transport cost (0.104), in-transit inventory cost (0.096) and cargo damage ratio (0.092).

In the cargo and quality control dimension, "cargo damage ratio" is perceived to be the most important sub-criterion. The grain containers are stored in an open area in the container yards before they are loaded on board in the loading port and picked up by the consignees in the discharging port. Grain containers are directly exposed to strong sunshine and heavy rain for a lengthy period; thus, the cargo damage ratio could be higher than the grain shipped by a bulker. Because the bulker offload the grain into the quayside grain silos with adequate ventilation and humidity control, it has a lower cargo damage ratio.

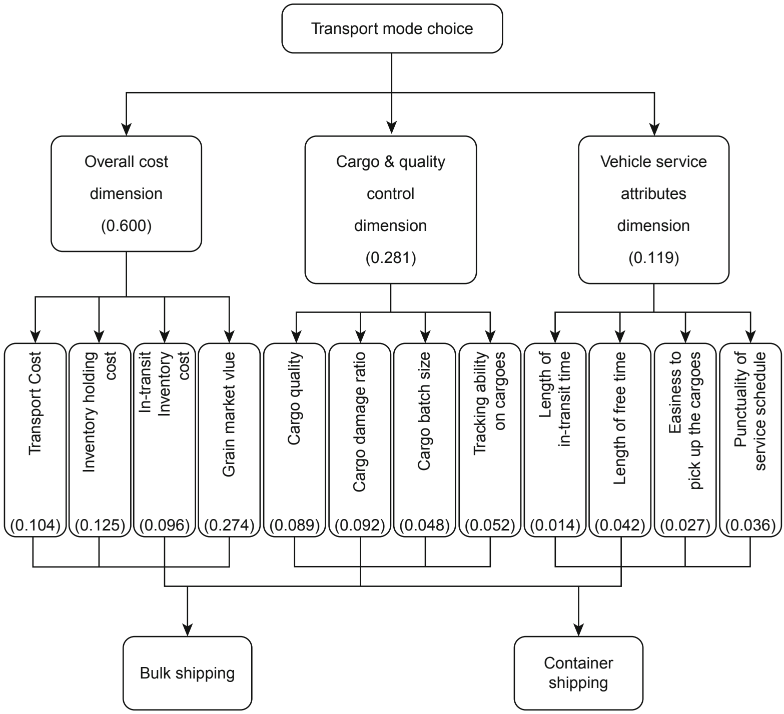

Figure 7.1.4 Hierarchical structure of grain importers' transport mode choice behaviour

In the vehicle service attribute dimension, the "length of free time" is perceived to be the most important factor. Grain importers could keep their grain containers in the quayside terminals for a lengthy period until the grain market value is high enough for the importers to sell the grains. This long free time practice also leads to the quayside congestion in many container ports in the Far East in 2007 and 2008.

From the grain shippers and importers viewpoint, the performance of the bulkers is higher than the container ships on all the decision-making sub-criteria except the following three sub-criteria: cargo batch size, length of in-transit time and free time. The grain shippers and importers perceived the two transport modes have the same degree of performance on "cargo tracking ability" factor (see Table 7.1.4).

Table 7.1.4 TFN and BNP performances of the two transport modes on various criteria

Criteria/Factors \ TFN & BNP	Bulker's performance		Container carriers' performance		Comparison
	TFN(R_{ij})	BNP_{ij}	TFN(R_{it})	BNP_{ij}	Performance between the two modes
Transport cost	(6.136, 6.968, 7.800)	6.968	(5.2, 6.136, 7.072)	6.136	*B>C*
Inventory holding cost	(6.875, 8.000, 9.000)	7.958	(6.875, 7.875, 8.875)	7.875	*B>C*
In-transit inventory cost	(5.088, 5.952, 6.816)	5.952	(4.992, 5.856, 6.720)	5.856	*B>C*
Market price of cargoes	(15.07, 17.262, 19.728)	17.353	(14.522, 16.988, 19.454)	16.988	*B>C*
Commodity characteristics	(5.340, 6.141, 6.853)	6.111	(4.806, 5.607, 6.319)	5.577	*B>C*
Cargo damage ratio	(6.072, 6.808, 7.544)	6.808	(4.508, 5.244, 5.98)	5.244	*B<C*
Cargo batch size	(2.352, 2.736, 3.168)	2.752	(2.976, 3.36, 3.744)	3.360	*B>C*
Tracking ability on cargoes	(2.808, 3.276, 3.692)	3.259	(2.808, 3.276, 3.692)	3.259	*B>C*
In-transit time	(0.770, 0.896, 1.022)	0.896	(0.784, 0.910, 1.022)	0.905	*B<C*
Free time in CY	(1.890, 2.352, 2.772)	2.338	(2.394, 2.772, 3.150)	2.772	*B<C*
Easiness to pick up cargo	(1.836, 2.052, 2.295)	2.061	(1.377, 1.620, 1.836)	1.611	*B>C*
Punctuality of service schedule	(1.98, 2.340, 2.664)	2.328	(1.800, 2.088, 2.412)	2.1	*B>C*
	R_{bulk}	BNP_{bulk}	R_{con}	BNP_{con}	
Total	(56.217, 64.783, 73.354)	64.785	(53.042, 61.732, 70.276)	61.7	*B>C*

Source: This research.

Conclusions and suggestions

This research has carried out two rounds of questionnaire surveys to measure the freight forwarders, ocean carriers and grain importers' viewpoints. The performance of the two transport modes on each of the 12 decision-making sub-criteria is measured. The degree of importance of each criterion is also surveyed. The strength and threat factors influencing the grain cargo transport modes choice are then concluded below.

1. In addition to the variables in the cost dimension, some variables in the cargo and quality control dimension are perceived to have a substantial degree of importance. The amount of grains produced in Australia is not as large as the amount produced in the US. Thus, it is not easy to aggregate all the importers' demand and jointly ship the cargo by a dry bulker. The Australian-origin wheat is mostly imported by the container carriers because of its limited trading volume in Taiwan. Importers can shorten the lead time by using container ships and maximise their profit when the domestic market price of the wheat is high.
2. Comparing with dry bulkers, drawbacks of the containerised grain shipping might include worse shipping schedule control, complicated documentation, complex custom clearance and quarantine inspection and an over-lengthy operation procedure. The container carriers charge higher inland transport freight, cargo handling fee, demurrage fee, inspection fee, custom clearance fee, container cleaning fee and other additional charges. Container ocean freight must be $10 USD/ton less than the bulker freight before it can compete with the bulker. Grains moved by containers have to be unloaded in the final destination, mostly a factory. Not all factories have equipped facilities to unload the containerised grains. Grains loaded in containers might have relatively high cargo damage ratio, and importers have to deal with the subsequent claiming procedure. The cargo damage risk could easily be shared by the other importers if grains are shipped by a jointly chartered dry bulker. The grain cargoes are only produced in specific seasons; thus, containerised grain shipping could result in the uneven containers demand through the whole year.
3. The advantages of containerised grain shipping might include the following points: flexible cargo batch size, easily grading, conspicuous country of origin and better quality control. Containerised grains are not stored in the quayside silo, the import quantity is kept secretly,

and thus, importers can use the asymmetric information advantage to maximise their profit.

In a stable freight market situation, grain importers perceived the dry bulkers to be the better transport mode than the container vessels. Containerised grain shipping outperforms the dry bulkers only on the following three sub-criteria: cargo batch size, in-transit time and free time. This might be related with grain shippers' and importers' previous experience of using dry bulkers to move their grains over the last several decades. The relationship between habitual domain and grain importers transport mode choice behaviour could be a possible avenue for the future research.

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7.2
Modelling the Impact of Factory Gate Pricing on Transport and Logistics

Andrew Potter, Chandra Lalwani, Stephen Disney and Helder Velho

Introduction

Over the past 30 years, the grocery supply chain has evolved considerably in the drive to reduce costs and improve the service level provided to customers. The 1970s and 1980s saw the development of distribution centres (DC) for ambient products, with retailers taking over responsibility for deliveries to their stores. The 1990s brought the introduction of consolidation centres to reduce the level of transport demand required to deliver products to the DCs (Finegan, 2002). The latest development is for retailers to take control of the delivery of goods into their DCs. This movement has gained momentum recently and is known as factory gate pricing (FGP). The evolution of grocery distribution is shown in Figure 7.2.1.

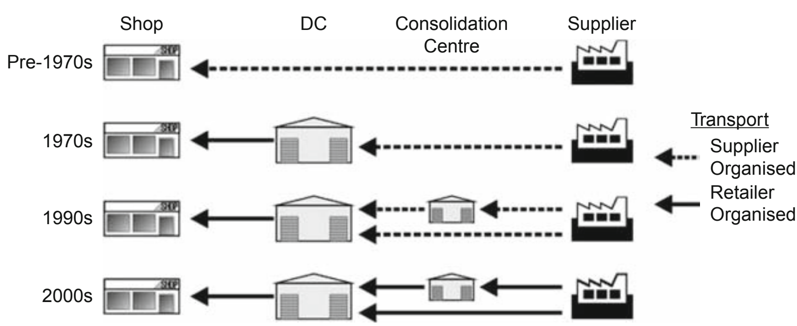


Figure 7.2.1 The evolution of grocery distribution

Source: Based on Finegan (2002).

Having taken control of their inbound logistics, retailers are looking at further improving their efficiency by increasing the backloading of store delivery vehicles and the consolidation of smaller loads into consolidation centres. The aim of this paper is to demonstrate how the increased use of consolidation centres in the inbound network can be modelled and to quantify the impact on transport demand in both the ambient and fresh networks of a major UK retailer. The paper proceeds by first providing more details about FGP, before describing the case study company. The method adopted as part of the task force is then outlined, including details on the modelling process. The results of this modelling are then presented and conclusions are drawn.

Factory gate pricing

The concept of FGP has a long tradition. In international trade, ex-works is an accepted trade term that has the same implications as FGP. Domestically, one of the first sectors to pioneer the concept was the fashion industry in the early 1990s (Lewis, 2002) in response to the need to improve delivery times. It has also been used in the automotive sector for the supply of parts to manufacturers (Brown, 2002b). However, the application of FGP to the UK grocery sector represents probably the most complex application yet. Tesco was the first to implement it, and Sainsbury's has followed the lead while Asda and Carrefour have established processes similar to FGP. Its implementation has triggered a broad debate in both trade and professional journals, for instance, see Beevor (2002), Meczes (2002) and Rowat (2002).

FGP has been defined as "the establishment of a price for completed goods excluding transport costs" (Finegan, 2002). However, the term has seen a wider use in referring to both the contractual arrangements and the physical movement of the products to the DCs. Under FGP, the retailer takes over control of the transport of the goods from the supplier. This may involve an outside contractor or the use of store delivery vehicles for backhauling. Either way, the aim is to make the best use of the available vehicles, with the retailer coordinating flows to provide loads in both directions. In light of this, a broader definition of FGP is the use of an ex-works price for a product and the organisation and optimisation of transport by the purchaser to the point of delivery.

A number of reasons have been put forward as to why FGP has become a reality in the grocery sector. Until recently, one of the constraints was the lack of computer packages capable of managing the many flows involved in grocery distribution. With these tools now available, the necessary infrastructure can be provided (Lewis, 2002). This has provided the catalyst for the implementation of FGP by the retailers, with five main drivers behind the move:

- Price transparency – by being able to separately identify the costs of both freight and products, these can then be managed more easily by the retailer (Kyle, 2002).
- Maximisation of the use of vehicle capacity – by managing all of the flows together, retailers can consolidate movements to reduce transport demand (Lewis, 2002).
- Cost reduction – in an industry with tight margins, this is important, and decreasing the demand for transport will reduce transport costs (Rowat, 2002).
- Green issues – retailers are becoming increasingly aware of their environmental responsibilities, and reducing transport is environmentally beneficial (Lewis, 2002).
- Improved delivery reliability – by managing inbound deliveries directly, it is easier for retailers to ensure on time deliveries (Brown, 2002a).

Case study – Tesco

Tesco is the largest grocery retailer in the UK, with 759 stores, annual sales of £25.6 billion and a market share of 25.8% (Osborne, 2003). It were the first company in the UK grocery sector to move towards FGP in late 2001. Overall, the ambient network handles 168,000 pallets per week while 135,000 pallets pass through the composite network. Before FGP some consolidation of incoming deliveries took place, equating to about 3% of ambient volume and 34% of fresh products. Once complete, approximately 20% of ambient and 40% of composite products will be consolidated before delivery to the DC. Initially, FGP has been implemented within the UK supplier base. Implementation for deliveries from Europe will take place in due course.

