"FIT" FOR TURBULENT TIMES A CASE STUDY IN THE CHEMICAL INDUSTRY ON REDUCING DEMAND VARIABILITY AND INCREASING SUPPLY CHAIN FLEXIBILITY

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Abstract:
Purpose: The chemical supply chain has come under pressure. In times of high market volatility, its focus on efficiency is increasingly posing a threat to firm profitability. The purpose of this paper is to identify actionable measures, suitable for counteracting demand volatility in this industry.

Design/methodology/approach: This paper provides an overview of measures aiming at reducing demand variability and increasing supply chain flexibility. By means of case study research, these measures are then investigated for their practical applicability in the chemical industry.

Findings: The intensity of demand variability, its root causes, and its effects on supply chain performance were investigated in one real-world chemical supply chain. Applicable measures for improving the "fit" between flexibility need and flexibility potential were identified. The results showed that the case study company acted rather conservatively in its selection of modern management practices. Nevertheless, the study also revealed that the company was able to significantly improve its ability to deal with variable demand.

Research limitations/implications: The paper's results are drawn from a single case study. While the case study supply chain is likely to be representative for many supply chains in the industry, we are calling for further in-depth case studies to be conducted in different environments to allow more substantiated conclusions.

Originality/value: This paper provides a comprehensive review of the literature on demand management measures. Additionally, a methodology for a fact-based selection of applicable measures to improve specific demand management challenges is provided.

Keywords: Demand management, Chemical industry, Supply chain flexibility, Demand variability

1. INTRODUCTION

Considering the aftermath of the global economic downturn, many chemical companies are now enjoying a return to profitability. At the same time, however, the industry is facing several other challenges. Competition within the industry has become harsh, customer requirements in terms of availability, flexibility, and reliability have increased, and lead times and logistics costs are rising. In response, a growing number of chemical companies have begun focusing on supply chain management. They have learnt that they need to continuously improve their supply chain performance to remain competitive. There is one development, however, that keeps threatening supply chain and financial performance alike, viz. the industry's high level of volatility. Feedstock prices as well as demand volumes have been exposed to severe instabilities. Furthermore, opportunistic buyer behavior has shown to further complicate managing chemical supply chains.

In this volatile environment, the chemical supply chain – once deliberately designed to achieve top performance under relatively stable demand conditions – has come under pressure. The supply chain's current focus on efficiency is increasingly posing a threat to firm profitability. The production system that has been built on economies of scale and closely interlinked production processes and stages, fails to fully cater to the conditions of the industry's "new normal". Sustainable success and profitability more and more depend on the ability to manage volatility in order to successfully meet customer demand.

The aim of this paper is to identify actionable measures for counteracting demand volatility in the chemical industry. The starting point for our investigation is the demand management process that has been mentioned as one of eight essential supply chain management processes by Croxton et al. (2001). Demand management is defined as: "the supply chain management process that balances the customers' requirements with the capabilities of the supply chain. […] The process is not limited to forecasting. It includes synchronizing supply and demand, increasing flexibility, and reducing variability" (Croxton et al., 2002, p. 51). While forecasting in a highly volatile environment at some point naturally reaches its limits, the other aspects for improving demand management appear promising. So far, however, little attention has been paid to these other aspects, especially in asset-intensive upstream supply chains (Taylor/Fearne, 2006). In this paper, we focus on measures suitable for bridging the gap between supply and demand by reducing demand variability and increasing supply chain flexibility.

According to contingency theory, organizational effectiveness results from fitting characteristics of the organizations to contingencies that reflect the situation of the organization. High performance develops if a fit of organizational characteristics and contingencies exists (Donaldson, 2001). For our investigation this means that a fit between flexibility need (driven by demand variability) and flexibility potential (enabled by the capabilities of the supply chain) has to exist for optimal supply chain performance. Figure 1 shows the underlying considerations of this paper graphically.

