A Value Chain Approach to Studying Antecedents of Delivery Flexibility

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Abstract: The literature on manufacturing flexibility indicates that much work remains to be done on understanding the various dimensions of flexibility. This paper focuses on one particular dimension, namely delivery flexibility, which is defined as the ability to adjust delivery dates and accommodate rush orders and special orders (Sawhney, 2006). In order for a firm to provide delivery flexibility to its customers, it is necessary to coordinate the entire link that extends down the value chain, from the supplier- to the marketing-end, which is the focus in this paper. We draw on the existing literature to identify several antecedents of delivery flexibility at these different stages of the value chain. We then embellish the literature with field observations to develop a conceptual framework and testable model. We also develop a measure for delivery flexibility, which was necessary for testing the proposed model.We employ data from printed circuit board firms that share characteristics like high technology and rapid new product development, and require highly responsive supply chains. The findings support assertions often made in the literature regarding the need for better integrating the supplier, process, and marketing stages of the value chain to contribute to delivery flexibility.

Keywords: Value Chain Approach, Delivery Flexibility,

I. Introduction

Organizations face several different types of uncertainties, extending from the firm's environment down to the lowest task within the organization. Such uncertainties manifest themselves in the form of inconsistency in supplier lead-time, fluctuations in demand, product mix, actions of competitors, equipment breakdowns, variable task times, queuing delays, rejects and reworks, labor absenteeism and turnover, material mishandling, etc. Traditionally, flexibility, in its reactive use, has been viewed as a coping mechanism against such uncertainties in an organization's internal and external environment. Within the broad array of flexibility dimensions, delivery flexibility, defined as the ability to accommodate rush orders and requested changes in delivery time (Sawhney, 2006), is being regarded by companies as a necessary competency for survival. It is being viewed as a necessary condition for supply chain agility (Christopher and Towill, 2001) and is considered as an order winner over price (Ketokivi, 2006).

In their study of Spanish automotive suppliers, Sanchez and Perez (2005) reported that delivery flexibility was rated the highest of several flexibility dimensions. "Because flexibility is viewed as a reaction to environmental uncertainty … in a global scenario, not only manufacturing, but also supply chain logistics and management can be an important source of competitive advantage" (Sanchez and Perez, 2005, p. 682). Thus, management of delivery time cannot be examined in isolation. Rather, it must be viewed as the reflection of a whole set of upstream and downstream operations and managerial actions, all along the supply chain. Given a lack of extant literature on the value-chain antecedents of delivery flexibility (Brown and Vastag, 1993; Milgate, 2001), we drew on field observations to supplement the literature. The field study was conducted in ten companies in the printed circuit board (PCB) industry. We then developed a theoretical model, adopting a value-chain perspective, of factors that influence delivery flexibility. Finally, we conducted a survey of PCB plants and utilized the data to empirically test our model.

II. Literature Review

Supply chain responsiveness can be viewed as the ability to create customer responsiveness and master uncertainty (van Hoek et al., 2001), so as "to exploit profitable opportunities in a volatile marketplace" (Naylor et al., 1999). While such responsiveness is "a business-wide capability," it necessarily presupposes manufacturing flexibility (Christopher and Towill, 2001), which is the ability to change or react with minimal penalty in time, effort, cost or performance (Upton, 1994).

As noted earlier, the literature to date reports few systematic empirical studies of manufacturing flexibility (Hill and Chambers, 1991; Upton, 1994; Koste and Malhotra, 1999; Sawhney, 2006). We found a lack of consensus even on the various dimensions of flexibility (D'Souza and Williams,2000; Sanchez and Perez, 2005). Delivery flexibility is often viewed as the ability to adapt lead-times to customer requirements (Slack, 1983; Suarez, 1992; Sanchez and Perez, 2005), or sometimes as the lead-time for rush orders (Dixon, 1987).

We scoured the literature to establish relationships between delivery flexibility and the upstream and downstream actions within the value chain that may promote it. The remainder of this section discusses the varied findings and threads them together. Specifically, we examined managerial actions related to the upstream (supplier), process, and downstream (customer) stages. To embellish the conceptual framework we employed field observations. The field study was conducted among 10 printed circuit board (PCB) manufacturing firms, which provided overwhelming support for the conceptual framework. Due to limitations of space the field study observations are not reported.