To support the management of inbound deliveries, a new network of consolidation centres is being established, and the design of this network is the focus of this paper. At an operational level, extensive use has been made of IT solutions to enable the management of the inbound movements. A single, integrated software package selects the most appropriate channel of distribution and haulier for every load, informing hauliers electronically across the Internet. This combination of haulier management and extensive IT use means that the distribution team in Tesco has practically become a fourth party logistics company (4PL).

Methodology

In order to carry out the work, a task force approach was taken. With this, a member of the research team spent several months working closely with the distribution team. As well as providing the necessary information for the modelling work, this also offered the opportunity to get an understanding of how the overall process worked. One of the aims of the task force was to validate the design of the consolidation centre networks, work that was initially carried out by Tesco.

The modelling work used a network planning computer package. The program allows the design of distribution networks and the testing of different structures to produce a best solution. The software makes a number of assumptions when carrying out the modelling, including demand being spread evenly across time, 100% availability at the supplier and a constant average speed for the vehicle. The data used in the model provided detailed information as to the volume of product from each supplier to every DC. Suppliers were contacted by telephone in order to identify the source points for the products. A strategic decision was taken to route those that supplied at least 18 pallets per day per DC direct to the DC. In effect, these were treated as full truckload consignments and removed from the data set accordingly. The remaining data covered less-than-truckload consignments only. Costs were based on current charges and levied on a per mile basis for transport costs and per pallet basis for handling charges at the consolidation centres.

The validation process initially involved reviewing the process undertaken by Tesco to design the consolidation network. This relied on archival evidence and also interviews with the personnel that undertook the work. By comparing the process with other work undertaken on network design (e.g., Hammant et al., 1999), the robustness of the process could be assessed. From this assessment, an area for improvement was identified in the design of the model. The Tesco version required constraints to be imposed for certain conditions, removing some of the decision-making capabilities of software package. Therefore, the structure was redesigned to allow these decisions to be made by the model and the Tesco results were cross-checked against this new design.

Finally, the number of consolidation centres that produced the lowest cost was identified. Centre of gravity modelling was used to identify potential structures and the transport and handling charges calculated accordingly. Recognising that the software would only produce good scenarios rather than the optimum, the modelling was repeated five times for each number of consolidation centres and the best result selected. It was then necessary to confirm that the solution proposed by Tesco was among the best possible solutions. Therefore, the locations of their consolidation centres were entered into the new model structure. The results were compared both against the option of all suppliers servicing the DCs direct, the 'As Is' scenario and the solution from the centre of gravity analysis.

Centre of gravity results

In the centre of gravity analysis, it was decided to look at structures for ambient products with between 5 and 10 consolidation centres, while the composite network was tested between 7 and 11 centres. These boundaries were chosen given the practical considerations of establishing and managing the network. The results of this analysis can be found in Table 7.2.1. To protect confidentiality, the costs have been normalised with the cost for the lowest number of consolidation centres being made equal to 100.

The ambient results do not appear to reach a minimum, cost continuing to fall as the number of consolidation centres increases. However, there are other factors that need to be taken into consideration in reaching a conclusion as to the best solution. In particular, the model is assuming the handling charge is constant regardless of volume. In reality, economies of scale would be present. Therefore, the handling charge is likely

Table 7.2.1 Average cost and volume against number of consolidation centres

Number of consolidation centres	**Ambient products**		**Composite products**	
	Cost	**Average volume**	**Cost**	**Average volume**
5	100	5139		
6	98.0	4299		
7	97.9	3793	100	9350
8	95.5	3357	97.8	8524
9	96.0	2974	99.0	7534
10	95.3	2706	99.6	6871
11			100.2	6137

to be lower, the higher as volume increases. For the ambient network, Tesco decided upon six consolidation centres, as it seemed reasonable to conclude that this delivers a low cost solution. For composite products, there is a U-shaped curve to the costs, which reaches a minimum at eight. Even allowing for economies of scale, the curve would still reach a minimum around this value. These findings agree with the results found by Tesco and so validates their solution.

Network validation results

Figure 7.2.2 compares the locations identified by Tesco as offering a low cost solution and the results from the validation exercise. Both solutions have a certain degree of synergy, with some consolidation centres being located close to each other. In the composite and ambient solutions, there are two exceptions. These can be largely attributed to the different model structures. In the ambient network, there are DCs close to both Bristol and Milton Keynes. Consequently, material for these is delivered direct rather than through a consolidation centre. This affects the centres of gravity by effectively removing them from the calculations. The same is true for the composite network, with DCs in the Bristol and Cambridge areas allowing the consolidation centres to be located elsewhere. From these results, the decision has been taken by Tesco to introduce a ninth consolidation centre at Portsmouth, a location identified in the validation model.

While the maps indicate that there is a case for moving some of the consolidation centres, it is necessary to quantify the benefits that such a move would bring. This was done using the modelling software to route the products through the network, enabling the level of transport demand (in terms of miles travelled), total cost and volume to be ascertained. The results of this analysis compared against both direct supply and the 'As Is' scenario can be found in Table 7.2.2.

As can be seen, the introduction of consolidation centres during the 1990s has had some impact upon the demand for transport, with small reductions for both ambient and composite networks. In terms of cost, there has been very limited reduction. However, these figures only take into consideration transport and handling charges and do not include an allowance for factors such as reduced DC congestion. With the move to FGP, it can be seen that there are significant gains in both transport demand and cost. For the ambient network, the Tesco solution will reduce the number of transport miles by 25.3%, while the validation model would offer a 27% reduction. This large reduction can be

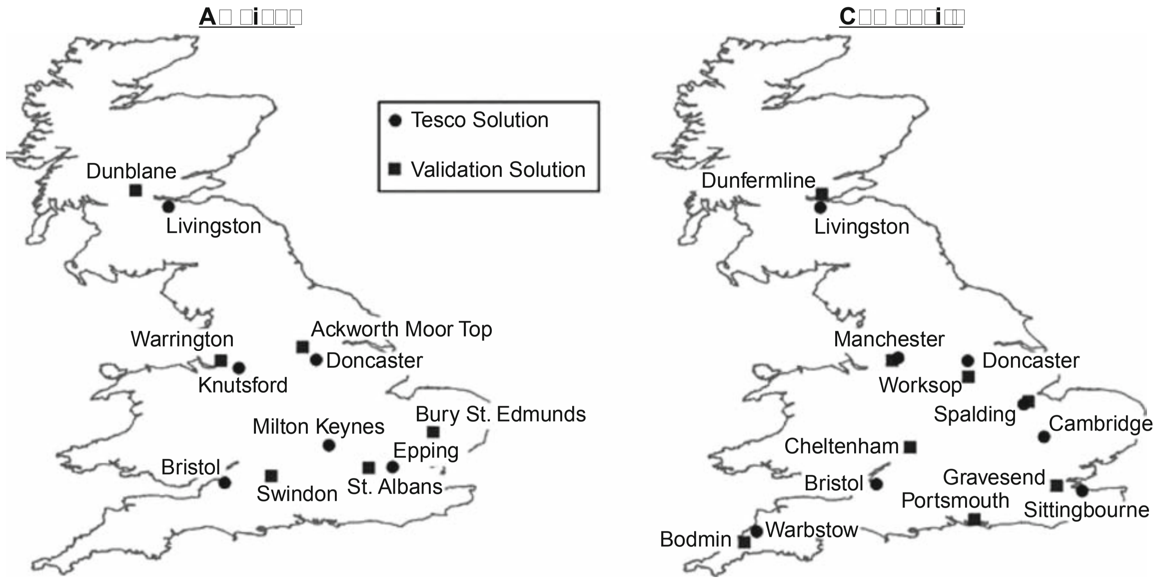
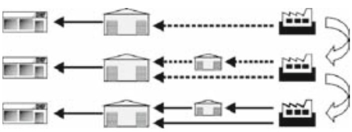


Figure 7.2.2 The location of the consolidation centres for ambient and composite products

Table 7.2.2 The transport miles, cost and volume split for ambient and composite products

Store	DC	Consolidation centre	Supplier	Ambient		Composite	
				Transport miles saving	**Cost saving**	**Transport miles saving**	**Cost saving**
				2.1%	0.4%	6%	–2.8%
				25.3%	13.9%	23.0%	17.2%
				(27.0%)	(15.3%)	(23.4%)	(17.4%)
Total Savings				26.9%	14.2%	27.7%	14.8%
				(28.5%)	(15.6%)	(28.2%)	(15.1%)

Note: Figures in brackets represent the results from the validation model network as opposed to the Tesco solution

attributed to the significant increase in ambient products that will be routed through consolidation centres in the new network. The Tesco solution will also reduce distribution costs by 13.9%. For composite products, similar gains will be made. The Tesco network (before the inclusion of Portsmouth) will reduce transport miles by 23% and cost by 17.2%. By comparison, the validation model would reduce transport miles by 23.4% and cost by 17.4% despite the increase in volume being less than before. This is because the management of the network will be coordinated centrally and flows routed through the shortest and most cost effective route. It can therefore be said that the network designed by the validation model offers little benefit over that produced by Tesco. In terms of the total savings when compared against a network without consolidation centres, transport miles are reduced by 26.9% for ambient and 27.7% for fresh products while cost savings of 14.2% and 14.8% respectively are predicted.

Conclusions

The concept of FGP is the latest development to be implemented within the grocery supply chain. Retailers are now responsible for the organisation and optimisation of transport from suppliers to the retailer DCs, paying an ex-works price for the product. Developments in information technology have provided the infrastructure for this change, while the drivers behind its implementation include price transparency, greater use of vehicle capacity, cost savings, environmental concerns and improved delivery reliability. Tesco was the first grocery company in the UK to implement FGP, and it will use a network of consolidation centres to improve the efficiency of inbound deliveries. The validation of this network design has been reported in this paper. There will be a reduction of around 28% in the mileage accumulated in transporting less-than-truckload consignments to DCs, equating to over 400,000 miles per week, as a result of the increased use of consolidation centres. This has significant economic and environmental benefits. Future work will look at confirming that the transport improvements predicted are actually being achieved within the consolidation network and to include store deliveries and backhauling within the model.

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7.3
The Load Planning Problem for Less-Than-Truckload Motor: Carriers and a Solution Approach

Naoto Katayama and Shigeru Yurimoto

Introduction

Progress of the supply chain management and the current trend towards deregulation of the Japanese trucking industry places the freight motor carriers in a highly competitive environment. As a result of that, the carriers need to consider strategies and tactics that satisfy both cost minimisation and a definite level of service quality. In general, a less-than-truckload motor carrier hauls shipments in the range of 50–5000 kg. Since a standard trailer can hold 10-ton to 30-ton of shipment, it is necessary for the less-than-truckload (LTL) motor carriers to consolidate the freight to make the best use of trailers. The freight originating at an end-of-line is loaded onto a line-haul truck, which carries it to a break-bulk terminal. At this terminal, the freight is unloaded, sorted and reloaded onto a trailer, which carries it to another terminal. One of the main problems faced by LTL motor carriers is to determine how freight should be routed over the network. This problem is called the load planning problem for LTL motor carriers. It can be formulated as a huge mixed integer optimisation problem.

Previous research on this problem is limited. Powell (1986) and Powell and Sheffi (1989) propose heuristic approaches using add-drop local search methods. Crainic and Roy (1992) describes a set-covering formulation and a solution method for the load planning problem. Powell-Delorme (1989) presents so-called NETPLAN, and Powell and Koskosidis (1992) uses a gradient-based local search method and the Lagrangian heuristic approach with a relaxation of minimum service level constraints. Hoppe et al. (1999) proposes a heuristic approach using the labelling algorithm and add-drop local search methods. Crainic (1999) surveys a wide variety of freight transportation planning problems.

