ALIGNING SUPPLY CHAIN FIRMS: FIRM TYPES AND SUPPLY CHAIN ORIENTATION

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ABSTRACT

Supply chains are becoming increasingly more complex as globalization brings many forms of relationships, opportunities and threats. Just like strategic mission and direction of an individual firm, supply chains should be properly aligned towards common goals, and chain activities should be accordingly coordinated. However, there are a few major frameworks that can help managers to determine strategic orientation, firm composition and alignment for the supply chain. This study reviews some of the supply chain strategic frameworks and designs an experimental study to test some hypotheses using a simulation methodology.

Keywords: supply chain, strategic alignment, simulation, capacity, flexibility

INTRODUCTION

Today, supply chains are getting increasingly complex and difficult to manage. The motivation for firms to enter supply chain relationships includes factors such as obtaining cost efficiencies and other competitive advantages. The supply chain literature recommends a system approach optimizing the whole supply chain network towards efficiencies or other goals including quality, time or flexibilities. In fact, many studies focused on how to integrate the internal functions within a firm while linking these functions to the external entities including suppliers, customers and other service providers. The integration is expected to result in increased competitive performance in the supply chain [15].

Due to the integration, the chain may act as if it is one big single entity. At this point, a need for strategic direction and alignment for the whole supply chain may be needed as some firms in the chain may show performance problems. Just like an individual firm, which develops certain capabilities in-house and outsources the others, supply chains may focus on certain competitive dimensions since it is often difficult to be an expert in all competitive capabilities [9].

The literature proposes several frameworks to align supply chains firms towards a specified mission. For example, some authors suggest that the type of supply chain should be linked tightly to product and market characteristics to obtain sustained competitive advantage [4,5,7,8,13]. For example, Fisher [8] proposed a conceptual model for matching product types to supply chain management strategies. In the conceptual model, products are classified into two types, functional products (with small demand variance and low profit margin) and innovative products (with uncertain demand, and high profit). Then, supply chain strategies are classified into 1) physically efficient processes to supply predictable demand efficiently at the lowest possible cost, and 2) market-responsive processes to provide quick response to unpredictable demands. These product and supply chain combinations are then matched for the best results. For example, functional products are a good match for efficient supply chains, and innovative products are best for responsive supply chains. Lee [13] adds more dimensions to the framework: Risk-hedging supply chains and agile supply chains. Risk-hedging supply chains are characterized by pooled and shared resources in the chain against supply uncertainties. Having alternative suppliers or pooled safety inventories are typical specific strategies used in this type of supply chains. On the other hand, agile supply chains could be considered responsive and risk hedging at the same time. Lapide [12] extends Fisher's original framework by adding "asset utilization" dimension. Asset utilization supply chains focus on how effectively assets, such as facilities, equipment, and inventories are being used. Industries of this type include steel, paper and coal that are capital intensive and have relatively stable demand.

In this paper, we assume firms that are characterized by their strategic focus and alignment according to the supply chain. For example, a firm is called a functional type when it focuses on producing functional products. Similarly, a firm is called risk hedging type when it focuses on collaborating and resource sharing with other firms in a supply chain to maintain product availability. Or, a firm is an asset utilizing firm when it focuses on maximizing utilization of limited resources in the supply chain.

Although these papers reviewed above provide general framework and methodologies to integrate, align and possibly redesign the supply chains, a few questions still remain. For example, to provide a functional product, should an efficient supply chain be formed by all efficient suppliers providing functional parts and products? Can an efficient supply chain include responsive suppliers with innovative products? Would that be a wasted, unnecessary capability in a functional supply chain? According to the literature, an innovative supplier in an efficient supply chain, or a functional supplier in a responsive supply chain would be a mismatch. In the former case, the responsiveness capability is wasted, and in the latter case, demand is too volatile for a typical functional supplier.

In this paper, we investigate performance of supply chains which are composed of different types of firms. Our main research question is whether or not a mixed combination of firms would result in significant performance losses in the supply chain. Borrowing from frameworks in the literature, we define five types of supply chains: Efficient, responsive, risk hedging, agile and asset utilizing. Firm types are defined similarly as functional, innovative, risk hedging, agile, and asset utilizing as shown in Table 1. Assuming the supply chain and its firms provide a single type product, the suggested supply chain alignment in the literature is a line or web of firms of the same type. For instance, a four company efficient supply chain would have functional firms (F) in the formation of [F, F, F, F]. Using Supply_Chain[Firms] notation, we wonder how performance of mixed combinations would result, such as in supply chains of E[F, F, I, I], R[I, I, I, U], or H[H, I, H, A]. Theoretically, the literature implies a homogenous alignment, such as the one made of *all* innovative firms in a responsive supply chain, or *all* agile firms in an agile supply chain. However, this is probably too idealistic when it comes to actual practice. Therefore, research work investigating less than ideal combinations should merit practical benefits.