Figure 1: Achieving fit between flexibility potential and flexibility need

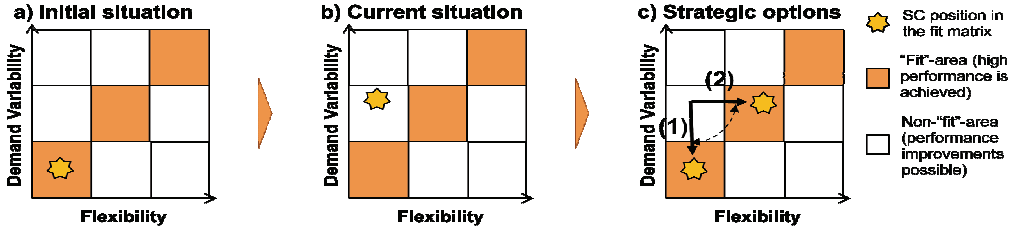


Figure 1:

Figure 1(a) shows the initial situation in the chemical industry during times of relative stability. Demand for chemical products was reasonably predictable. Environmental uncertainty and demand variability, therefore, relatively low. A fit, and consequently high supply chain performance, was achieved by implementing an efficient supply chain strategy. Chemical companies focused on cost-efficiency and not on responsiveness to (non-existent) variability. The supply chain's position in the first matrix was in the lower left "fit area" (low demand variability, low flexibility).

Due to increased uncertainty and demand variability, the efficient supply chain strategy many chemical manufacturers are still applying, does not fit the environmental contingencies anymore. Firms that are still operating an efficient supply chain strategy are struggling to compete in this environment. The position of their supply chains in the fit matrix has moved out of the “fit area” into a “non-fit area” (medium to high demand variability, low flexibility) as indicated in the matrix in Figure 1(b). Non-fit areas are characterized by suboptimal performance levels. To move back to a state of high performance, either demand variability has to be reduced or more flexibility needs to be incorporated into the supply chain. These two strategic options are indicated in the matrix in Figure 1(c).

The paper takes up this fit consideration in order to answer the following research questions:

RQ1: How can fit between flexibility need and flexibility potential be improved in the chemical supply chain?
RQ2: Which measures are appropriate to improve fit, and ultimately, performance in one specific case study supply chain in the chemical industry?

We applied the following research approach for identifying appropriate measures. First, we elicited a set of measures suggested by literature. These measures were then investigated for their practical applicability by the use of case study research.

2. LITERATURE REVIEW

2.1 The chemical supply chain

According to Fisher (1997), there are two generic forms of supply chain strategies, viz. the efficient and the customer responsive supply chain strategy. The efficient supply chain is catering for functional goods that are characterized by stable, predictable demand, long product life-cycles, low product variety, and rather low margins. Primary purpose of the efficient supply chain strategy is to supply predictable demand at the lowest possible cost. Innovative products are characterized by unpredictable demand, short life-cycles, high product variety, and high margins. Supply chains for innovative products, therefore, focus on responsiveness, rather than on costs.

The chemical industry with its large-scale facilities, complex and interlinked production processes and stages has been a typical example of the former. Producing huge volumes at few large chemical plants helps exploiting economies of scale and minimizing resource consumption. All of this makes perfect sense, as long as demand is predictable, but poses significant challenges in times of economic turbulence. There have been attempts of chemical companies to increase the responsiveness and flexibility of their manufacturing networks, but modifying the molecular design of chemical products and changing production processes and plants that were built to last for decades is a very capital intensive long-term approach. What the industry now needs are measures that are implementable in the short- and medium-term. Contributing to this goal is the aim of our paper. We will be focusing on customer-facing supply chain management measures that help reducing demand variability and increasing supply chain flexibility.

2.2 A new era of volatility

Chemical supply chains are increasingly faced with rising volatility. The industry has managed to master prior economic turbulences quite well. However, there is a difference to previous crises this time. The “supply chain volatility index” by Christopher/Holweg (2011) shows that the levels of volatility are far higher than they were in prior crises. It is at the same time not just volatility in the price of oil, but volatility in many key business parameters (e.g. exchange rates, interest rates, raw material prices, transportation costs, and stock markets) that is driving this general turbulence and it is expected that we are not just facing a temporary shock but are entering a new “era of volatility”.

The chemical industry, too, is exposed to these new market forces. Most chemical companies have seen demand return to pre-recession levels by 2011. Volatility and uncertainty, however, remain high. A recent study identified the industry as generally relatively weak in the area of supply chain agility. The industry’s mean score in this agility index was in the poor-to-moderate range (Fenton, 2009). This poses a significant threat to the industry. Volatile supply costs and volatile sales turnover can, if not managed properly, translate into profit volatility with all its negative valuation effects (Kannegiesser, 2008). In the current era of volatility, successful companies will be those that have the tools and skills to respond to the challenges ahead. We have identified demand management as an important capability in responding to these challenges.