The principal concern in the load planning problem is about determining how to consolidate freight on small lot consignment over a load planning network including break-bulk terminals in order to minimise the total line-haul cost. This problem is approached as a two-tiered problem: (1) between which pairs of terminals should direct service be offered, (2) given a set of direct services, how should the freight be routed over the network. This problem is formulated as follows: (1) line-haul costs between terminals should be minimised, (2) the minimum frequency of delivery per week between a pair of terminals must satisfy a given service level, (3) the paths from all origin terminals into a destination terminal form a tree, which reflects that the freight at a terminal with same destination should be loaded onto a truck heading for one terminal. Figure 7.3.1 illustrates an example of the load planning network. Figure 7.3.2 illustrates frequency of service between a pair of terminals. In this study, we propose a load

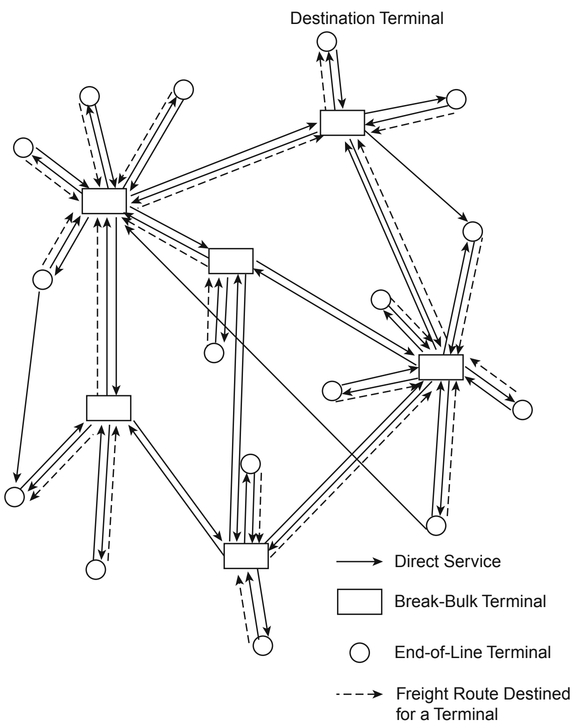

Figure 7.3.1 Illustrative load planning network

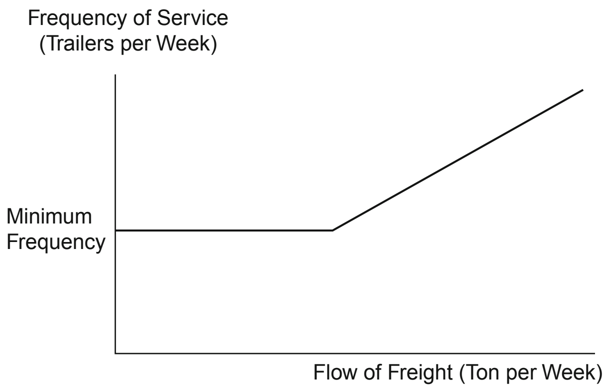

Figure 7.3.2 Frequency of direct service between a pair of terminals

planning model and new algorithm using a Lagrangian relaxation method.

Formulation for the load planning problem

The load planning problem can be formulated as a mixed integer programming problem. We use the following notation for our model. N is the set of nodes, which consists of end-of-line and break-bulk terminals. A is the set of all potential links for direct services in the load planning network, $A \subseteq N \times N$ f_{ij} is the minimum frequency of trailers per week on the link (i,j) from node i to j, $(i,j) \in A$. e_{ij} is the load capacity of a trailer on the link (i,j). a_{ij} is the line-haul cost per trailer on the link (i,j). q^{od} is the total LTL freight demand of commodity (o,d) originating at terminal o and destined for terminal d per week, $o \in N$, $d \in N$. δ_n^{od} is a constant, which equals to 1 if node n is destination d, –1 if node n is origin o and 0 otherwise, $n,o,d \in N$. z_{ij} is the total line-haul cost on the link (i,j). x_{ij} is the total freight flow on the link (i,j). x_{ij}^{od} is the binary decision variable, which equals to 1 if the freight flow of commodity (o,d) is routed on the link (i,j) and 0 if not. y_{ij} is the binary decision variable, which equals to 1 if a direct service is being offered on the link (i,j) and 0 if not. y_{ij}^{d} is the binary decision variable, which equals to 1 if the freight flow destined for terminal d is routed on the link(i,j) and 0 if not.

The load planning problem can be stated as follows:

$$(LTL) \text{ minimise } \sum_{(i,j)\in A} z_{ij} y_{ij} \tag{1}$$

$$\text{subject to } \sum_{i\in N} x_{in}^{od} - \sum_{j\in N} x_{nj}^{od} = \delta_n^{od} \quad n \in N, o \in N, d \in N \tag{2}$$

$$x_{ij} = \sum_{o\in N} \sum_{d\in N} q^{od} x_{ij}^{od} \quad (i,j) \in A \tag{3}$$

$$x_{ij}^{od} \le y_{ij}^{d} \quad (i,j) \in A, o \in N, d \in N \tag{4}$$

$$y_{ij}^{d} \le y_{ij} \quad (i,j) \in A, d \in N \tag{5}$$

$$\sum_{j\in N} y_{ij}^{d} \le 1 \quad i \in N \setminus \{d\}, d \in N \tag{6}$$

$$\sum_{j\in N} y_{dj}^{d} = 0 \quad d \in N \tag{7}$$

$$z_{ij} = \begin{cases} a_{ij}x_{ij} / e_{ij} & if\, x_{ij} \ge f_{ij}e_{ij} \\ a_{ij}f_{ij} & if\, x_{ij} < f_{ij}e_{ij} \end{cases} \quad (i,j) \in A \tag{8}$$

$$x_{ij}^{od} \in \{0,1\} \quad (i,j) \in A, o \in N, d \in N \tag{9}$$

$$y_{ij} \in \{0,1\} \quad (i,j) \in A \tag{10}$$

$$y_{ij}^{d} \in \{0,1\} \quad (i,j) \in A, d \in N \tag{11}$$

The objective function (1) is the total line-haul cost and should be minimised. Constraint (2) expresses the standard flow conservation. Constraint (3) shows the relationship between the total freight flow and the demands of commodity (o,d). Constraint (4) states that if the flow destined for d is not routed on the link (i,j), then the flow of every commodity (o,d) on the link (i,j) must be zero. Constraint (5) states that if the direct service on the link (i,j) is not being offered, then the flow destined for d must not be routed on the link (i,j). Constraints (6) and (7) insure that the paths from all origin terminals into a destination terminal form a tree. Constraint (8) states that the minimum frequency of deliveries between a pair of terminals must satisfy a given service level. Constraints (9), (10) and (11) are the binary requirements.

A Lagrangian relaxation problem

The Lagrangian relaxation is one of general solution strategies for solving mathematical programming problems that permit us to decompose problems to exploit their special structure. When we use vectors of the Lagrange multipliers $\boldsymbol{v} = \{v_i^{od}\}$ relative to constraint (2) and $\boldsymbol{w} = \{w_i^{d}\}$

relative to (6) and (7), and add them to the objective function (1), the following Lagrangian relaxation problem *LG* can be formed:

$$(LG)\ \text{minimise}\ \sum_{(i,j)\in A} z_{ij}y_{ij} + \sum_{(i,j)\in A}\sum_{d\in N}\left\{\sum_{o\in N}(v_i^{od}-v_j^{od})\ x_{ij}^{od} + w_i^d y_{ij}^d\right\} + \sum_{d\in N}\sum_{o\in N}(v_d^{od}-v_o^{od}) - \sum_{d\in N}\sum_{i\in N\setminus\{d\}} w_i^d \quad (12)$$

subject to (3)–(5) and (8)–(11)

where $w_i^d \geq 0, i \in N\setminus\{d\}, d\in N$.

Given the Lagrange multipliers $\boldsymbol{v}$ and $\boldsymbol{w}$, we can deal with the third and the fourth terms of the objective function (12) as constant terms. *LG* can be decomposed into following subproblem LG_{ij} for each link (i,j).

$$(LG_{ij})\ \text{minimise}\ z_{ij}y_{ij} + \sum_{d\in N}\left\{\sum_{o\in N}(v_i^{od}-v_j^{od})\ x_{ij}^{od} + w_i^d y_{ij}^d\right\} \quad (13)$$

$$\text{Subject to}\ x_{ij}^{od} \leq y_{ij}^d \quad o\in N,\ d\in N \quad (14)$$

$$y_{ij}^d \leq y_{ij} \quad d\in N \quad (15)$$

$$z_{ij} = \begin{cases} \sum_{o\in N}\sum_{d\in N} a_{ij}q^{od}x_{ij}^{od}/e_{ij} & if \sum_{o\in N}\sum_{d\in N} q^{od}x_{ij}^{od} \geq f_{ij}e_{ij} \\ a_{ij}f_{ij} & if \sum_{o\in N}\sum_{d\in N} q^{od}x_{ij}^{od} < f_{ij}e_{ij} \end{cases} \quad (16)$$

$$x_{ij}^{od} \in \{0,1\} \quad o\in N, d\in N \quad (17)$$

$$y_{ij} \in \{0,1\} \quad (18)$$

$$y_{ij}^d \in \{0,1\} \quad d\in N \quad (19)$$

Furthermore, LG_{ij} can be decomposed into following two sub-problems, LG_{ij}^1 and LG_{ij}^2.

$$(LG_{ij}^1)\ \text{minimise}\ \sum_{d\in N}\left\{\sum_{o\in N}(a_{ij}q^{od}/e_{ij}y_{ij} + v_i^{od} - v_j^{od})x_{ij}^{od} + w_i^d y_{ij}^d\right\} \quad (20)$$

$$\text{subject to}\ \sum_{o\in N}\sum_{d\in N} q^{od}x_{ij}^{od} \geq f_{ij}e_{ij} \quad (21)$$

(14), (15) and (17)–(19)

$$(LG_{ij}^2)\ \text{minimise}\ a_{ij}f_{ij} + \sum_{d\in N}\left\{\sum_{o\in N}(v_i^{od}-v_j^{od})\,x_{ij}^{od} + w_i^d y_{ij}^d\right\} \quad (22)$$

$$\text{subject to}\ \sum_{o\in N}\sum_{d\in N} q^{od}x_{ij}^{od} < f_{ij}e_{ij} \quad (23)$$

(14), (15) and (17)–(19)

When we give the Lagrange multipliers $\boldsymbol{v}$ and $\boldsymbol{w}$, and solve the Lagrangian relaxation problem *LG* or further a relaxation problem optimally, a lower bound for *LTL* can be obtained.

An optimal solution for a Lagrangian relaxation problem

At first, we assume that the Lagrange multipliers $\boldsymbol{v}$ are given and let $\boldsymbol{w} = \mathbf{0}$. Then LG_{ij}^{1} can be rewritten as a simple problem.

$$\text{minimise} \quad \sum_{d\in N}\sum_{o\in N}(a_{ij}q^{od} / e_{ij}y_{ij} + v_i^{od} - v_j^{od})\, x_{ij}^{od} \tag{24}$$

$$\text{subject to} \quad x_{ij}^{od} \le y_{ij} \quad o \in N, d \in N \tag{25}$$

(17), (18) and (21)

We decompose this problem into two sub-problems in the case of $y_{ij} = 0$ and $y_{ij} = 1$. Obviously, when $y_{ij} = 0$, the optimal solution is $x_{ij}^{od} = 0 (\forall o, d \in N)$ and the optimal value of Equation (24) is 0. When $y_{ij} = 1$, this problem can be rewritten as the following 0–1 knapsack problem LG_{ij}^{11}.

$$(LG_{ij}^{11}) \quad \pi_{ij}^{1} = \text{minimise} \sum_{d\in N}\sum_{o\in N}(a_{ij}q^{od} / e_{ij} + v_i^{od} - v_j^{od})\, x_{ij}^{od} \tag{26}$$

subject to (17) and (21)

This problem relaxed 0–1 conditions turn out to be the continuous knapsack problem and can be simply solved by sorting, and then a lower bound and the relaxation solution for LG_{ij}^{11} are easily obtained. Accordingly, the lower bound for LG_{ij}^{1} is $min\{0, \pi_{ij}^{1}\}$, which is the minimum value of the optimum in the case of $y_{ij} = 0$ and $y_{ij} = 1$.

As with LG_{ij}^{1}, LG_{ij}^{2} can be decomposed into two cases of $y_{ij} = 0$ and $y_{ij} = 1$. When $y_{ij} = 1$, this problem can be rewritten as the following problem LG_{ij}^{21}.

$$(LG_{ij}^{21})\ \pi_{ij}^{2} = \text{minimise}\ a_{ij}f_{ij} + \sum_{d\in N}\sum_{o\in N}(v_i^{od} - v_j^{od})\, x_{ij}^{od} \tag{27}$$

subject to (17) and (23)

Consequently, the optimal value or the lower bound for *LG* is

$$\sum_{(i,j)\in A}\min\{0,\pi_{ij}^{1},\pi_{ij}^{2}\} + \sum_{d\in N}\sum_{o\in N}(v_d^{od} - v_o^{od}) - \sum_{d\in N}\sum_{i\in N\setminus\{d\}} w_i^{d} \tag{28}$$

For $(i,j) \in A$, the optimal solution is $y_{ij} = 1$ if $\pi_{ij}^{1} < 0$ or $\pi_{ij}^{2} < 0$ and $y_{ij} = 0$ if not. For $o \in N$, $d \in N$, $(i,j) \in A$, the optimal value of x_{ij}^{od} is X_{ij}^{od1} if $\pi_{ij}^{1} \le \pi_{ij}^{2}$

and $y_{ij} = 1$, X_{ij}^{od2} if $\pi_{ij}^{2} < \pi_{ij}^{1}$ and $y_{ij} = 1$, and 0 otherwise, where X_{ij}^{od1} is the solution for LG_{ij}^{11} and X_{ij}^{od2} is the solution for LG_{ij}^{21}. Additionally, for $d \in N$, $(i,j) \in A$, the optimal solution is $y_{ij}^{d} = 1$ if some $x_{ij}^{od} > 0 (o \in N)$ and $y_{ij}^{d} = 0$ if not, because $\boldsymbol{w} = \mathbf{0}$. From these expressions, we can solve the Lagrangian relaxation problem LG and obtain the lower bound for the load planning problem LTL.

