End-to-End supply chain strategy: a consumer packaged goods industry perspective

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Abstract

The giant retailers has become the sole channel to the market for many consumer goods. Retailers usually dictate the sale strategy of consumer-packaged goods (CPG) companies. However, CPG manufacturers can choose between two sale strategies determined by retailers: everyday lower price (EDLP) vs. promotion/SKU proliferation (PP). For sourcing packaging material there are two alternatives of Make (M) and Buy (B). This work analyzes the impact of sale (i.e., EDLP and PP) and sourcing (i.e., M and B) strategies on total supply chain costs. An analytical approach is adopted to model total supply chain costs (i.e. physical, marketability and transactional costs). By analyzing the CPG manufacturer's cost to serve we attempted to analyze the tradeoffs and determine the best combination of two strategies. A Monte Carlo simulation is conducted to generate data and analyze the model results.

Keywords: Sales strategy, sourcing strategy, supply chain strategy, consumer-packaged goods industry.

1. Introduction

Consumer packaged goods (CPG) is characterized with intense completion, saturated innovation and increased power of retailers. Having a commoditized product base, and a very price-sensitive consumer base and the channel (i.e., retailer) which demand very specialized service to manufacturers are other attributes of the industry. Price pressure for the players in this industry comes from diverse sources: consolidation of retailers to create mega-retailer and higher bargaining power against CPG manufacturers, using private label by mega-retailers to offer a low-cost alternative to branded products, emergence of other channels such as discounter to pressure retailer keeping the prices low, online and omni-channels which enhanced the consumer's information on the price and make them more price conscious. CPG manufacturers need not only be consumer-focused but also channel (customer) centric to succeed. Special product promotion is one essential action for these manufacturers to survive and succeed in the business. SKU proliferation (promotion) allow the manufacturers to gain many benefits: product differentiation primarily in packaging or special offers, providing value-added personalized service to retailers, consumers see value in them which allows manufacturer to charge premium price and make it hard for consumers to compare the prices, and it works in such a way to sway sales away from competitor's products.

There are conflicting views on the impact of product line extension on the financial performance of the firm (Hayes and Weelwright, 1984; Kekre and Srinivasan, 1990). According to Hayes and Weelwright (1984), product proliferation lead to higher overhead expenses and increased per unit cost in terms of producing, storing and delivering low volume products. Beside overhead expenses, Abegglen and Stalk (1985) argue that direct labor and material cost would also increase. As product lines proliferate, operations complexity rises multifold and lead to higher overhead expenses: greater material handling and inventories, more heterogeneous process flows, higher supervision requirement, higher yield loss and defects, and greater resources for scheduling, coordination and control due to more frequent and shorter runs (Abegglen and Stalk 1985; Johnson and Kaplan 1987). Often firms expand their product lines in order to spread the overhead expenses to a larger base, however it adds to complexity in logistics and manufacturing (Bitran 1988). The alternative approach is to reduce the complexity and rationalizing the number of SKUs (Alfaro and Corbett 2003) and relying on focused factory (Skinner 1974). A common practice in CPG supply chain is utilizing every day low price (EDLP) to circumvent the problems of promotion-based environment. The trade-off to be optimized here is the lower price with lower cost versus premium price with higher operation cost in EDLP and SKU proliferation respectively. CPG manufacturer can choose between two sales strategies in terms of selection of the retailer who utilizes either strategy although once the retailer is selected manufacture has to adopt to what retailer dictates. In this study, the combination of sales and sourcing strategies trade-offs are analyzed by modeling the total supply chain costs (i.e., cost-to-serve). Data is generated using Monte-Carlo simulation to analyze further the trade-offs.