Table 1: Types of supply chains and firms

Supply Chain Type	Firm Type*	Demand	Focus
Efficient (E)	Functional (F)	Less volatile	Minimizing cost
Responsive (R)	Innovative (I)	Volatile	Minimizing cost
Risk hedging (H)	Risk hedging (H)	Less volatile	Maximizing service level
Agile (A)	Agile (A)	Volatile	Maximizing service level
Asset utilizing (U)	Asset utilizing (U)	Less volatile	Maximizing capacity utilization

* Best (theoretical) matching firm type for the given supply chain

In this paper, using a simulation methodology, we simulate three firms (two assemblers, and a supplier to the assemblers) in a supply chain. The supply chain structure is chosen this way so that various firm type combinations could be constructed adequately in a simulation model. Short term capacity change cost (a function of firm's volume flexibility/overtime), idleness (a function of initial long term capacity expansion decision), holding cost (a function of the safety stock level) and service level are the performance measures. The implications of firm type in the supply chain, and effects of environmental variables such as company ordering policies are investigated.

RESEARCH MODEL

The simulated supply chain includes three companies formed in a V shaped chain. All three companies operate in a make-to-stock environment in which products are manufactured based on demand forecasts. Production scheduling is based on "rolling horizons" procedure [2]. On a given day, the plan is implemented; planned production quantities for the day are manufactured and stored at the warehouse. The next morning, when customer's exact demand is known, shipment is made to the customer. Demand not satisfied is loss of sales. This procedure is implemented every R periods to keep up-to-date with the changes in demand. During the re-planning, forecasts and production plans are updated for the un-frozen planning periods. At the companies, a "level" production strategy is used to smooth out the changes in demand. According to this strategy, total demand in the newly frozen area is divided by R to find out daily production quantity. Firms have communication links to transmit order schedules. Each company manufactures only one major product, and manufacturing one unit of end product requires one unit of capacity. Batch manufacturing lead time at each company is R periods and shipment is instantaneous. There are no stock outs or backorders. Safety stocks are held against supply uncertainty.

We assume that the end customer demand follows a normal distribution with a mean of 1000 units per day. The volatility of the demand is incorporated into the model by using different levels of standard deviations for the demand. High volatile demand has a standard deviation of 600 units, and low volatile demand has a standard deviation of 200 units. We assume that both of the assemblers observe the same kind of volatility at the same time (i.e. high-high or low-low).

Independent Variables

The type of a firm is a factor under study (5 levels). Since there are 3 positions in the supply chain (2 assemblers and 1 supplier), there are initially 15 (=3x5) combinations. Environmental factors under study include end customer demand standard deviation (2 levels), safety stock levels at the assemblers (2 levels), assembler-1's batching policy (3 levels), assembler-2's batching policy (3 levels), and supplier's re-planning interval length (4 levels). Thus, total number of combinations is 1080 (15x2x3x3x4).

Type of supply chain firms

We consider five basic types for each firm: functional, innovative, risk hedging, agile and asset utilizing. In [X, X, X] notation, first two letters represent the assembler firms, and the last one represent the type of the supplier.

We define a "functional" firm as the one selling a functional product in the face of a relatively stable demand. In response to the stable demand, functional firm has organized internal production operations to satisfy most of the customer demand in an efficient manner. Functional firm may incur additional costs when the demand exceeds expectations with unusually large orders. Similarly, the innovative firm has organized internal operations to satisfy most of the customer demand in a responsive manner, probably with ample capacity resources and flexible operations. A "risk hedging" firm is the one who pools its component stocks with other firms in the chain. When it comes to the simulated supply chain, the two assemblers only can be designated as resource pooling firms. Supplier has no identical firm to pool its resources. When the assemblers are the pooling firms, the part orders not satisfied directly from the supplier may be satisfied from one another. An "agile" firm is similar to a risk hedging firm except it receives a more volatile demand than a risk hedging firm. The "asset utilizing" firm is characterized by high levels of utilization. The initial capacity is set so tight that the capacity idleness is relatively low on average. Thus, satisfying volatile customer demand may require frequent use of overtime.

Batching Policy

Since assemblers place orders for the supplier's product using specific batch sizes, they effectively determine demand characteristics for the supplier. We assume a Period Order Quantity (POQ) policy for the assemblers only. In the POQ policy, demand over a certain number of periods is satisfied by a single batch. The levels for this factor are 1, 4 and 7 periods for both assemblers.

Re-planning Interval Length

It may also be interesting to see the behavior of the system under different re-planning intervals (R) since previous studies found significance of this variable in affecting manufacturing system performance [17,19,11]. Also, R value determines number of days the production batch should be completed (batch lead time). Thus, when a shorter R is used, daily capacity requirements would be higher per day than that of a longer R. Higher capacity requirements may lead to costly overtime production. We take supplier's re-planning interval length as an independent variable, with levels 4, 6, 8, and 10 periods. Assemblers' interval is constant and set to 4 periods. Also, to avoid calculation errors, frozen area length is set to 2 * R, and length of the horizon (H) is set to 32 periods.