A multiplier adjustment and a sub-gradient method

We develop the multiplier adjustment method for setting the value of $\boldsymbol{w}$. Increasing the value of $\boldsymbol{w}$ from $\mathbf{0}$, while $\boldsymbol{w}$ is feasible and the solution $\boldsymbol{x}$ and $\boldsymbol{y}$ for LG do not change, we could also increase the lower bound for LTL.

For

$$\begin{aligned} LG_{ij}^{1}, \text{let } \phi_i^1 = \min\{&\min(a_{ij}q^{od} / e_{ij}y_{ij} + v_i^{od} - v_j^{od} \mid x_{ij}^{od} = 0, \\ &\qquad o \in N, d \in N) \\ &- \max(a_{ij}q^{od} / e_{ij}y_{ij} + v_i^{od} - v_j^{od} \mid x_{ij}^{od} > 0, \\ &\qquad o \in N, d \in N) \mid j \in N\} \quad i \in N \end{aligned} \tag{29}$$

For

$$\begin{aligned} LG_{ij}^{2}, \text{let} \phi_i^2 = \min\{&\min(v_i^{od} - v_j^{od} \mid x_{ij}^{od} = 0, \\ &\qquad o \in N, d \in N) \\ &- \max(v_i^{od} - v_j^{od} \mid x_{ij}^{od} > 0, \\ &\qquad o \in N, d \in N) \mid j \in N\} \quad i \in N \end{aligned} \tag{30}$$

Then we set the increment value of $\boldsymbol{w}$ as

$$w_i^d := max\{0, \min(\phi_i^1, \phi_i^2, \varphi_i^{1d}, \varphi_i^{2d})\} \quad i \in N \setminus \{d\}, d \in N, \quad if\ K_i^d \geq 2 \tag{31}$$

where

$$\begin{aligned} \varphi_i^{1d} = min\{&-\sum_{d \in N} \sum_{o \in N} (a_{ij}q^{od} / e_{ij}y_{ij} + v_i^{od} - v_j^{od}) x_{ij}^{od} \\ &- \sum_{d' \in N \setminus [d]} w_i^{d'} \mid j \in N\} \end{aligned} \tag{32}$$

$$\varphi_i^{2d} = min\{-a_{ij}f_{ij} - \sum_{d \in N} \sum_{o \in N} (v_i^{od} - v_j^{od}) x_{ij}^{od} - \sum_{d' \in N \setminus [d]} w_i^{d'} \mid j \in N\} \tag{33}$$

$$K_i^d = \{the\ number\ of\ x_{ij}^{od} \mid x_{ij}^{od} > 0, o \in N, j \in N\} \tag{34}$$

When the values of $\boldsymbol{w}$ ascend up to these values, $\boldsymbol{w}$ is feasible because $w_i d \geq 0$, and the optimal solutions for *LG* still do not change. Then the lower bound can be increased as much as

$$\sum_{d \in N} \sum_{i \in N \setminus \{d\}} w_i^d (K_i^d - 1) \tag{35}$$

The first term $w_i^d K_i^d$ is the increment value of the second term in Equation (12) and the second term $-w_i^d$ is the decrement value of the fourth term in Equation (12).

For setting the values of $\boldsymbol{v}$ approximately, we apply the standard sub-gradient optimisation procedure (Fisher, 1981). This is an iterative procedure, which uses the current multipliers $\boldsymbol{v}$, the current lower bound and an upper bound, in order to compute the new multipliers $\boldsymbol{v}$ used in the next iteration. Sub-gradient $\boldsymbol{g}$ of $\boldsymbol{v}$ can be defined follows,

$$g_n^{od} = \delta_n^{od} - \sum_{i \in N} x_{in}^{od} + \sum_{j \in N} x_{nj}^{od} \quad n \in N, o \in N, d \in N \tag{36}$$

Then, using a step size s^t in iteration t, the new set of multipliers are given by

$$v_n^{od} := v_n^{od} + s^t g_n^{od} \quad n \in N, o \in N, d \in N \tag{37}$$

It can be shown for a finite cardinality, if the step size s^t is selected so that $\lim_{t \to \infty} s^t = 0$, while $\sum_{t=0}^{\infty} s^t = \infty$, then the sequence $\boldsymbol{v}$ converges to the optimal value. We use the step size as

$$s^t = p^t \times (\text{the best known upperbound} - \text{the current lower bound}) / \|\mathbf{g}\|^2 \tag{38}$$

where p^t is a scalar which is initially equal to 1 and is reduced every some iteration number.

Numerical experiments

In order to test the performance of our Lagrangian relaxation method, a set of numerical experiments is carried out using IBM compatible computer with PENTIUM4 1.7GHz, memory 256Mb and OS Windows 2000. This solution method is coded in COMPAQ VISUAL FORTRAN Ver.6. The problem data used in these experiments is randomly generated up to 50 nodes. *N*, the set of nodes presented end-of-line and break-bulk terminals is drawn from a uniform distribution over a rectangle measuring 100 by 100. A, the set of all potential links of direct services is $N \times N$. The line-haul cost per trailer on the link is in proportion to the Euclidean distance between nodes. Each of LTL freight demand is 1, the minimum frequency is 1 and the load capacity is $|N|$.

Obtaining for an upper bound and approximate solutions, we use three kinds of Lagrangian heuristic algorithms (Katayama, 2002), which are a link delete heuristic, a successor matrix modification heuristic and a tabu search method.

Table 7.3.1 briefly summarises the effectiveness of the Lagrangian relaxation method. It shows the number of nodes, potential direct services, commodity and the percentage gap between the best upper bound and the best lower bound. The percentage gaps range from 1.90% to 6.32%. Figure 7.3.3 shows the rate of convergence for the problem with

Table 7.3.1 The transport miles, cost and volume split for ambient and composite products

|N|	**|A|**	**Commodity**	**Gap (%)**
10	90	90	1.90
20	380	380	3.39
30	870	870	3.72
40	1560	1560	5.31
50	2450	2450	6.32

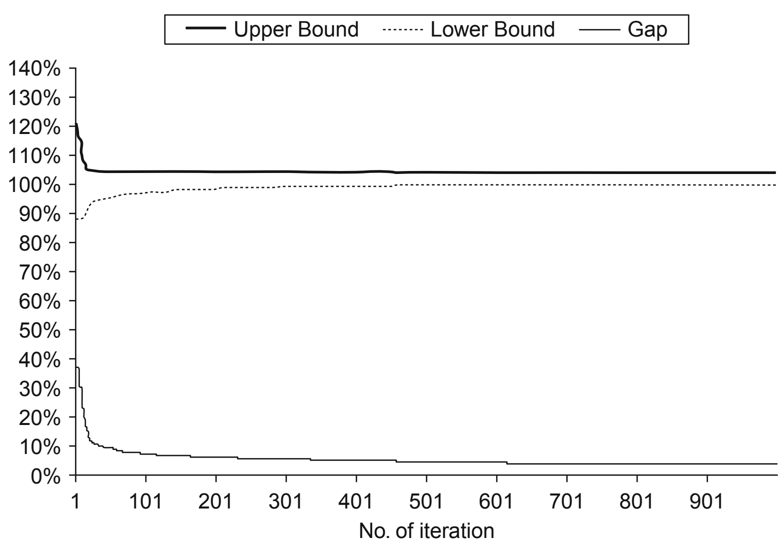

Figure 7.3.3 Convergence of method for 30 nodes

30 nodes. The sub-gradient optimisation algorithm exhibited the fastest rate of convergence.

Conclusions

In this paper, we developed the load planning problem for LTL motor carriers and its solution method using the Lagrangian relaxation. The result of the experiments suggest that our Lagrangian relaxation problem and solution approach can perform a good job of identifying a lower bound of the load planning problem for LTL motor carriers. This research is underway to adapt solutions to the real world problems, such as the empty trailer balancing, the transit time and the number of transhipment, etc.

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8
Sustainable and Responsible Supply Chains

8.1
Does Firm Size Influence Sustainable Performance in Food Supply Chains: Insights from Greek SMEs

Michael Bourlakis, George Maglaras, Emel Aktas, David Gallear and Christos Fotopoulos

Introduction

According to Carter and Rogers (2008), sustainable supply chain management (SCM) is "the strategic, transparent integration and achievement of an organisation's social, environmental, and economic goals in the systemic coordination of key interorganisational business processes for improving the long term economic performance of the individual company and its supply chains". They posit that a deliberate long-term strategy combining environmental and social aspects of sustainability, which extend beyond a firm's boundary with economic objectives, helps firms to mobilise those supply chain activities that directly support sustainability. Similarly, performance measurement systems that include sustainability considerations can be a driver for sustainability performance improvement (Angell and Klassen, 1999). Small and medium-sized enterprises (SMEs) are not immune from these pressures, particularly given that their total (cumulative) impact on sustainability is high (Gadenne et al., 2008). Moreover, many SMEs have not progressed in the adoption and development of sustainable supply chain practices due to the upfront cost of greening and although the literature is rich on supply chain performance measurement in general (e.g., Gunasekaran et al., 2004), and there is a dearth when more specific contexts are considered. Furthermore, while the literature on various aspects of sustainability strategy creation in SMEs (e.g., Gadenne et al., 2008) and/or food supply chains (e.g., Jamsa et al., 2011) has recently started to develop, a careful examination of the literature indicates only a handful of contributions that have specifically addressed sustainability performance measurement in supply chains in the context of SMEs (Gunther and Kaulich, 2005), and none in the context of SMEs in the food supply chain; thus, a major gap exists in the literature. This gap is confirmed in a recent work by Bititci et al. (2012) who conducted a literature review synthesis and stressed that further challenges in relation to performance measurement include performance measurement in SMEs and sustainability issues in performance measurement. Our work addresses this shortcoming by investigating sustainability performance, analysing the effect of firm size at SME level (micro, small, medium) on various appropriate indicators developed through a careful review of sustainability measures for food supply chains found in the literature. In accordance with the definition of SMEs from the European Commission (2005), the micro category included firms employing less than ten persons and with annual turnover or annual balance sheet totalling no more than €2 million. The small category included firms employing less than 50 persons and with annual turnover or annual balance sheet totalling no more than €10 million. In the medium-sized category, we included firms with less than 250 employees and with annual turnover no more than €50 million or annual balance sheet totalling no more than €43 million (European Commission, 2005).

Sustainability performance measures for food chains

We have adopted a performance measurement framework widely used (Aramyan et al., 2007). The framework allows chain-wide measurement, comprises four categories (*efficiency*, *flexibility*, *responsiveness* and *product quality*, Aramyan et al., 2007) and a total of 18 sustainability measures relevant to food industry supply chains are identified (Table 8.1.1).

The first group are efficiency measures. Specifically, the food supply chain's production processes and delivery systems can have a significant negative impact on the environment if not designed effectively and managed efficiently (Angell and Klassen, 1999). Delivery and distribution costs are clearly a critical efficiency measure in food supply chains of all types and sizes while storage costs in the food supply chain are an important indicator of food supply chain members' sustainability performance. Waste is one of the most pervasive sustainability issues in food supply chains, and minimisation is frequently identified in the literature as a core measure for environmental sustainability in food production (Maloni and Brown, 2006). The financial cost associated

Table 8.1.1 Sustainability supply chain performance measures

Performance element	**Measures**
Efficiency	Production/operational/raw materials cost Storage cost Delivery and distribution cost Waste Financial cost Gross profit margin
Flexibility	Flexibility in extra volume orders Flexibility in delivering in extra point of sales
Responsiveness	Responsiveness in the arranged lead time Responsiveness in delivery in terms of arranged point of sale Responsiveness in delivery of ordered product (exact code, quality, etc.)
Quality	Quality of the firm's product Product conservation time Consistency of traceability system Storage and delivery conditions Quality of packaging
Total supply chain	Firm's perception of its own supply chain performance Firm's perceptions of market opinion regarding its chain performance

with the administration of food supply chain operations is an important sustainability performance indicator. To these preceding cost-based and waste efficiency measures, we add a sixth, namely gross profit margin. This was identified by Kolk (2004) as a key sustainability measure. Flexibility is widely used as group of performance indicators in the supply chain literature (Aramyan et al., 2007). Two flexibility measures are particularly important for SMEs operating in food supply chains: flexibility in delivering to extra points of sale and flexibility in extra volume orders (Ilbery and Maye, 2005). Our third group of measures are concerned with responsiveness, which reflects the ability of the food chain to deliver a high customer service (Shepherd and Gunter, 2006). We propose three measures of responsiveness: the responsiveness in meeting the arranged lead times, the responsiveness in delivering to the arranged point of sales (location) and the responsiveness in delivering the product as ordered (correct type and quantity). The fourth category of sustainability measures concern product quality. Product quality is widely recognised and used as a key sustainability performance criterion (Aramyan et al., 2007). Final product quality is highly dependent on primarily product conservation time. Product conservation time refers to the length of time a food product within the food supply chain maintains the desired properties and characteristics before it starts to deteriorate and become unusable. Lastly, raw material quality is important for final product quality. In this paper, raw material quality is considered as part of the final product quality, and hence, it is not examined separately. A near mandatory requirement in food supply chains is food traceability, and it is considered as an essential sustainability measure. In addition, regulatory and/or consumer demands for recyclable or returnable packaging and for clearer information on the nutritional and dietary characteristics of the food products has heightened the importance of the need for packaging of good quality (Angell and Klassen, 1999). To the preceding 16 food supply chain sustainability measures, we have added two complementary measures. These recognise explicitly the importance of the chain members' own evaluation of its overall performance as a contributor to the sustainability of the food supply chain of which it is a part, but also these members' own evaluation of the possible external market's opinion of that performance. Overall, we seek responses to the following research questions:

1. How do micro, small and medium-sized members of the Greek food chain perform in key sustainability measures?
2. Are there any differences in the sustainable performance of the Greek food chain with respect to firm size?