2. Research background

One stream of literature notes the impact of product line breadth on market and financial performance of the firm. Kekre and Srinivasan (1990) showed that product line extension has a significant effect on firm's higher market share and profitability in both industrial and consumer markets (i.e., economy of scope). Surprising finding in Kekre and Srinivasan (1990) finding was a non-significant effect of product line breadth on direct costs, inventory costs and manufacturing costs (Foster and Gupta 1990). However they provided possible explanation on this result as firms in their sample may have adopted manufacturing strategies (Suarez, Cusumano, and Fine 1991) to offset the negative impact of product proliferation such as (1) moving from traditional process or product layouts to manufacturing cells and group technologies, (2) streamlining the manufacturing process through just-in-time practices and reducing set-up times to handle higher product variety, (3) by adopting FMS, (4) by better alignment of marketing, manufacturing and distribution activities, (5) by having focused factory dedicated to a product family, (6) by achieving product differentiation through maintaining high level of common parts and components, (7) by delaying the product differentiation at later stages of manufacturing process. Another drawback of these researches is the fact that they ignore the impact of product mix heterogeneity i.e., the extent of product attribute diversity among the products and considering this aspect, variety has significant positive impact on the cost (Anderson 1995). MacDuffie. Sethuraman, and Fisher (1996) in an automobile plant context found three types of variety: model mix variety, option variety and parts variety. There is conflict among the scholars on how these variety types impact on productivity. While MacDuffie. Sethuraman, and Fisher (1996) found a positive impact of model mix, a negative impact of part variety on labor productivity and car-to-car variability of installed options significantly improve productivity, Fisher and Ittner (1999) argue that car-to-car variability on installed options reduces productivity largely due to the fact that high options variability increase the hassle of production scheduling and parts delivery. In a larger scope the variety may have impacts on the downstream processes such as distribution (Zhou et al., 2017) , after-sale service, end of lifecycle management of the products. Ton and Raman (2010) studied the effect of higher variety and inventory on sale and they observed that although higher inventory and variety leads to higher sale yet it has a negative indirect effect on the store operation and eventually its sale. They coined the term of Phantom products – products that are present physically in the store but in storage area and not visible for the customers to see and purchase them- in retail operations due higher complexity stem from increased inventory level and variety.

Some researchers noted the structuring of operation and supply chain flexibly in horizontal direction to be able to accommodate with more variety (Graves and Jordan 1995; Graves and Tomlin 2000; Simchi-Levi and Wei 2012; Iravani, Oyen and Sims 2005; Tekin, Hope, Oyen 2002) and vertical supply chain flexibility has recently gained attention by scholars as well (Hope, Iravani and Xu 2010). “One size doesn’t fit all” statement was also illustrated by Fisher (1997) by suggesting different overall supply chain structure for various product nature. In an empirical study Randall and Ulrich (2001) found research evidence for their hypotheses on when firm compete on certain dimensions of variety if the production cost is high they tend to centralize the production - for instance for special tooling to make certain frame shapes in bicycle industry – and decentralize it when offered dimensions of variety result to higher probability of supply-demand mismatch such as high color variation in bicycle.
Ramdas (2003) clarifies the notion of variety and the difference between physical and augmenting (i.e., brand, packaging, marketing channels, warranties, and level of after-sale support) product features. The prevalent type of variety in CPG industry is augmenting product features.

In another stream of literature, the scholars studied the implication of product proliferation on product/process changes (Lee 1996; Lee and Tang 1997,1998; Swaminathan and Lee 2001) and rationalization of product base (Alfaro and Corbet 2003). Alfaro and Corbett (2003) found that in the SKU proliferated environment, uncertainty and variability pooling (across inventories, and locations) is a robust and effective solution when an optimal inventory policy is employed regardless of whether demand is normally distributed or not; and usefulness of pooling is questionable when after and before pooling a suboptimal inventory policy is used. Variegation point where the generic wedges gets customized is increasingly shifting to downstream and sale point (Lee 1996) Lee (1996) observed that in a broaden product line setting, manufacturer may need to change their process and product design in both make-to-order and make-to-stock models to accommodate with higher product variety. Delaying variegation (or differentiation) points is examined through production process restructuring via postponement or reversal of operations (Lee and Tang 1998), and product redesign via modular design, standardization (Lee and Tang 1997). Lee and Tang (1998) argue that the saving in manufacturing cost and supply-demand mismatch cost due to operations reversal is very dependent on demand variance and covariance. Whang and Lee (1998) took into consideration of delaying variegation points not just from operational cost perspective but from marketing standpoint and its impact on demand forecast accuracy. Designing an assembly production process and sequencing the activities to delay variegation points for product families and reduce support, manufacturing and supply-demand mismatch costs was studied by Swaminathan and Lee (1998, 1999) and Gupta Krishnan (1998). Desi, Kekre, Radhakrishnan and Srinivasan (2001) modeled the trade-offs between product design, manufacturing and marketing when a company pursues product proliferation and tries to change product design based on common components. Obviously identifying commonality across the product lines would streamline manufacturing process however the adverse effects on marketing and product pricing needs to be taken into account.