Safety stocks

Keeping safety stocks is an option against unpredictable demand or supply. We assume safety stocks are held only by the assemblers against supply uncertainty. To see the impact of having safety stocks, we set two levels for this factor: zero and 100 units. The portion in an order that is not satisfied directly from the supplier is recorded in the simulation and assumed to be satisfied from external sources at a higher than regular price.

Setting and changing the capacity

We assume that the supply chain firms set a fixed core capacity level for the long run when they become part of the supply chain. We define this long term capacity as the regular time production capacity during the simulation. We model regular time capacity cost as a fixed amount paid per unit capacity held during production cycles, which is set in the beginning of the supply chain partnership. Unlike regular time capacity, overtime costs are typically incurred when capacity is expanded beyond regular time capacity during periodic production cycles, and become more expensive with each additional unit. The overtime cost curve may rise sharply after a certain point reached due to decreasing efficiency of production resources [16]. Usually cost curves are used to discuss flexibility which varies inversely with the cost [10]. We therefore use overtime cost functions based on volume flexibility. We assume that a firm can accommodate most order sizes as long as its overtime (short term capacity change) cost is paid. We assume capacity requirements during the year are normally distributed with N (μ, σ). When the unit cost of regular capacity is k dollars, setting regular capacity level to μ and keeping it at this level costs the company kμ dollars every day. Note that the firm pays this amount every period even if the capacity is not fully used. When the capacity need is more than the average, overtime cost is incurred, which is increasingly higher when the capacity requirement is closer to $Q_m = \mu + z\sigma$. After this threshold size, the cost would not go up indefinitely but instead levels off, since we assume the extra capacity needed could be obtained from outsourcing at a fixed cost. Thus, the unit capacity change cost function is defined as:

$$G(Q) = \begin{cases} k & 0 \leq Q \leq \mu \\ \dfrac{c-k}{Q_m - Q} & \mu < Q < Q_m \\ C & Q \geq Q_m \end{cases}$$

Dependent Variables

We will collect total capacity cost (k μ + G(Q) Q; Q> μ), total idleness, and total holding costs at both firms. We define capacity change costs as costs of necessary operational actions to complete an order on time. Idleness is defined as the difference between regular capacity level and actual capacity used in a period (Q - μ; Q> μ). Holding costs are calculated by multiplying inventory carried in a period and unit holding cost per period. Also, we collect data on supplier's customer service which is defined as the percent of orders that is satisfied by the supplier.

Experimental Procedure

There are 1080 experimental conditions. We will validate the simulation model using pilot runs observing the behavior of the response variables. Also, resulting values will be verified with hand calculations. A simulation run is 500 periods. Data from the first 100 periods and the last 100 periods will be discarded. The remaining 300 periods of data will be used for the analysis. There are 10 replications, and each replication uses a different random number set. We use Microsoft Excel for charts, and SAS statistical package for statistical analysis. Rank orders using Duncan's test will be also reported along with ANOVA results.

CONCLUSION

The purpose of this study is to evaluate supply chains in terms of composition and performance. A supply chain model is developed based on strategy, operations and supply chain literature. A simulation analysis is conducted to test the hypotheses. We assume a three company supply chain in which two assemblers purchase parts from a single supplier. Next, we present several frameworks for the general direction of the supply chains independently developed by different scholars for the right supply chain mix. We agree that right combination of firms in a supply chain could be critical for the success of the chain and individual firms. If they do not match, this could result in stock-outs, or excessive production costs. However, we argue that a supply chain made of the same type of firms may not perform better than a mixed type supply chain under certain environmental conditions.

We think that Fisher's product-supply chain matching model is valuable. However, the model is based on end product demand behavior (functional/innovative). When it comes to dependent demand within a supply chain, what is considered a functional, stable demand may become volatile as the demand is distorted through the supply chain levels (for example, due to batching). Thus, observing a volatile demand, originally an efficient supplier may need to adjust and be more responsive and volume flexible than the firms downstream. This logic brings up the hypothesis that a supply chain consisting homogeneous firms may not be the best performer. Mixed combinations may result in better supply chain performance. For example, in our simulated supply chain, we expect to see [F, F, I] combination to perform better than [F, F, F] in terms of capacity change costs since increased demand volatility could be absorbed by a more responsive, innovative supplier resulting a lower total supply chain cost.

In terms of managerial implications of this paper, if the arguments and hypotheses presented in this paper are supported by the data, this may suggest that supply chain managers should carefully analyze production capabilities of firms that are to be a part of their supply chain. The volatile demand created within a supply chain may disturb operations of a less flexible company. Managers are advised to discuss several scenarios, such as 'less than expected' and 'more than expected' demand situations even if this is a so called efficient supply chain.

References available upon request from Ahmet Ozkul, aozkul@newhaven.edu