Methodology

We employed a structured questionnaire survey divided in two sections. The first section included questions on five performance categories (efficiency, flexibility, responsiveness, quality and total supply chain). Efficiency indicators were assessed in terms of percentage of the firm's turnover while the remaining indicators were evaluated on a seven point Likert scale (1 = Extremely satisfactory performance; 7 = Extremely unsatisfactory performance). The second section included questions on demographic representation in order to analyse differences in performance with respect to micro, small and medium-sized firms. The questionnaire was pre-tested through a qualitative stage while the final quantitative stage focused on the key members of the Greek food chain in relation to firm size. It is worth noting that many changes have taken place in this food chain during the past two decades including the advent of many international manufacturers and retailers, the significant investment in logistics infrastructure by the major retail multiples and the use of sophisticated systems (see Bourlakis et al., 2012). Firms were identified through relevant directories (e.g., ICAP Business Directory, ICAP 2007), and our sample covered a representative number of firms from various supply chain stages and sectors involved. Initially, we contacted each firm by telephone to identify the potential respondents – "key informants". As we were focusing on SMEs, the appropriate key informant was normally the general manager or the owner of the firm who was deemed appropriate to answer our questionnaire due to their expert knowledge of their organisations. Data collection was carried out by a professional research agency by means of a Computer Aided Personal Interviewing system (CAPI), and we only solicited one response per each firm sampled in the survey. Questionnaires were answered through telephone surveys representing every Greek region. On many occasions, these key informants suggested other SMEs who might be interested to participate in our work, and they also suggested other SMEs they were collaborating with. As a result, we analysed 997 responses. Finally, we employed analysis of variance (ANOVA) to determine whether the chain members have significant differences with respect to the 18 indicators. ANOVA is a method for investigating statistical differences in performance and many examples are found in the supply chain literature (Lai et al., 2004).

Empirical findings

Table 8.1.2 shows the number of firms in each key food supply chain stage and their size.

On average, turnover is between €500,000 and €1,000,000 for growers, manufacturers and wholesalers. For retailers, the average turnover is €200,000–€500,000.

Table 8.1.2 Firms classified according to supply chain role and firm size

	Growers	Manufacturers	Wholesalers	Retailers	Total
Micro	139	82	233	137	591
Small	19	108	167	25	319
Medium	6	36	34	11	87
Total	164	226	434	173	997

Firm size versus supply chain role

We analysed the differences among micro, small and medium-sized firms with respect to their supply chain role, namely, growers, manufacturers, wholesalers and retailers in order to examine the effect of firm size on performance. The following sub-sections report the significant differences observed between micro, small and medium-sized firms in terms of the individual performance measures. Out of these measures, we report those where we observed significant differences in terms of firm size in the ANOVA test (at 0.05 significance level). The best performer for each indicator is emphasised in bold.

Growers

The growers in the Greek food supply chain do not generally have processing operations, with the micro growers serving primarily local markets. Table 8.1.3 reports significant differences in performance measures when growers' data is analysed using ANOVA. There are two statistically significant differences in the sustainable performance measures with respect to firm size for the growers. Small growers perform better in terms of flexibility in extra volume orders and consistency of traceability system and average scores indicate "very satisfactory" perception in terms of these two variables. There are no statistically significant differences in performance between micro firms and the total sample or between medium firms and the total sample in terms of flexibility in extra volume orders and consistency of traceability system.

An explanation of these findings may relate to the fact that the micro growers do not have enough capacity (and flexibility) to cope with changes in orders as they produce small volumes. These firms have not developed their supply chain and they often do not have the time, resources or information (and flexibility) to deliver the requested

Table 8.1.3 Differences between micro, small and medium-sized growers

Performance measure	**Micro (*n* = 139) Mean (SD)**	**Small (*n* = 19) Mean (SD)**	**Medium (*n* = 6) Mean (SD)**	**Total (*n* = 164) Mean (SD)**
Flexibility in extra volume orders	3.26 (2.02)	**1.95 (1.03)**	3.67 (1.75)	3.12 (1.97)
Consistency of traceability system	2.53 (2.03)	**1.26 (0.56)**	1.50 (0.84)	2.35 (1.93)

extra volume orders. Medium-sized firms may be negatively impacted by their size in relation to flexibility because, although they have larger capacity in comparison to micro and small firms, they usually deal with large, multiple retailers or wholesalers and their production capacity is not always sufficient to accommodate extra, large orders from these firms. In terms of the consistency of using a traceability system, micro firms are likely to be operating in local markets, in relatively short supply chains giving products to local buyers; hence, they may be less likely to use consistent traceability systems. Conversely, small and medium-sized growers may be shipping greater distances serving large retailers and wholesalers concerned with traceability implementation.

Manufacturers

Following an ANOVA test for manufacturers (Table 8.1.4), we observed a successful performance of micro firms in terms of gross profit margin. These micro manufacturers sell primarily to local and regional retailers and wholesalers and they usually manufacture niche products which command larger profit margins. The latter may also explain the high profit margin exhibited by small manufacturers. Medium-sized manufacturers distribute to larger national retailers and wholesalers and could be therefore facing higher financial demands. For the remaining meas-

Table 8.1.4 Differences between micro, small and medium-sized manufacturers

Performance measure	**Micro (*n* = 82) Mean (SD)**	**Small (*n* = 108) Mean (SD)**	**Medium (*n* = 36) Mean (SD)**	**Total (*n* = 226) Mean (SD)**
Gross profit margin	**12.05 (10.5)**	11.2 (10.7)	5.60 (3.33)	10.56 (10.0)
Flexibility in extra volume orders	3.02 (1.70)	2.23 (1.2)	**2.17 (1.6)**	2.51 (1.55)
Flexibility in delivering in extra POS	3.04 (1.83)	2.33 (1.6)	**2.08 (1.3)**	2.55 (1.69)
Quality of packaging	2.21 (1.64)	1.85 (1.4)	**1.44 (0.7)**	1.92 (1.44)
Firm's perception of chain performance	2.46 (1.17)	**1.97(0.7)**	**1.97 (0.7)**	2.15 (0.95)
Firm's perceptions of market opinion regarding its supply chain performance	2.37 (1.18)	**1.98(0.8)**	**1.97 (0.9)**	2.12 (1.03)

ures exhibiting statistical significance, medium-sized firms outperform small and micro manufacturers.

In comparison to growers, manufacturers are more likely to have operational systems in place, and therefore, they are more flexible to accommodate changes in customer volume orders and points of sales. Specifically, medium-sized manufacturers outperform micro manufacturers in most sustainability indicators given in Table 8.1.4. This can be related to higher economies of scale achieved in various operations including packaging. In terms of the firm's perception of its own supply chain performance and the firm's perceptions of market opinion regarding its supply chain performance, micro manufacturers perform worse than small and medium-sized manufacturers. Micro manufacturers may be aware of that, and they may have resource constraints as well as limited use of relevant systems and processes. Equally, medium-sized manufacturers perform slightly better than small manufacturers in these two indicators and are possibly aware of their ability to attract higher economies of scale (and scope by manufacturing products in similar categories) in their operations.

Wholesalers

Small wholesalers perform better in most performance measures with the exception of quality of packaging (Table 8.1.5). Specifically, packaging in the food sector requires specific know-how and medium-sized wholesalers may be able to have better access to the necessary resources than micro and small wholesalers.

Table 8.1.5 Differences between micro, small and medium-sized wholesalers

Performance measure	**Micro (*n* = 233) Mean (SD)**	**Small (*n* = 167) Mean (SD)**	**Medium (*n* = 34) Mean (SD)**	**Total (*n* = 434) Mean (SD)**
Consistency of traceability system	2.24 (1.55)	**1.80 (1.3)**	2.03 (1.82)	2.05 (1.50)
Quality of packaging	3.40 (2.44)	2.58 (2.25)	**1.71 (1.1)**	2.95 (2.35)
Firm's perception of its own supply chain performance	2.36 (0.98)	**2.07 (0.84)**	2.47 (1.40)	2.26 (0.98)
Firm's perceptions of market opinion regarding its supply chain performance	2.31 (1.14)	**2.08 (0.90)**	2.53 (1.21)	2.24 (1.07)

Micro wholesalers are less inclined to have consistent traceability systems. This may be related to the fact that they serve primarily the local market. It may also be the outcome of the low profit margins that wholesalers command, making the use of traceability systems, which are quite expensive, possibly prohibitive. Equally, small wholesalers (and medium) are more inclined to achieve consistency in terms of traceability.

Retailers

Micro retailers outperform small and medium-sized retail firms in terms of gross profit margin (Table 8.1.6), and this can be explained by the fact that micro retailers are generally operating in remote and distant areas and sometimes they have a monopoly by being the only retailer or store in a village. Waste performance of medium-sized retailers is much better than the micro and small firms. Medium-sized retailers manage larger volumes of product than the micro and small retailers and offer many promotions and product discounts. Therefore, they should be more proactive (and could perform better) in terms of reducing waste in their operations. Finally, small firms perform better in terms of flexibility in extra volume orders and responsiveness in delivery in terms of the ordered type of product (exact code, etc.).

Greek food chain

We also examined the differences between micro, small and medium-sized firms in the whole sample in order to expose the under- and over-performing firms. Out of the 18 performance indicators, we only report

Table 8.1.6 Differences between micro, small and medium-sized retailers

Performance measure	**Micro (n = 137) Mean (S D)**	**Small (n = 25) Mean (SD)**	**Medium (n = 11) Mean (SD)**	**Total (n = 173) Mean (SD)**
Gross profit margin	**14.81 (11.5)**	5.67 (5.28)	5.44 (3.64)	12.66 (11.0)
Waste	6.95 (6.54)	3.58 (3.82)	**2.00 (1.8)**	5.95 (6.13)
Flexibility in extra volume orders	2.80 (1.57)	**1.80 (0.9)**	2.55 (1.75)	2.64 (1.54)
Responsiveness in delivery of ordered product (e.g., exact code)	1.77 (1.11)	**1.48 (0.6)**	2.55 (2.30)	1.77 (1.18)

those where we observe significant differences in terms of firm size (at 0.05 significance level, see Table 8.1.7).