The cost-to-serve concept has emerged in SCM literature due to primarily operational complexity stem from various market channels, different customer segments, product complexity, etc. (Braithwaite and Samakh 1998, Norek and Pohlen 2001, Guerirrero et al., 2008). The notions is essentially implying that in a holistic approach to costing and customer profitability, the firms not only concern about the product manufacturing costs but also analyze and reduce cost to serve various customers to accurately account for all the cost and estimate the firm's profit. In the same vein, the total supply chain cost can be classified into three categories: physical (i.e., inventory, facility and transportation), marketability (i.e., obsolescence and lost sale) and transactional (i.e., transactional and coordination).

3. The model

Take note of a firm that operates in an industry in which there is a simple product (i.e., few parts and components in BOM with standardized interfaces among the parts and not facing with rapid pace of technological change) and there is multiple production and replenishment opportunity for the products to the market. The supply chain structure is depicted in Figure 1:

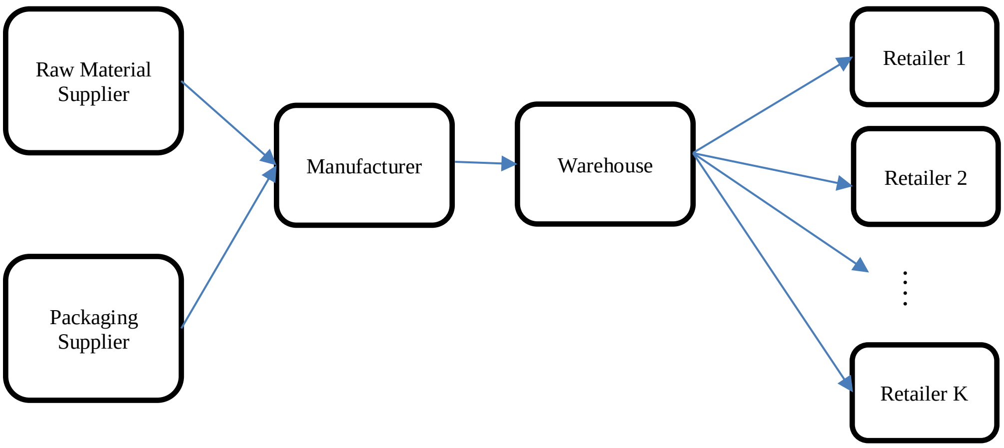

Figure 1: The supply chain structure

Consumer Packaged Goods (CPG) supply chain is an example of this setting and operates as a make-to-stock inventory problem (Lee 1996) in which inventory as finished goods is stored and the differentiation point is primarily in packaging at very late stage. The supply chain configuration is based on a warehouse fed by plants and serving multiple retailers (Schwarz 1989; Federgruen and Zipkin 1984). Demand information is retailer's specific and dependent upon whether retailer (i) adopt everyday low price (EDLP) strategy or promotion-based/SKU proliferation (PP). We characterize demand function for EDLP strategy as z_i which follows distribution of $F(z_i)$ and demand for PP strategy as y_i which follows $G(y_i)$. The $\sigma^2(y_i)$ is far greater than $\sigma^2(z_i)$. Under each strategy we assume that there is no correlation of demand across time units however there is covariance of demand across end products which is characterized by ρ_{ik} which is denoted covariance of demand for product *i* and *k* in a time unit.

We further assume that coefficient of variation for the end products under EDLP is much less than coefficient of variation of demand for end products under PP, i.e., $\frac{\sigma_i}{\mu_i}$ is equal for all *i* within each strategy but $\frac{\sigma_i}{\mu_i}$ is equal for all *i* under EDLP is smaller as compared to SKU proliferation. We define also that $R_i = \frac{\sigma_i}{\sum_j \sigma_j}$. In addition to backordering a portion of unmet demand we assume there is lost sale and obsolescence costs related to matching supply with demand. A decision should also be made on how to source packaging material. The total supply chain cost is a function of make (M) or buy (B) decision of packaging material. We ask the following question: how to characterize the cost performance of such a system as a function of *t*, *T*, total supply chain cost (marketability, physical and transactional), target fill rate, demand distribution of end products. The system performance is analyzed under a combination of sale and sourcing strategies to show which combination is more effective. Our model assumes that a firm chooses to pursue either make or buy strategy and also sell its product to either an EDLP or PP retailer. We do not consider hybrid sales or sourcing strategies. This assumption enables us to examine the tradeoffs of two sales and sourcing strategies and draw insight instead of making the model too complicated. This simplification is commonly used in OM analytical-based model literature (Wu and Zhang 2014).