Upstream

Supplier responsiveness is an important factor in improving supply chain agility (Lowson et al., 1999; Reichhart and Holweg, 2007). Likewise, it is also important factor in improving an individual company's ability to provide delivery flexibility (Narasimhan and Das, 2000). Clark (1989) associated Japanese automobile manufacturers' competitiveness with suppliers who could respond in a very short lead-time and accommodate changes quickly. Conversely, difficulties with suppliers rapidly surge forward through the supply chain (Sawhney, 2006). Increasingly, however, firms are demanding tighter and more reliable delivery performances from their suppliers.

H-1: *Better supplier capability provides higher delivery flexibility.*

Process

Frohlich (2002) found that supply chain integration was impeded more by internal than external barriers. On a similar note, looking closer to home, an important factor impacting delivery flexibility is the effectiveness of the process. Delivery flexibility being an "external" flexibility type (of interest to the customer; Upton, 1994), it needs to be supported by appropriate "internal" flexibility types such as machinery, material handling, operations, routing, etc. (Reichhart and Holweg, 2007), all of which point to the need for process excellence.

Conversely, delivery flexibility can also be fostered by the minimization of process uncertainties, such as equipment breakdowns, variable tasks times, queuing delays, rejects and rework, labor absenteeism and turnover, material mishandling, etc. Each of these uncertainties can pass to the customer in the form of delivery problems, unless buffered by inventories.

Schmenner (1988) argued that reducing throughput time forces management to improve on *all* fronts, including quality, inventory, process rationalization, attention to bottlenecks, less chaos, overhead elimination, quick market response, improved capital appropriations, etc. Only an effective process (Kumar and Harms, 2004) with fast throughput time can respond rapidly to the delivery needs of the customers. Improved process effectiveness, as reflected in reduced throughput time (Hall 1987), may be achieved through actions such as flow charting process steps, removing non-value added activities, incorporating efficient work-flows facilitated by improved layouts, synchronizing dependent activities through improved scheduling, redesigning to allow parallel processing of independent activities, etc.

Researchers have long associated reduced cycle time and increased delivery flexibility with setup time reduction (Hall, 1987; Mileham et al., 1999). Such setup reduction can be achieved by adopting several practices associated with the Toyota Production System, for example organizing the workplace, moving setup activities from internal to external, preparing and positioning personnel and materials, training technicians and operators, maintaining the tooling, standardizing fixtures, etc. (Shingo, 1981, 1985; Monden, 1981; Hall, 1987; Ohno, 1988).

Labor is another important factor in fostering flexibility within the process. Organizational behavior researchers such as Cotton (1993) and Lawler, et al. (1995) have discussed the various benefits of employee involvement. Some of the outcomes typically attributed to employee involvement include (Margulies and Black, 1987; Ledford, et al., 1988): greater acceptance of change; greater team identity, cooperation, and coordination; greater understanding of objectives; greater fulfillment of psychological needs. Employee involvement is also an important factor in developing greater workforce agility (Sumukadas and Sawhney, 2004). For example, encouraging workers to become multi-skilled allows bottlenecks to be addressed more effectively, which can in turn improve delivery flexibility.

H-2: Higher process excellence leads to higher delivery flexibility.

H-3: Higher process uncertainty leads to lower delivery flexibility.

H-4: Greater employee involvement leads to higher delivery flexibility.

H-5: Better set-up reduction practices lead to higher delivery flexibility.

Downstream

Looking downstream in the value chain, many studies have called for better integration externally with the customer. However, "how can we integrate externally with other companies when we cannot even speak with one voice … internally?" (van Hoek and Chapman, 2007, p. 239). Interdepartmental integration is considered the bedrock without which external integration is futile (Mentzer, 2004). Our focus in this paper is more internal than external.