Specifically, micro firms outperform small and medium-sized firms only in terms of production/operational/raw material cost and profit

Table 8.1.7 Significant differences with respect to firm size (ANOVA test)

Performance measure	**Micro (*n* = 591) Mean (SD)**	**Small (*n* = 319) Mean (SD)**	**Medium (*n* = 87) Mean (SD)**	**Total (*n* = 997) Mean (SD)**
Production/ operational/raw material cost	**43.74 (27.9)**	49.53 (26.2)	50.93 (29.65)	46.32 (27.67)
Gross Profit margin	**12.52 (11.3)**	11.45 (11.4)	8.10 (8.60)	11.83 (11.22)
Delivery & distribution cost	6.55 (6.70)	8.40 (7.05)	**5.61 (6.99)**	7.07 (6.90)
Flexibility in extra volume orders	2.82 (1.69)	**2.25 (1.27)**	2.49 (1.78)	2.61 (1.59)
Flexibility in delivering in extra points of sales	3.04 (1.89)	**2.38 (1.54)**	2.52 (1.73)	2.78 (1.80)
Responsiveness in delivery in terms of arranged point of sale	2.00 (1.43)	**1.76 (1.12)**	1.95 (1.36)	1.92 (1.34)
Responsiveness in delivery product	2.07 (1.62)	**1.71 (1.20)**	1.89 (1.43)	1.94 (1.49)
Product conservation time	3.59 (2.15)	**3.16 (2.00)**	3.32 (2.21)	3.43 (2.11)
Consistency of traceability system	2.35 (1.80)	1.84 (1.42)	**1.75 (1.47)**	2.14 (1.68)
Storage and delivery conditions	1.80 (1.17)	**1.55 (0.94)**	1.57 (1.01)	1.70 (1.09)
Quality of packaging	3.35 (2.43)	2.36 (2.05)	**1.84 (1.58)**	2.90 (2.32)
Firm's perception of its chain performance	2.41 (1.12)	**2.06 (0.81)**	2.24 (1.13)	2.28 (1.04)
Firm's perceptions of market opinion for its chain performance	2.34 (1.15)	**2.09 (0.90)**	2.24 (1.09)	2.25 (1.08)
Number of employees	4.18 (2.24)	20.51 (10.9)	86.49 (46.00)	18.73 (29.05)
*Turnover	5.81 (1.81)	6.71 (1.14)	6.68 (1.22)	6.22 (1.61)

Notes: * 1: <20,000 €; 2: 20,000–<50,000 €; 3: 50,000–<100,000 €; 4: 100,000–<200,000 €; 5: 200,000–<500,000 €; 6: 500,000–<1,000,000 €; 7: >1,000,000 €.

margin. This can be explained by the simpler management structures employed by micro firms. It may be also due to the greater prevalence of owner-managers in micro firms compared to the greater prevalence of (non-owner) managing directors in small and medium-sized firms. The presence of owner-managers creates a heightened level of loyalty from the local market, particularly with food micro retailers where there are frequent repeat customers and there is a high level of customer contact. These factors, in turn, have been observed to afford such firms the ability to command premium prices thus supporting higher profit margin. Finally, micro firms also have lower labour cost, especially if they are operating in rural areas. Medium-sized firms perform better in terms of delivery and distribution cost which may be due to the economies of scale enjoyed and they also perform better in the consistency of traceability system and quality of packaging. This may be explained by increased knowledge and skills possessed by the greater number of people working in these firms. Medium-sized firms tend to outsource their storage activities more than micro and small firms and this may help towards the reduction of their delivery and distribution cost. These medium-sized firms could also benefit by gaining expertise for packaging and traceability issues from the outsourcing providers. Small firms perform better in terms of the remaining measures. Specifically, they perform better for the four responsiveness and flexibility measures (see Table 8.1.7). Small firms also outperform in terms of product conservation time but the score of this measure is alarming (a mean score of 3.16 for small firms and a mean score of 3.43 for all firms suggesting slightly satisfactory). Therefore, product conservation time needs to be urgently improved. We need to stress that product conservation time is affected by the highly perishable nature of food products, and this is reflected as a challenge for the SMEs operating in the food chain. Medium-sized firms serve larger markets and greater distances, and this is also reflected in storage and distribution costs. Another interesting difference relates to storage and delivery conditions where small firms outperform micro and medium-sized firms. This may be due to high level of skills required especially for food products for deliveries and storage where a cold chain needs to be maintained throughout; conversely, micro firms underperform in this indicator.

Conclusions, managerial and policy implications

Limited work has examined sustainability performance measurement in supply chains for SMEs (Gunther and Kaulich, 2005) and none, according to our knowledge, in relation to SMEs in the food supply chains. Based on the above, we believe that our work has addressed this gap in the performance measurement literature (Bititci et al., 2012) by shedding light on the major sustainable performance differentials between all SME categories (micro, small and medium-sized firms) and by focusing at the same time on the same chain, the Greek food chain. Our work has generated many implications for managers and policymakers. For example, managers for micro firms need to be alert to the fact that their firms are underperforming in a range of measures and management action is required. Policymakers should also support these micro firms and identify ways to improve their sustainability performance especially when nine out of ten SMEs are micro firms at European and global levels (European Commission, 2005). One possible remedy may be the use of e-business tools that can facilitate information exchange between chain members and could improve performance in terms of, inter alia, responsiveness and flexibility especially when SMEs tend to make limited use of these tools. A major managerial and policy implication of this work relates to product conservation time. Managers need to prioritise the development of sufficient infrastructure, and policymakers should provide relevant incentives to SMEs to undertake appropriate improvements in this measure (and any other measures where there is scope for improvement). Overall, our work has highlighted a range of areas where improvement is required urgently, and it will support managers of SMEs in terms of prioritisation of their resources which are limited for SMEs. Finally, a limitation of this work is that we made use of specific measures examining a specific sector in a given national setting (Greek food chain), and it precludes the generalisation of findings to other sectors and countries.

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8.2

Setting Targets for Reducing Carbon Emissions from Logistics Operations: Principles and Practice

Alan McKinnon

Introduction

Scientific evidence of a pronounced global warming effect continues to accumulate, while more governments around the world are developing carbon reduction policies for their economies. Although binding international commitments to reduce greenhouse gas (GHG) are taking much longer than expected to agree, consensus is building in government and business circles that dramatic reductions in GHG emissions will have to be made over the next few decades to avert climatic and ecological disaster. It is against this background that companies are examining ways of reducing their carbon footprints.

Businesses can have numerous motives for cutting carbon emissions. The most compelling for many companies is simply the desire to save money. The pursuit of "eco-efficiency" is often driven mainly by financial concerns but presented as an environmental endeavour for marketing and Corporate Social Responsibility (CSR) reasons. The early efforts that companies made to reduce their GHG emissions have typically involved harvesting the "low hanging fruit", wherever it can be found, but not part of a structured programme of carbon mitigation. As their commitment to carbon reduction has strengthened and their understanding of their carbon footprint has deepened, their quest for carbon savings has become more systematic. Some of the corporate leaders in sustainability have now developed, or are developing, explicit carbon reduction strategies. These strategies naturally prioritise those core activities accounting for a large share of the corporate carbon footprint and/or offering the most cost effective options for carbon reduction. For logistics service providers, wholesalers and many multiple retailers, transport and warehousing are clearly core activities. Even in manufacturing businesses, however, where logistics' share of total GHG emissions is often less than 10%, it is still seen as being potentially an important source of emission savings.

An earlier paper outlined a seven-stage procedure that companies can use to develop a decarbonisation strategy for logistics (McKinnon, 2011). One of the key steps in this procedure was the derivation of a carbon reduction target for the logistics operation. This paper examines this process of target-setting in greater detail. It considers the reasons for setting a target for future carbon emissions, explores the different types of targets that companies can adopt and shows how an industry-level target can be established. The paper concludes by proposing a series of principles for companies to follow when deriving carbon reduction targets for logistics.

Methodology

The paper is based on reviews of the literature on environmental target-setting in business, previous research on the decarbonisation of logistical activity and the public policy context for climate change initiatives in logistics. Primary data has been collected from discussions with a sample of managers in companies that have set carbon reduction targets for logistics. Some of these companies were early entrants to the Logistics Carbon Reduction Scheme (LCRS), set up by the UK Freight Transport Association in 2010. The interviews investigated whether companies had specific carbon reduction targets for logistics, and if so, the extent to which they were based on quantitative analysis and aligned with corporate, industry and governmental goals.

Reasons for establishing carbon reduction targets

The setting of targets is a fundamental part of the strategy development process. They establish clear goals for the company to meet, define its future direction, concentrate the minds of managers and provide a benchmark against which the success of the strategy can be judged. Targeting is widely applied in other areas of business activity such as sales, customer service, finance, operations and HR, and so its application to environmental policy, and in particular carbon emissions, would seem logical. There are, nevertheless, two important differences between carbon reduction targets and most of the other business targets which companies routinely set. First, carbon targets are often declared publicly, for marketing and CSR reasons, in contrast to many other targets which are essentially for internal consumption. Indeed targets can be used as a form of "competitive greenery" where companies use their environmental credentials as a differentiator and try to outbid each other in terms of their future environmental performance. Second, unlike most other targets over which the company has full discretion, carbon reduction targets, to be credible, must be aligned with externally defined climate change policies and objectives emanating from governments, trade bodies or environmental agencies. By publicly committing to cut carbon emissions by a certain amount and by a specified date, a company shows that it is trying to conform to wider industry norms and government expectations.

Types of carbon reduction target for the logistics sector

The targets that companies have set for cutting logistics-related GHG emissions can be differentiated in several ways.

Top-down and bottom-up targets

Top-down carbon reduction targets for logistics are imposed by higher level management, such as a board of directors or executive board. They are often company level targets applied uniformly across all functional areas. In most cases, they are not based on a detailed analysis of the potential for cutting carbon emissions either at a corporate of functional level and instead are aligned with targets quoted by competitors, trade bodies and/or government agencies. As such they have several shortcomings:

1. They lack credibility because they are not based on an analysis of what is possible within operational, technological and financial constraints.
2. They fail to recognise important differences between companies in terms of their GHG-generating characteristics, their past record of environmental improvement and the baseline conditions pertaining at the time when the target is set.
3. Applying the same target across the business ignores the fact that there are wide cross functional variations in the potential for carbon abatement and its cost-effectiveness. This is illustrated, in an idealised way, in Figure 8.2.1. It shows how the shape of the carbon abatement cost curve can vary between business functions (F1–4), both in

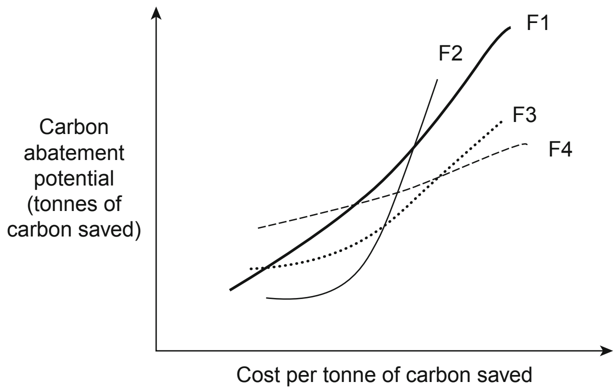

Figure 8.2.1 Carbon abatement and related cost profiles for four business functions

> its highest value (maximum potential carbon saving) and its gradient (cost per tonne of carbon saved). This gradient is unlikely to be constant as the initial carbon savings can normally be obtained more cheaply than the later ones. This explains why the lines are curved rather than linear. It is desirable to set higher targets for those functions offering greater GHG savings and savings that can be achieved at a lower cost per tonne of emissions.

Bottom-up targets generally overcome all three of these problems. They are rooted in an analysis of GHG-generating processes and a micro-level assessment of the potential for cutting these emissions. This generally involves plotting a business as usual (BAU) trend for a specific function or activity and then estimating the extent to which the actual trend can deviate from this BAU projection as a result of the application of decarbonisation measures. The company must decide what measures are appropriate, at what rate they can be applied and what the resulting GHG savings are likely to be. Summing the savings achievable by a particular date can define the target. Software tools, such as a decarbonisation tool developed by Heriot-Watt University for the FTA,[1] can be used to assist this calculation, testing various combinations of measures and various degrees of application. The analysis can also include financial data to assess the relative cost-effectiveness of the measures considered. In summary, therefore, bottom-up targets are company- and function-specific, grounded in an analysis of what is actually possible and affordable.

Absolute versus intensity targets

Meeting an "absolute" target would reduce the total amount of GHG emitted by a logistics operation regardless of changes in the level of activity. Most companies fear that the pursuit of an absolute reduction will constrain the growth of their business and carry a financial penalty. They therefore prefer to express the target as a decline in their carbon emissions relative to the level of business or logistical activity. They must then decide against which corporate or logistics variable(s), or "normalisers", the reduction in GHG emissions should be measured. This can be difficult as there is seldom an ideal denominator for the carbon intensity fraction. Corporate level economic variables such as turnover, value-add and employment may be appropriate for companies whose core activity is logistics, but for others, the link between these general indicators and logistics-related CO_2 can be fairly tenuous. Logistics-specific normalisers are clearly preferable as they are less susceptible to distortion by other structural changes within the business over the target period. These normalisers can include the number of units delivered, the number of units moved multiplied by the distance transported (e.g., tonne-kms, pallet-kms), warehouse throughput, etc. For example, in 2007, Tesco adopted a target of cutting CO_2 emissions per case delivered by 50% over a five year period (Freight Best Practice Programme, 2010). In its annual CSR, the company reports this declining intensity value.

The main problem with intensity-based targets is that if the underlying level of activity continues to rise, there may be little or no net reduction in GHG emissions. This runs counter to government climate change policies which are setting *absolute* GHG reduction targets. UK governments, for example, are legally obliged by the 2008 Climate Change Act to cut total GHG emissions in 2050 by 80% relative to their 1990 level. As the country is expected to achieve substantial economic growth over the next 40 years, there will have to be a dramatic reduction in carbon intensity per £billion of economic output. Just as within businesses, the potential for and cost of cutting GHG emissions varies between sectors, so across national economies there are wide inter-sectoral variations in these variables. To our knowledge, no national government has yet set GHG reduction targets for individual economic sectors, although it has been acknowledged that these are unlikely to be uniform.