The sequence of events is as follows. In the beginning of each time unit, the level of inventory is checked and based upon which two actions will be taken: first, an allocation decision is made on how the items that is just completed the generic stage of production process should be allocated to be customized in packaging stage, and second, the number of new items to begin the production is determined. Eppen and Schrage (1981) have suggested that the optimal inventory policy for a make-to-stock system with a single warehouse serving multiple retailers is order-up to level for each finished good under the fairly mild assumptions and using linear inventory holding and backlog costs (Clark and Scarf 1960). Let S_i be order up to level for finished goods *i*. Thus, at the beginning of each time unit, the quantity of new items to begin production is equal to the demand in previous time unit. An equal fractile allocation rule is utilized to determine the quantity of each items which completed the generic portion (h time unit of total H) of manufacturing process and is ready to begin get customized. This rule prescribes that, after allocation, the inventory position for each end products should be sum of the mean demand for the finished goods over H – h time units (packaging customization stage) and a common safety stock factor multiplied by standard deviation of demand over H – h time units. Hence, the steady-state end of period inventory, I_i , has expected value and variance as follows (more detail is provided in Eppen and Schrage 1981 and Schwarz 1989):

$$E(I_i) = A_i - R_i H \sum_j \mu_j$$

$$Var(I_i) = R_i^2 h \left\{ \sum_j \sigma_j^2 + \sum_{j \neq k} \rho_{jk} \right\} + (H-h)\sigma_i^2$$

where A_i is a function of S_i and μ_j but independent of h. Using these two moments, the service measures such as fill rate can be derived. To meet the target service level, the value of S_i then can be determined (Schwartz 1989).

3.1 End-to-End supply chain strategies

We model the total supply chain cost (cost-to-serve) function in each time unit is defined as below:

$$Total\ Supply\ Chain\ Cost\ (TSCC) = Physical\ cost(PC) + Marketability\ or\ supply - demand\ mismatch\ cost(MC) + Transactional\ cost(TC)$$

$Physical\ cost = facility\ cost + storage\ cost$
$Facility\ cost = direct\ labour + direct\ material + facility\ overhead\ cost$
$Storage\ cost = warehouse\ operating\ cost + inventory\ carrying\ cost$
$Marketability\ cost = lost\ sale\ or\ opportunity\ cost + obsolescence\ cost$
$Transactional\ cost = transactional\ cost + coordination\ cost$

Proposition 1: the expected total supply chain cost of four end-to-end supply chain strategies are as follows:

EDLP-MAKE (LM) strategy:

Total expected supply chain cost is modelled for L-M strategy. We use M and B subscripts to indicate make and buy sourcing strategies respectively. In each time unit, the production quantity is given by order-up to level S policy which is essentially the demand in *t-1*. The demand distribution in L is z_i which follows distribution of $F_i(z_i)$. Given initial inventory of $E(I_{t,i})$ total expected physical cost is given by:

$$PC_{t,i}^M = \int_0^{q_i} FC_i(z_{i,t-1} - I_i)dF_i(z_i) + \int_0^{I_i} ICC_i(I_i - z_i)dF_i(z_i) \quad i = 1, \dots, n; t = 1, \dots, m$$

where:

$n = number\ of\ products\ (SKUs)$
$FC_i = facility\ cost\ for\ product\ i$
$ICC_i = inventory\ carrying\ cost\ for\ product\ i$

It should be noted that CPG industry supply chain is a multiple-replenishment inventory problem and there is no full overage and underage costs. However, based on industry practice usually a portion of unmet demand is lost and a fraction (θ) of excessive inventory gets obsolete. Then we have:

$$MC_{t,i}^M = \theta \int_0^{I_i} OC_i(I_i - z_i)dF_i(z_i) + \int_{I_i}^{\infty} UC_i(z_i - I_i)dF_i(z_i) \quad i = 1, \dots, n; t = 1, \dots, m$$

where:

$UC_i = underage\ or\ opportunity\ cost\ for\ product\ i$
$OC_i = obsolescence\ cost\ for\ product\ i$

$$TC_{t,i}^{M} = K + \int_{0}^{q_i} MC_i(z_{i,t-1} - I_i)dF_i(z_i) \quad i = 1, \dots, n; t = 1, \dots, m$$

where:

$K = Initial\ investment\ to\ make\ the\ product\ in - house$

$MC_i = per\ unit\ cost\ of\ making\ the\ product\ i\ in - house$

EDLP-BUY (EB) strategy:

The physical and marketability costs categories are the same for this strategy and only transactional cost changes which is given below:

$$TC_{t,i}^{B} = \int_{0}^{q_i} BC_i(z_{i,t-1} - I_i)dF_i(z_i) \quad i = 1, \dots, n; t = 1, \dots, m$$

where:

$BC_i = per\ unit\ cost\ of\ buying\ the\ product\ i$

PP-MAKE (PM) strategy:

In this combination, the demand is more variable as compared to EDLP. The demand function is denoted by y_i which follows $G_i(y_i)$. PP strategy is characterized by more variable demand function and more number of products (i.e., $N \ggg n$). The expected physical, marketability and transactional costs are given as follows:

$$PC_{t,i}^{M} = \int_{0}^{q_i} FC_i(y_{i,t-1} - I_i)dG_i(y_i) + \int_{0}^{I_i} ICC_i(I_i - y_i)dG_i(y_i) \quad i = 1, \dots, N; t = 1, \dots, m$$

$$MC_{t,i}^{M} = \theta \int_{0}^{I_i} OC_i(I_i - y_i)dG_i(y_i) + \int_{I_i}^{\infty} UC_i(y_i - I_i)dG_i(y_i) \quad i = 1, \dots, N; t = 1, \dots, m$$

$$TC_{t,i}^{M} = K + \int_{0}^{q_i} MC_i(y_{i,t-1} - I_i)dG_i(y_i) \quad i = 1, \dots, N; t = 1, \dots, m$$

PP-BUY (PB) strategy:

Physical and marketability cost functions don't change. Expected transactional cost is given below:

$$TC_{t,i}^{B} = \int_{0}^{q_i} BC_i(y_{i,t-1} - I_i)dG_i(y_i) \quad i = 1, \dots, N; t = 1, \dots, m$$

3.2. Comparison of End-to-End supply chai[i]n strategies

Let (D, U) denote an end-to-end supply chain strategy, whereby D indicates a sale and U a sourcing alternative. Let $\pi_{DU} := [\theta E(I_i) - \theta^* E(I_i)]/\theta^* E(I_i)$ denote how far the obsolescence cost deviates from optimal cost and $\gamma_{DU} := \frac{TC - TC^*}{TC^*}$ denote how far transactional cost deviates from optimal cost. π_{DU} represents sales inefficiency of end-to-end supply chain strategy. Based on industry practice, obsolescence cost is noted more detrimental than lower fill rate. CPG manufacturers typically can fill backorder orders in later time by infusing some flexibility in their production process however the leftover inventory especially for particular promotional events are quite costly. Similarly γ_{DU} reflects sourcing inefficiency of end-to-end supply chain strategy. To procure packaging material which are more exposed to variation in demand, transactional cost varies according to M and B alternatives. Deviation from the optimal transactional cost reflects the inefficiency of an end-to-end supply chain strategy. If a buy strategy is adopted the firms typically expense on coordination cost with outside partner. In our model we exclude coordination cost due to intractability of analytical modelling. We also believe that this simplification would serve our purpose of analysing end-to-end supply chain strategy to provide insight on their trad-offs. Lower values of π_{DU} and γ_{DU} are desirable. Three corollaries of proposition 1 illustrates the conditions under which an end-to-end supply chain strategy dominates another.