2.3 Demand management

Demand management is more and more recognized for its importance in efficiently and effectively managing supply chains. A considerable amount of literature exists in the area concerned with the management of demand in supply chains. It ranges from the early work on demand amplification by Forrester (1958) to more recent initiatives, like efficient consumer response (e.g. Corsten/Kumar, 2005) and continuous planning, forecasting, and replenishment (e.g. Seifert, 2004). However, most of this literature focuses almost entirely on the retailer-manufacturer link in supply chains. Research on demand management in the upstream part of supply chains, remains in its infancy. But especially there, companies face a significant challenge. Fragmentation and a commodity culture regularly leave these companies at the end of a long bullwhip. Thus, these primary producers are increasingly confronted with the challenge of balancing uncertainty in supply with growing uncertainty in demand (Taylor/Fearne, 2006).

According to our understanding, demand management is more than merely promoting the improvement of demand forecasting and information sharing. In fact, we argue that demand management is the ability to understand customer demand and to balance it with the capabilities of the supply chain (Croxton et al., 2001; Rexhausen et al., 2012). Little industry specific literature exists focusing on these aspects of demand management. The work of Taylor (2005, 2006a, 2006b), Taylor / Fearne (2006, 2009) and Adebanjo (2009) can be highlighted in this regard with their research focus on the food industry. No in-depth analyses on the use of demand management practices are yet known in the chemical industry.

2.4 Demand management measures

Variability is inherent in nearly any business environment. To minimize the negative impact of variability, two things can be done: reduce variability itself or increase the flexibility to react to it. As Croxton et al. (2002, p. 62) state: “A key component of demand management is an ongoing effort aimed at doing both.” Increased flexibility makes the firm responsive to internal and external events. Reduced demand variability improves performance through consistent planning. Variability should first be reduced. Building flexibility into a system often involves considerable investments and operational costs. Therefore, only in a second step, the unavoidable variability should be managed by flexibility. Our analysis follows this two step approach. We will start with measures aiming at reducing demand variability and then analyze measures aiming at increased flexibility.

Measures aiming at reducing demand variability

Reduction of demand variability by information sharing

The bullwhip effect, as an important concept concerning demand variability has been studied intensively. Strategies aiming at the reduction of the bullwhip effect have been formed (e.g. Lee et al., 1997). However, as Killingsworth (2011, p. 6) states: “The dynamics of supply chains and large supply networks are still not well understood and major inefficiencies are the costly result. As supply chains have become more global and increasingly complex, supply chain dynamics and the associated risks and costs plague companies around the world.” Also in the chemical industry, the bullwhip effect remains to be a relevant challenge. It seems appropriate to start our analysis with approaches aimed at the reduction of variability through improved information sharing. Three established supply chain measures were identified: vendor managed inventory (VMI), collaborative planning, forecasting and replenishment (CPFR), and the use of supply contracts.

Exchanging information on inventory levels and sales is well suited to reduce demand variability. The VMI concept centers on the sharing of these types of information. Instead of ordering, the customer shares demand information with the supplier who is responsible for replenishment and to maintain predefined service levels (Angulo et al., 2004). Demand variability due to randomness can be considerably reduced, since the demand that the customer faces is directly passed on to the supplier. Since replenishment is usually based on stable prices, any price-driven variability is also tackled by this concept (Poiger, 2010). CPFR goes further than VMI in sharing information among supply chain partners. It involves all members of a supply chain in jointly developing demand forecasts, production and purchasing plans, as well as inventory replenishments (Sari, 2008). While its implementation requires more intensive organizational resources than VMI, CPFR is expected to additionally reduce demand variability.

If central planning is not possible or not desired, supply chain coordination can occur by the use of supply contracts. Reducing demand variability is possible by entering quantity flexible contracts. A variety of different types of these contracts exist (e.g. Tsay, 1999; Hening et al., 1997; Bassok/Anupindi, 1997). Regarding demand variability it can be assumed that the customer places better forecasts with the manufacturer, leading to decreased forecast errors (Poiger, 2010). Also price incentives for advance purchase can be given. Under such an agreement, order behavior can be influenced by the pricing component and orders may be shifted towards earlier commitment, thus decreasing forecast errors and reducing demand variability (Lian/Deshmukh, 2009).

Although the reduction of demand variability by information sharing is widely known in academia and put into practice in some industries, it has hardly been used in the chemical industry as a systematic approach. Due to business function orientation that is still predominant in this industry (Fritz/Hausen, 2009) and cultural conservatism (Shaw et al., 2005), the use of modern management methods seems to be restricted. Often C-level attention is not given to supply chain issues. For the successful implementation of collaborative practices, however, top management support is an important driver (Sandberg, 2007).