Many researchers have studied the integration between marketing and logistics (van Hoek et al., 2008). However, there is a shortage of research on integration among other peer functions (van Hoek et al., 2008), such as logistics and other functions (Mentzer and Kahn, 1996), marketing and other functions (Kahn and Mentzer, 1998; Min and Mentzer, 2000), or among other peer functions (Morash et al., 1996;

Gimenez and Ventura, 2005; Chen et al., 2007). Abernathy (1976) called for more integration between marketing and operations. Hayes and Wheelwright (1979) embodied this notion in their "product-process" matrix. Abad and Sweeney (1982) demonstrated that interdependent marketing and operations actions were superior to independent ones. Communication between peer functions is a frequently mentioned factor in improving interdepartmental integration (Murphy and Poist, 1992; Kahn and Mentzer, 1996; Ellinger et al., 2000; van Hoek et al., 2008). Sawhney and Piper (2002) empirically demonstrated that the speed and quality of the interface between marketing and operations impacts the value delivered to customers, including delivery responsiveness. Thus, in terms of delivery flexibility, faster and more complete information flow between marketing and operations helps firms become more responsive.

H-6: Faster communication between marketing and operations leads to higher delivery flexibility.

H-7: Better quality of information exchanged between marketing and operations leads to higher delivery flexibility.

III. Research Methodology

The PCB industry provided an excellent venue to study delivery flexibility. PCB manufacturers share many characteristics of a high technology industry, such as rapid new product development, with the need to operate at high levels of delivery flexibility. Furthermore, PCB manufacturers typically operate in a make to order environment, with little inventory to buffer against uncertainty. The delivery flexibility of PCB manufacturers is critical to their customers, original equipment manufacturers (OEMs), to launch new products ahead of the competition. The demand cycle for PCBs is very short.

A mail questionnaire survey methodology was adopted to test the hypotheses. The population was the 300-plus plants of the North American PCB industry. A stratified sample of 180 plants was drawn based on plant size. Equal numbers of plants were selected from each of three plant-size strata. Lack of resources, time paucity, and the desire to maintain equal representation from the three plant-size strata precluded the inclusion of every plant in the industry. Thirteen firms were later dropped from the sample because they were either prototype shops or printed wired board facilities, and thus outside the sample frame. Dillman's (1978) total design principles of mail questionnaires were followed. A total of 74 usable responses were received from the reduced sample of 167 firms, resulting in a 45% response rate. The high response rate instills confidence that the responses are representative of the population. The results can also be considered representative from an economic perspective, since the 74 responding firms accounted for nearly 70% of total industry sales.

Construct Measurement and Validation

Due to limitations of space, we are not reporting the discussion on the development of the constructs and their validity. Summary is presented in table 1. Each construct in our model is not an underlying phenomenon that is reflected in its measurement items; rather, the construct itself is formed by its measurement items (akin to an index). Accordingly, the constructs have been conceptualized as formative. Jarvis et al. (2003) found that many studies failed to use formative indicators when they should, resulting in model misspecification. Recent examples of the application of formative constructs in the supply chain management area include Golicic (2007) and Wang and Wei (2007). Chin (1998) suggested a simple test for determining whether the measurement items of a construct are formative: "Is it necessarily true that if one of the items … were to suddenly change in a particular direction, the others will change in a similar manner? If the answer is no … the items are in fact formative." Based on this test, we found it necessary to model the constructs as formative. As noted earlier, the second order constructs in our model are also conceptually formed from the first order constructs. Thus, they are also modeled as formative.

IV. Results of the Model Analysis

The model was tested with partial least squares analysis (PLS), using Visual PLS software (version 1.04b1). PLS analysis enables testing of a structural equation model with formative constructs (Chin, 1998). PLS is also ideally suited for exploratory stage research as it imposes fewer constraints regarding a priori theory. Moreover, PLS is useful for analyzing models using relatively small samples; sample size requirement is only five to ten times the largest number of paths loading on any single model variable, akin to multiple regression. Further, PLS analysis is distribution free, i.e., it does not impose requirements of multivariate normal data distributions. (See Sumukadas and Sawhney, 2004.)