Corollary 1: when selling to retailers with PP, the strategy of M is superior to B, i.e., $(P,M) \succ (P,B)$ when $\pi_{PM} - \pi_{PB} < \gamma_{PB} - \gamma_{PM}$. Similarly when selling to retailers with EDLP, the strategy of M is superior to B, i.e., $(L,M) \succ (L,B)$ when $\pi_{LM} - \pi_{LB} < \gamma_{LB} - \gamma_{LM}$.

Corollary 2: when sourcing from in-house, the strategy of selling to PP retailers is superior than EDLP retailers i.e., $(P,M) \succ (L,M)$ when $\pi_{PM} - \pi_{LM} < \gamma_{LM} - \gamma_{PM}$. Similarly when sourcing from outside supplier, the strategy of L is superior to P, i.e., $(L,B) \succ (P,B)$ when $\pi_{LB} - \pi_{PB} < \gamma_{PB} - \gamma_{LB}$.

Corollary 3: the end-to-end supply chain strategy of selling to PP retailers and sourcing internally is superior than selling to EDLP retailers and sourcing from B, i.e., $(P,M) \succ (L,B)$ when $\pi_{PM} - \pi_{LB} < \gamma_{LB} - \gamma_{PM}$. Also selling to EDLP retailers and sourcing internally is superior to selling to PP retailer and souring from outside supplier, i.e., $(L,M) \succ (P,B)$ when $\pi_{LM} - \pi_{PB} < \gamma_{PB} - \gamma_{LM}$.

The three corollaries determine under which condition which end-to-end supply chain strategy is superior than other three strategies. The numerical exercise using Monte carlo simulation confirmed our above corollaries.

4. Conclusion

Our analysis shows under which condition what end-to-end supply chain strategy is more preferable. CPG companies typically face with the dilemma that under dictated sales strategy by retailers what sourcing alternative for packaging material lead to better performance of the supply chain and the firm. This study provides some insight to shed more lights on this important trad-offs to be made in sales and sourcing strategies.

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References

Wu, X., F. Zhang. 2014. Home or overseas? An analysis of sourcing strategies under competition. Management Science 60(5) 1223-1240.

Abegglen , J. C., & Stalk, G. J. (1985). *KAISHA, The Japanese Corporation.* New York: Basic Books.

Lee, H. L. (1996). Effective inventory and service management through product and process redesign. *Operations Research, 4*(1), 151-159.

Alfaro, J. A., & Corbett, C. J. (2003). The value of SKU rationalization in practice (the pooling effect under suboptimal inventory policies and nonnormal demand). *Production and Operations Management, 12*(1), 12-29.

Anderson, S. W. (1995). Measuring the impact of product mix heterogeneity on manufacturing overhead cost. *The Accounting Review, 70*(3), 363-387.

Balakrishnan, A., Geunes, J., & Pangburn, M. S. (2004). Coordinating supply chains by controlling upstream variability propagation. *Manufacturing and Service Operations Management, 6*(2), 163–183.

Braithwaite , A., & Samakh, E. (1998). The cost-to-serve method. *International Journal of Logistics Management, 9*(1), 69-84.

Schwarz, L. B. (1989). A model for assessing the value of warehouse risk-pooling: risk-pooling over outside-supplier leadtimes. *Management Science, 35*(7).

Hayes, R. H., & Wheelwright, S. C. (1984). *Restoring Our Competitive Edge: Competing Through Manufacturing.* New York: John Wiley.

Kekre , S., & Srinivasan, K. (1990). Broader product line: a necessity to acheive success? *Management Science, 36*(10), 1216-1231.

Johnson, H. T., & Kaplan, R. S. (1987). *Relevance Lost: The Rise and Eall of Management Accounting .* Cambridge. MA.: Harvard Business Press.

Bitran, G. R. (1988, June 6). Quote from, "How the New Math of Productivity Adds Up". *Business Week*.

Skinner, W. (1974, May-June). The focused factory. *Harvard Business Review*, 113-121.

Foster, G., & Gufta, M. (1990). Manufacturing overhead cost drivers analysis. *Journal of Accounting and Economics, 12*, 309-337.

Suarez, F. F., Cusumano, M. A., & Fine, C. H. (1991). *Flexibility and Performance: A Literature Critique and Strategic Framework.* Cambridge, MA: Massachusetts Institute of Technology Sloan School WP# 3298-91-BPS.