The European Commission (2011), for example, has recognised that it will be more difficult to cut GHG emissions in the transport sector than in the EU economy as a whole by setting a significantly lower GHG reduction target for transport: 60% by 2050 as opposed to 80–90%. These are absolute targets. As the transport target has not been split between personal and freight transport, let us assume that the 60% figure applies to freight transport. It has been forecast, on a BAU basis, that freight tonne-kms in the EU will grow by roughly 160% between 2010 and 2050 (Freightvisions, 2010). If this forecast growth of freight traffic were to materialise, for total GHG emissions from freight transport to fall by 60% by 2050 the average GHG-intensity of freight movement would have to be reduced by 85%. A company wishing to align its carbon reduction target for freight transport with that of the EU as a whole would then have to cut its emissions per tonne-km to less than a sixth of the 2010 level. This would be a daunting task.

Scope of the target

This can be defined in organisational, geographical, functional and hierarchical terms:

Organisational: This relates to the division of emissions between a company, its contractors and trading partners in the supply chain. This usually reflects the allocation of financial responsibility between these organisations. As a general rule, whoever pays for the activity should be assigned the related CO_2 emissions. The Greenhouse Gas Protocol established three "Scopes" to differentiate emissions for which a company was directly responsible (Scope 1), emissions related to its electricity consumption (Scope 2) and those released indirectly by other organisations working on its behalf (Scope 3) (WBCSD, 2004). For example, a manufacturer outsourcing its entire logistics operation and measuring only Scopes 1 and 2 emissions would effectively exclude logistics from its carbon footprint. It is now considered good and soon to become standard practice to record and report all three categories of emission. In setting GHG reduction targets, however, companies naturally prefer to focus attention on those activities over which they have strong or total control. The targets that companies have been setting over the past few years have tended to be specific to their logistics operation (either in-house or outsourced) and not to their wider supply chain. For example, retailers importing products on a free-on-board (FOB) basis and paying for the deep-sea container movement, typically regard the foreign port of exit as the boundary of their carbon calculation. This also defines the scope of the carbon reduction target for logistics. For logistics service providers, a major issue is whether to subsume emissions from sub-contractors within their carbon target. For example, DHL, which sub-contracts around 80% of its transport on the European mainland, initially set a 10% CO_2 reduction target for its "own assets" for the period 2007–2012, but by 2020 aims reduce emissions across its in-house and contracted operations by 30% (Sonnabend, 2010).

Geographical: Multi-national companies typically set a single carbon reduction target for their entire logistics operation. There is, nevertheless, some merit in varying the target by country or continent to reflect differences in national government targets and incentive schemes, the nature of the logistics market and geographical factors, such as terrain, climate and the level of urbanisation.

Functional: This relates to the range of logistical activities covered by the target. It is common for targets to be confined to the freight transport operation. This is understandable as it accounts for around 90% of all logistics-related emissions (World Economic Forum/Accenture, 2009), and government climate change policies tend to treat transport as a separate activity. It is, however, desirable to keep the range of activities as comprehensive as possible and preferably inclusive of all the activities for which the logistics department has responsibility. One important reason for adopting this more holistic approach is that "carbon tradeoffs" often have to be made between logistical activities. For example, centralising inventory in larger warehouses will, other things being equal, tend to reduce energy use and emissions per unit of throughput, but at the expense of lengthening delivery distance and related transport emissions. Setting a target for the logistics operation as a whole forces the company to take account of these tradeoffs when implementing a carbon reduction scheme.

Under this functional heading, consideration should be given the extent of the system boundary to be drawn around the freight transport operation. NTM (2009) has differentiated five cumulative levels of system boundary. To date, almost all measurements of carbon emissions from logistics and almost all the targets that have been set are enclosed within system boundary 1 (SB1) and relate to the direct emissions from the vehicles, handling equipment and warehouses. At SB2 level, the boundary is expanded to embrace emissions from the energy supply chain, making a "well-to-wheel" assessment. SB3 also includes the servicing and maintenance of vehicles and transport infrastructure, while SB4 extends the boundary further to include emissions from the manufacture of the vehicles, construction of transport infrastructure and their subsequent scrappage and dismantling. SB5 brings emissions from related office functions and the activities of staff within the perimeter of the calculation. Data limitations currently confine most companies' carbon auditing and, hence, targeting, to levels SB1 and SB2, although it should not be too difficult to include emissions from vehicle servicing, IT and personal travel. Emissions from the manufacture of logistics equipment and from infrastructure construction and maintenance are not only difficult to quantify, they are also outside the logistics operator's control and hence justifiably excluded from the target-setting.

Hierarchical: This relates to the level at which the target is applied and can range from the logistics operation as a whole to individual stock-keeping units (SKUs). It depends on the extent to which the company can disaggregate its GHG emissions data by market segment, product category, handling unit and SKU. Relatively few companies currently have the capability and hence there are very few examples of these lower level targets. In the longer term, carbon measurement and targeting may follow the same course as logistics cost accounting between the 1960s and 1990s. Over this period, companies moved from a "total logistics cost" approach to increasingly disaggregated costing by customer, service, mission and product. Efforts have already been made to develop the carbon equivalent of "cost-to-serve" (Braithwaite and Knivett, 2008) and "direct-product profitability" (e.g., THEMA 1, 2009). The latter effort to carbon footprint individual products has generated a great deal of interest and debate (discussed in McKinnon, 2010), although following the long tradition of life cycle analysis (LCA), it generally adopts an end-to-end supply chain perspective and not does not simply focus on the logistics-related emissions. Indeed, the logistics-related emissions generally represent a small percentage of the total life cycle emissions (Carbon Trust, 2006). This fact, combined with companies' lack of carbon measurement capabilities at the SKU level, probably explains why no examples have been found of companies setting logistics emission targets at an individual product level.

Timescales

All targets have to have a start and end year. These tend to vary between companies making it difficult to compare them. It is common for companies to set 2015 and/or 2020 as end years. Others prefer to fix a 3, 5 or 10 year time horizon beyond the date when the target is declared. Sometimes the base year is not the year in which the target is announced but an earlier year, giving the company an opportunity to factor past carbon savings into the calculation and thereby reduce the level of future carbon savings required to meet the target. For example, if over the past two years, our company has acquired a fleet of double-deck trailers and switched 10% of its freight from road to rail, reducing it logistics carbon footprint by, say, 20%, there is naturally a strong temptation to set the carbon baseline for targeting at 2010.

The overall length of the target period is also significant. The longer the period, the greater will be the degree of uncertainty about future economic and business trends, public policy and technological advances. Advice is available on these external trends to help companies set longer term targets. For example, various attempts have been made to project the development and uptake of various low carbon technologies for road freight vehicles (e.g., AEATechnology/Ricardo, 2011), while some government documents, such as the EU white paper on transport (European Commission, 2011), outline a longer term policy framework for the decarbonisation of freight transport. The replacement cycle for vehicle and other logistics assets also dictates the rate at which the company can exploit the carbon benefits of new technology.

Setting a target for a single year in the distant future naturally raises suspicions about the credibility of the exercise. For example, the CEO of one large logistics firm once stated that its objective was to become carbon neutral, although he refused to say when and how this might be achieved. The further into the future the targeting extends, the less likely it is that the current management will be around to see the targets delivered and more likely it is that people will have forgotten about them or that they will have been “overtaken by events”. To be credible, therefore, long-term targets need to be accompanied intervening targets or “milestones” for earlier years, thus plotting a carbon reduction trajectory.

Reliance on carbon offsetting

Some carbon reduction targets relate solely to savings that can be achieved within the company’s operations. Others include an allowance for carbon offsetting, that is, where a payment is made to another organisation to cut CO_2 levels on our company’s behalf by planting trees, financing the adoption of low carbon technologies, etc. Logistics-related carbon reduction targets sometimes include provision for carbon offsetting to close the gap between the predicted decline in carbon emissions, as determined by the bottom-up analysis, and higher level corporate or industry goals. Projections of the future cost of carbon offsetting need to be factored into the calculation and compared with the cost-effectiveness of the company’s own decarbonisation measures.

Industry-level carbon reduction targets for logistics

For companies wishing to adopt the top-down approach to target-setting, one option is to join an industry-wide carbon reduction scheme such as the LCRS in the UK. This collective approach to target-setting is beneficial in that it gains the endorsement of industry peers, helps to build up momentum for decarbonisation across the industry, ensures greater consistency in targeting and demonstrates to government that business is serious about meeting its climate change obligations. The question that then arises is how a logistics-reduction target should be set for an industry rather than a single company. If the industry is fairly homogeneous, the companies are undertaking similar logistics operations and they are at a similar level of "eco-efficiency", it should, in theory, be relatively easy to derive an industry target. The LCRS, on the other hand, comprises a diverse mix of manufactures, retailers, wholesalers and logistics service providers at different stages in the decarbonisation of their logistics operations. It was a challenge, therefore, to determine a carbon reduction target that would command wide support. Rather than simply impose a target, it was decided to ask members of the LCRS and the wider membership of the FTA what level of CO_2 reduction they thought would be attainable between 2010 and 2015 on a carbon intensity basis. This consultation process could be regarded as bottom-up. Some companies were able to base their responses on quantitative analysis of their past experience and/or future plans, but other answers were more speculative.

The questionnaire surveys of LCRS and other FTA member companies did not ask managers directly about possible reductions in carbon intensity. Instead, they enquired about possible changes in a series of five "logistics efficiency indicators". These indicators are key parameters in a macro-level freight decarbonisation model (Piecyk and McKinnon, 2010): modal shift, average payload weight, empty running, fuel efficiency and carbon content of the fuel. The survey data was analysed using this freight decarbonisation model, weighting company responses by size of vehicle fleet. Subsequent analysis of the spread of responses revealed that the mean figures were being significantly skewed by a few extreme figures at the upper end of the distribution. It was decided, therefore, in discussion with FTA officials, to base the target on the response of the lower three quartiles in the samples. This yielded a target of 8% for the reduction of freight-related CO_2 emissions by 2015 relative to the level of business activity. A further round of consultation with members of the LCRS confirmed this target was acceptable and that for many companies it would be "stretching". The target was formally declared in the Annual Report of the LCRS (FTA, 2011) and has since been endorsed by the UK government.

This exercise showed how an industry-level target for logistics carbon reductions can be derived by analysing data from company surveys and supplementing this with a second round of consultation to test reaction to the proposed target figure. It essentially pooled industry knowledge and experience and kept the process fairly democratic.

General principles

The Greenhouse Gas Protocol lists five principles that companies should follow when measuring and reporting their carbon emissions (WBCSD/WRI, 2004). These are encapsulated in five words: relevance, completeness, consistency, accuracy and transparency. Some of these terms can also be applied to the setting of carbon reduction targets for logistics, but they need some reinterpretation and need to be supplemented by others.

Good practice in target-setting should observe the following six principles:

1. Company-specific targets should be based on a bottom-up analysis of the potential for and cost of cutting carbon emissions over particular time frames.
2. Where possible, targets should apply to the whole logistics operation in recognition of the carbon tradeoffs that exist between logistical activities.
3. Targets should be expressed in terms of carbon intensity with logistics output measures used as the normalisers.
4. Where the target period is greater than 3–4 years, "bridging" targets should be set for intervening years to show the trajectory for carbon reduction.
5. The scope of the logistics carbon measurement and related target should be made explicit, delimiting the relevant organisational, geographical, functional and hierarchical boundaries.
6. Where appropriate, a company should join an industry-wide carbon reduction scheme and conform to the targets that it sets.

Conclusion

Setting a target for cutting logistics-related GHG emissions is a new experience for most companies. Guidance is available from government and business organisations on the measurement and reporting of these emissions but not on targeting. As a result, companies have devised their own procedures and often set targets which are not consistent, not rooted in an analysis of carbon abatement potentials and promulgated for marketing rather than environmental reasons. This paper has reviewed current practices and problems and proposed a series of principles that companies should try to adopt when defining carbon-reducing targets for their logistics operations.