The results of the analysis are shown in Figure 1. The model explains over 50% of the variance in delivery flexibility ($R2 = 0.502$). At this stage in the research, we are yet to conduct significance testing. The regression model explained 73% of the variance in delivery flexibility ($F=18.568$, $p \leq 0.00$). As hypothesized, delivery flexibility was positively related to supplier capability ($p \leq 0.000$), process excellence ($p \leq 0.000$), labor climate ($p \leq 0.029$), setup reduction practices ($p \leq 0.083$), and MOI -Speed ($p \leq 0.037$); and negatively related to process uncertainty ($p \leq 0.010$). In other words, plants can improve their delivery flexibility by working closely with the critical dimensions of the supply chain, namely the supplier, the process, and the customer-interface. Unexpectedly, delivery flexibility was negatively related to MOI-Quality, though the effect was non-significant ($p \leq 0.207$). A plausible explanation to the negative relationship maybe, that MOI-Quality is impacting the two components of delivery flexibility (delivery-time and delivery-performance) differently. A good integration between marketing and production may facilitate defect-free execution of customer requirements, thus favorably impacting delivery-performance. However, the time consuming, detailed, information exchange may adversely impact delivery-time. Our hunch came true when we explored a simple correlation between delivery-time, delivery-performance, and MOI-Quality. The results revealed a strong positive correlation between delivery-performance and MOI-Quality, and an insignificant negative correlation between delivery-time and MOI-Quality – thus confirming our premonition.

V. Conclusions

This paper set out to identify the antecedents of delivery flexibility along the value chain. It is clear from the results of the model analysis that the value chain approach to identifying factors that impact delivery flexibility has a lot of merit. Rather than looking at delivery flexibility as being influenced simply by factors within the production "black-box," our model included a wide range of factors dealing with both upstream and downstream decisions and managerial actions. In other words, plants can improve their delivery flexibility by working closely with the critical dimensions of the supply chain, namely the upstream, process, and downstream factors. In approaching delivery flexibility from a value chain perspective, therefore, this study has made tremendous strides in bridging two areas of the operations management literature, namely, manufacturing flexibility and supply chain management. A further contribution to the literature is the development of the measurement scales necessary to test the research model, in particular the scales for delivery flexibility.

This study provides practitioners a handy checklist of things to look at and manage at different parts of their own value chains. As a related benefit, the study also provides practitioners pointers on how to practically measure their performance and progress on these factors. The measurement scale for delivery flexibility, in particular, is a heretofore unavailable tool. Well-defined measures of delivery flexibility can be invaluable, for example, to compare rival technologies, or monitor their effectiveness after installation.

Table 1 - Measurement Scales

Delivery Promise (Cronbach's α = 0.633; AVE = 0.607)	**Loadings**
Days promised for prototype order delivery	0.681
Days promised for rush order delivery	0.875
Days promised for non rush order delivery	0.770
Delivery Performance (Cronbach's α = 0.806; AVE = 0.465)	**Loadings**
Fraction of rush orders delivered late *	0.716
Fraction of non rush orders delivered late *	0.736
Rush order defect rate *	0.615
Non rush order defect rate *	0.584
Average days late for rush orders *	0.766
Average days late for non rush orders *	0.655
Supplier Capability (Cronbach's α = 0.66; AVE = 0.565)	**Loadings**
You typically receive material that is less than what you had ordered *	0.758
Your supplier's promised delivery dates are reliable	0.688
You receive material that is defective *	0.804
Process Uncertainty (Cronbach's α = 0.714; AVE = 0.591)	**Loadings**
Employee turnover	0.721
Management's perception of uncertainty caused by absenteeism and turnover	0.731
Fraction operating time lost due to equipment failures	0.560
Management's perception of uncertainty caused by equipment failures	0.784
Defects due to mishandling of material on the shop-floor	0.631
Management's perception of uncertainty caused by material mishandling	0.516
Process Excellence	**Loadings**
Time taken to finish a typical order once released to the shop floor	1.000
Employee Involvement (Cronbach's α = 0.674; AVE = 0.643)	**Loadings**
Extent to which labor practices allow workers to be used in multiple jobs	0.884
Extent to which the plant floor employees are rotated between jobs	0.771
Management's perception of the labor climate at the plant	0.744
Setup Reduction Practices (Cronbach's α = 0.585; AVE = 0.570)	**Loadings**
Standardized fixture and clamps used to reduce setup times	0.797
Trial and error adjustments reduced	0.775
Personnel, materials, and test equipment positioned prior to changing setup	0.721
MOI-Quality (Cronbach's α = 0.839; AVE = 0.501)	**Loadings**
Operations consults marketing before making process changes	0.607
Marketing consults operations before accepting early delivery requests	0.791
Marketing consults operations before accepting special feature requests	0.849
Order system provides info on existing orders, completion time, and capacity	0.537
MOI-Speed	**Loadings**
Time taken by marketing to pass order information to production	1.000

* Reverse coded

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Figure 1
Results of the Analysis