MacDuffie, J. P., Sethuraman, K., & Fisher, M. L. (1996). Product variety and manufacturing performance: evidence from the internaional automotive assembly plants study. *Management Science, 42*(3), 350-369.

Fisher, M. L., & Ittner, C. D. (1999). The Impact of Product Variety on Automobile Assembly Operations: Empirical Evidence and Simulation Analysis. *Management Science, 45*(6), 771-786.

Zhou, Y. M., & Wan, X. (2017). Product variety and vertical integration. *Strategic Management Journal, 38*, 1134–1150.

Ton , Z., & Raman, A. (2010). The Effect of Product Variety and Inventory Levels on Retail Store Sales: A Longitudinal Study. *Production and Operatiuons Management, 19*(5), 546–560.

Jordan, W. C., & Graves, S. C. (1995). Principles on the benefits of manufacturing porocess flexibility. *Managment Science, 41*(4), 577-594.

Graves , S. C., & Tomlin, B. T. (2003). Process flexibility in supply chains. *Management Science, 49*(3), 907-919.

Simchi-Levi, D., & Wei, Y. (n.d.). Understanding the Performance of the Long Chain and Sparse Designs in Process Flexibility. *Operations Research, 60*(5), 1125–1141.

Iravani, S. M., Van Oyen, M. P., & Sims, K. T. (2005). Structural Flexibility: A New Perspective on the Design of Manufacturing and Service Operations. *Management Science, 51*(2), 151–166.

Tekin, E., Hopp, W. J., & Van Oyen, M. P. (2002). Benefits of Skill Chaining in Production Lines with Cross-Trained Workers: An Extended Abstract. *Manufacturing and Service Operations Management, 4*(1).

Hoppe, W. J., Iravani, S. M., & Xu, W. L. (2010). Vertical Flexibility in Supply Chains. *Management Science, 53*(3), 495–502.

Randall, T., & Ulrich, K. (2001). Product Variety, Supply Chain Structure, and Firm Performance: Analysis of the U.S. Bicycle Industry. *Management Science, 47*(12), 1588–1604.

Ramdas, K. (2003). Managing product variety: an integrative review and research directions. *Production and Operations Management, 12*(1), 79-101.

Lee, H. L., & Tang, C. S. (1997). Modeling the costs and benefits of delayed product differentation. *Management Science, 43*(1), 40-53.

Swaminathan, J. M., & Lee, H. L. (2003). Design for postponement. In S. C. Graves, & A. G. De kok, *OR/MS Handbook on Supply Chain Management: Design, Coordination and Operation.* Amsterdam, Netherlands: Elsevier Publishers.

Lee, H. L., & Tang, C. S. (1998). Variability Reduction Through Operations Reversal. *Management Science, 44*(2), 162-172.

Whang, S., & Lee, H. L. (1998). Value of postponement. In T. H. Ho , & C. S. Tang, *Product Variety Management: Research Advances.* Boslon/Dordrecht/London: Kluwer Academic Publishers.

Swaminathan, J. M., & Tayur, M. S. (1998). Managing broader product lines through delayed differentiation using vanilla boxes. *Management Science, 44*(12), S161–S172.

Gupta, S., & Krishnan, V. (1998). Product family-based assembly sequence design methodology. *IIE Trans, 30*, 933–945.

Desai, P., Kekre, S., Radhakrishnan, S., & Srinivasan, K. (2001). Product differentiation and commonality in design: balancing revenue and cost drivers. *Management Science, 47*(1), 37-51.

Braithwaite, A., & Samakh, E. (1998). The cost-to-serve method. *The International Journal of Logistics Management, 9*(1), 69-84.

Guerreiro, R., Rodrigues Bio, S., & Villamor Merschmann, E. (2008). Cost-to-serve measurement and customer profitability analysis. *The International Journal of Logistics Management, 19*(3), 389-407.

Norek, C. D., & Pohlen, L. (2001). “Cost knowledge: a foundation for improving supply chain relationships. *International Journal of Logistics Management, 12*(1), 37-51.

Eppen, G., & Schrage, L. (1981). Centralized Ordering Policies in a Multiwarehouse System with Lead Tiroes and Random Demand. In L. B. Schwarz.

Clark, A. J., & Scarf, H. (1960). Optimal policies for a multi-echelon inventory problem. *Management Science*, 474-490.