Note

1. A copy of this tool can be downloaded from: http://www.fta.co.uk/policy_and_compliance/environment/decarbonisation_tool.html

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8.3
On the Operational Logistic Aspects of Reuse

Simme Douwe P. Flapper

Introduction

For still more companies, it is or will become important to pay attention to the possibilities for reusing the products they produce and the items, like pallets and package materials, that they use for distributing their products or which are used by others for supplying their products to them. One important reason for the above is the growing concern for the natural environment, among others resulting in environmental laws which not only force companies to take back their products from their customers and the items used for the distribution of these products when these products or distribution items (DIs) are no longer desired by these customers, but also to take care of the environmentally friendly disposal of these products and Dis. However, due to the same reason, this disposal is becoming still more difficult and expensive (see e.g., Cairncross, 1990). Apart from being forced by law, companies feel forced to do the above because of competition and public opinion. But there are more reasons why it may be worthwhile for companies to consider reuse: there are products, components, materials and DIs that can be obtained cheaper or more quickly via reuse than via purchasing or producing anew.

Reuse may not only concern the items that are sold or rented to others, but also the reuse of rejected items or the reuse of items that have been made to stock for which actual demand turned out to be less than expected. Reuse always requires the following activities to be executed: **collection** of potentially reusable items, transformation of collected items into reusable items (to be denoted by **processing** hereafter) and the **distribution** of the latter to their customers. The questions to be answered within the context of reuse from a logistics' point of view are:

When, where and how to collect and process which items and in which quantities to realise (as much as possible) the potential benefits of reuse or to restrict (as much as possible) the undesired consequences of forced collection and processing?

Most of the available literature on the logistic aspects of reuse deals with its strategic aspects in rather general terms (see e.g., Thierry et al., 1993; Kopicki et al., 1993; Stock, 1992) or concerns steady state studies (see e.g., van der Laan, 1993). What is missing, however, is a systematic study on how to plan and control reuse activities at the operational level.

The purpose of this paper is to give insight, in a systematic way, into a number of operational logistic problems that may occur in the context of reuse and the correspondences between these problems and logistic problems that occur in other situations for which strategies are given in literature. Thereby, only attention will be paid to the collection and processing activities because at first sight there does not seem to exist differences between the distribution of completely new copies of items and the distribution of copies of items obtained via reuse.

The starting point for the rest of this paper will be the upper part of the following Figure 8.3.1.

Clearly, Figure 8.3.1 gives an oversimplified representation of reality. Only the flows related to reuse have been depicted and not the flows related to all kinds of losses and final disposal. For a more realistic representation see for example, Flapper (1995).

In the following two sections of this paper, the logistic aspects of collection and processing will first be considered separately. Next, some attention will be paid to the problems that may be related to the integration of the above two groups of activities as well as to their integration with the other procurement, production and distribution activities of the company.

Collection

The question to be answered here is: When to collect which quantities of which items where?

Just because items are no longer (or not) used does not necessarily mean that they are actually available for reuse. They may, for instance, be kept in stock by their last user, as denoted by the left hand upside down turned triangle in Figure 8.2.1 or they may be disposed as waste. From a logistics' point of view, it is important to distinguish between flows that can be completely determined by a company itself

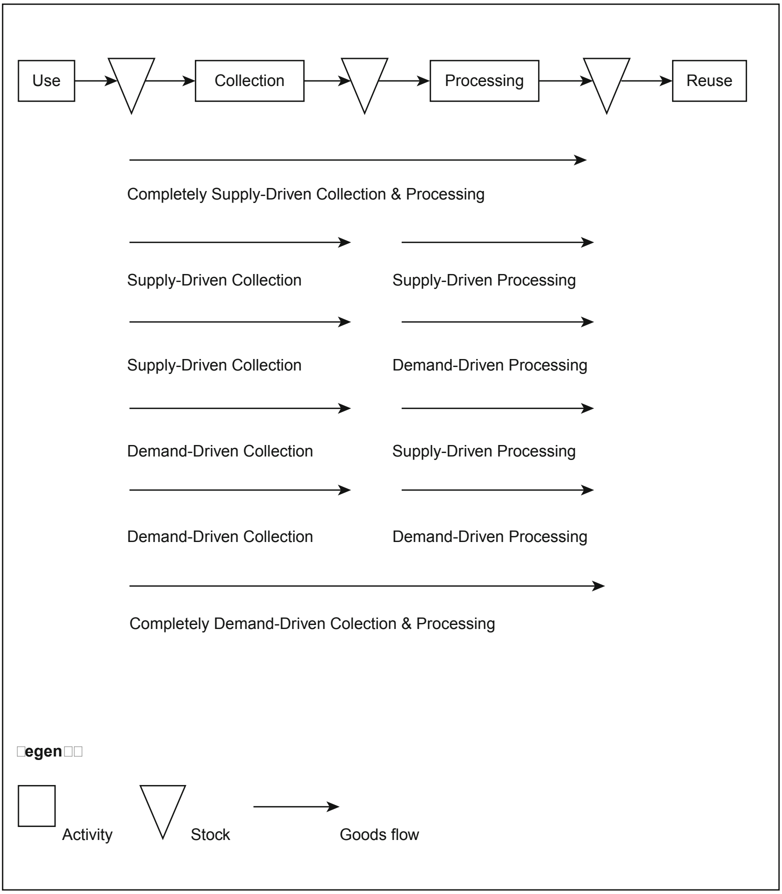

Figure 8.3.1 Goods flows in the context of reuse

(*demand-driven flows*) and flows that are completely out of control of a company (*supply-driven flows*). An example of purely supply-driven collection concerns the supply of organs of donors who died, whereas the collection of a specific type of car by a car dealer is an example of demand-driven collection. Usually collection in the context of reuse is a combination of "spontaneous" autonomous supply and demand-driven collection activities, as will be clear from the car dealer example. Apart from distinguishing between flows which behaviour can or cannot be influenced by a company, it is also important to distinguish between flows which behaviour can be forecasted and flows for which this does not apply.

In general, a flow has three logistic aspects: time (the moment that it *is* generated), quantity (its size) and quality (its composition). The above sub-division into supply- and demand-driven concerns each of these aspects separately. In the next sub-sections, we shall deal in more detail with each of these aspects for the flows between the last users of an item so far to the place where it will be processed (in Figure 8.2.1 the flows at the left hand side of the middle upside down triangle).

The time aspect of flows of reusable items

The time when items are delivered for reuse usually depends on many things, including the costs of keeping these items in stock, new technologies or being the rate of use. In general, there exist a number of possibilities for a company to influence the moment that items are delivered for reuse, including high deposit fees and requiring that used copies of an item are delivered in order to obtain new copies. For further details and options, see for example, Flapper (1995. Note that by being able to influence the moments that items become available for reuse, a company may also influence the quality and reuse possibilities of these items (compare with preventive maintenance). Whereas the supply of individual copies of an item at the points where they are initially collected may be very irregular, as for example, applies to the supply of used cars and empty bottles, the same does not necessarily apply to the deliveries at the processor. For instance, containers for collecting glass usually are only emptied at pre-set dates.

The size of flows of reusable items

Forecasting the size of flows of reusable items can vary from simple, as in case of fixed scrap quantities, up to very difficult, as in used cars. Even forecasting the total quantity of an item that ultimately will become available for reuse may be difficult, although an upper bound is given by the number of copies of an item that have been sold or bought, where the latter applies to distribution items like pallets. Reasons for the above are among others losses of items during usage (like cars lost by accidents), alternative usage possibilities (like crates for beer bottles used as seats), disposal as waste (e.g., because there are no collection points nearby the customer) or delivery to competitors (e.g., applies for used cars or copiers). The strategies mentioned under a. for influencing the moment items are supplied for reuse may also be used for influencing the size of the return flows.

The composition of flows of reusable items

Apart from the above mentioned two aspects, the composition of flows of potentially (partly) reusable items is also very important in the context of reuse. Different copies of the same item do not need to be the same due to the way they have been used or stored. Due to this, giving an answer to the quantity aspect of the question stated at the beginning of this section may be more complicated than it may have looked like at first sight. We shall return to this important aspect later.

At first sight, it seems that the possibilities for demand-driven collection will depend on the number of suppliers of potentially reusable items, the number of copies of the items that the different suppliers may deliver and the relations between the supplier, the collector, the processor and the reuser.

In case of many suppliers, with each having only a few copies of a given item and no direct relationship between the user and reuser, it will often only be possible via global actions to obtain the desired quantities of items which in general will lead to high uncertainties with respect to time and quantity. It seems easier to obtain copies of items that are leased than copies of items that are sold.

Up to now, it was implicitly assumed that a given item could be obtained by processing one type of item. Notably in the case of components and materials, it may be that these items make up part of more than one assembly. For instance, a given engine may have been built into a number of different types of cars. In that case, it also has to be decided which quantities of which items are to be collected in order to fulfil a certain requirement.

Processing

The question to be answered here is: When to process which quantities of which items into which reusable (or disposable) items?

There are a number of reasons to start processing activities.

Actual or expected demand

An important problem that may have to be solved in this context is that a given requirement might be fulfilled by processing different items requiring the execution of different processes requiring different quantities of different resources. (Remember the engine example given at the end of the foregoing section.) This problem resembles the cutting problem occurring in metal and cardboard processing companies, where a given piece of material can be obtained from different sheets (see e.g., Bookbinder and Higginson, 1986). In this case, we are dealing with demand-driven processing.

Actual or expected supply

Here, processing activities are triggered by storage space restrictions. In case more than one type of item is stored in a given stock location, again it has to be decided which quantities of which items should be processed. It may be required as well to indicate into what the above items are to be processed. That is because it is possible that a given item can be reused in a number of mutually exclusive ways. In principle, an item may be reused as a whole (which may be after repair or replacement of parts or cleaning), via its components or building materials, where all of these may be reused as such or as a source of energy (see e.g., Thierry et al., 1993). To be concrete, a used car may be reused as a whole but also its parts, via its engine and the materials from which its dashboard etc. have been made. Processing purely triggered by actual or expected supply will be further denoted by supply-driven processing.

Actual or expected idleness of resources

As mentioned before, the quality and sometimes the composition of copies of the same item that are delivered for processing may vary. This implies that more companies will be forced to take care of all the copies of the products and items returned by their customers and use these products for the distribution. Further, more companies will have to deal with the same type of problem as companies processing natural raw materials like milk with a varying fat content, or companies producing semi-conductors starting from crystals supplied on crystal wavers which may contain crystals having different characteristics see e.g. (Campbell, 1988), as well as repair and maintenance shops. For a general discussion on the "active" part problem, see for example, van Rijn and Schyns, 1993. The above means that almost always items that are delivered for reuse have to be tested and sorted. Often processing involves disassembly, which almost always results in both reusable and non-reusable items, co- and by-products (see e.g., van Rijn and Schyns, 1993).

Due to the above uncertainties in quality, companies also may be confronted with uncertainties in the requirements for the resources involved in the processing activities, comparable to the uncertainties maintenance and repair shops often have to cope with. For a description of a possible framework concerning the logistic control of such shops see Bertrand et al. (1990). For the logistic problems related to processes having a variable yield see for example, New and Mapes (1984) and Lee and Yano (1988). In general, the above holds less for companies that lease the products they produce, such as the producers of copiers, than for companies that sell the products they produce, such as most car companies. The above uncertainties are important when deciding when and how much of what to process in order to fulfil a certain requirement.

Reuse: an integral activity

In the two foregoing sections of this paper, the collection and processing activities have been considered separately. In order to give some insight into the problems that may be related to the integration of these two groups of activities, the classifications of collection and processing activities into supply-driven and demand-driven activities as given in the two foregoing sections have been combined and depicted together in Figure 8.2.1. In this way, two often occurring problems (in the context of reuse) become clear: supply of items for which no actual demand exists nor demand is expected or requirements that cannot be fulfilled via reuse because no or not enough items are, or will be, timely available for processing. Similar problems also often occur with respect to fresh produce.

Optimal reuse not only requires the integration of collection and processing activities, but also the integration of these activities with the purchase, production and distribution activities of a company. The above may among others involve the timely allocation of processing and production activities to resources that may be used for both and the integration of the transport of new and used copies of items.

Without reuse, most companies obtain a certain item either by purchasing or producing. In the case of reuse, it may be possible to obtain a certain item as well via collection and processing, where differences may exist with respect to the delivery times, lot sizes and resources used in the context of these different options. How, in the latter case purchase, production and processing activities might be integrated is for purchase items with only one reusable sub-item (Flapper, 1994).

In case items returned for reuse are initially stored at a number of different, physically separated collection points, and the reusable parts of these items are rather expensive or difficult to obtain, it may be worthwhile to consider the usage of a DRP (distribution requirements planning) like (information) system to gain insight into the availability of potentially reusable items. Compare this with the usage of DRP in the context of the management of rail cars as suggested in Bookbinder and Sereca (1987).

Summary and conclusions

In this paper, an overview has been given of the most important logistics problems companies may have to deal with in the context of reuse. A classification of reuse activities has been presented. Relations with seemingly similar problems in other situations have been indicated as well as literature where (partial) solutions for these problems may be found. In this way, this paper may act as a starting point for both companies to set up a system for the logistic control of their reuse activities and for further research in the field of the logistics aspects of reuse.

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