Reduction of demand variability through demand shaping

In situations in which information sharing across supply chains is not feasible, influencing demand poses an opportunity to reduce variability and to better align supply and demand. The influencing of demand to match it with planned supply is generally known as demand shaping. At the strategic level, the emphasis is to match customers' demand patterns to long-term capacity constraints. At the operational level, it centers on influencing customer demand towards available supply by the use of pricing, promotions and product bundling (Dey/Singh, 2007).

Especially the adjustment of prices appears to be a powerful steering mechanism for chemical companies in times of volatile demand. The beauty of this measure is that, unlike many other strategies to align supply and demand, prices can be changed rapidly. Thus, customer response can be influenced quickly (Zhang, 2007). Pricing approaches to match supply and demand usually fall under the concept of revenue management. It is concerned with optimal sales and demand decisions to achieve increased revenues (Tallury/Ryzin, 2005). For our purpose, especially revenue management's focus on estimating demand and using price control to manage demand is an interesting research area. Pricing mechanisms can be based on the analysis of demand patterns to ensure that available capacities can be used in the most profitable way (Kannegiesser, 2008).

Demand shaping has not been incorporated on a broad basis yet. This is mainly due to immature pricing processes and the limited influence individual companies have in global supply chains (Dey/Singh, 2007). Additionally, in the chemical industry pricing has not been perceived as manageable. It has been mainly done reactively (Rüdiger et al., 2007). Nevertheless, first chemical companies have discovered the benefits of revenue management and its future relevance is assumed to be high (Kolisch/Zatta, 2009).

Reduction of demand variability through risk pooling

Demand uncertainty is in many cases tied to the differentiation of goods that occurs during manufacturing and logistics operations. Variability originating from this cause can be reduced if differentiation can be delayed until demand is better known (Pagh/Cooper, 1998). The concept of risk pooling can be applied in these cases. Demand variability for individual products is consolidated in order to reduce the portfolio's total variability (Oeser, 2011).

Postponing logistics activities (Pagh/Cooper, 1998) allows a company to keep its options open as to where inventory should be finally deployed and thus reduces the risk of wrong time and location of its products (Yang et al., 2004). Benefits are the overall reduction of inventory levels and the potentially improved responsiveness to changes in customer demand. However, since inventory is centralized, customer lead times are becoming an issue.

Closely connected to logistics postponement are the risk pooling measures virtual pooling and transshipments. Virtual pooling extends a warehouse beyond its physical inventory. This means that, virtually, the inventory of other warehouse locations is also available to the original warehouse's dedicated region. Inventory thus is not per se postponed physically, but virtually the same effect is realized. Cross-filling and inventory sharing are still possible and pooling effects can be achieved. Virtual pooling is empowered by the use of transshipments. This means that products are shipped between the same echelons of a supply chain (Oeser, 2011).

Measures aiming at increasing supply chain flexibility
In a volatile environment, we can assume that not all demand variability can be eliminated. To cater for the remaining variability, more flexibility can be incorporated into supply chains. Chemical companies that have previously aimed at order winning through low cost and standardized production, now increasingly face the need for supply chain flexibility (SCF). In this paper we define supply chain flexibility as a firm's "ability to respond to change without increasing operational and supply chain costs and with little or no delay in response time" (Simchi-Levi, 2010, p. 134).

Supply chain flexibility is more and more seen as a strategic capability (Skipper/Hanna, 2009). It has emerged from manufacturing flexibility which has been a hot topic especially in the 1980s and 1990s. From the beginning of this millennium on, the intra-firm view on flexibility has been extended to supply chain flexibility (Duclos et al., 2003; Sanchez/Perez, 2005). A wide body of literature has been created since then. For an extensive literature review on the topic we refer to Stevenson/Spring (2007). What is often missing in the existing literature, however, is guidance for the industry on how to incorporate SCF into their supply chains.

Forecasting and holding inventory might be the first logical reactions to increased demand uncertainty. Forecasting, however, reaches its limits in a dynamic environment (Sabath, 1998). If forecasting accuracy cannot be increased, inventory can be seen as a hedge against the underlying uncertainty (Cachon/Tierwisch, 2009). Inventory-based approaches, however, often are no option as they tie up too much capital and can even increase risk through obsolete inventory (Garber/Sarkar, 2007). To analyze how supply chain flexibility can be used to respond to demand variability in the chemical industry. We have identified the following strategic approaches: synchronizing the supply chain with market demand, improving flexible capacity allocation, and reducing lead times.

Synchronizing the supply chain with market demand
It is widely recognized that synchronizing supply chain activities leads to increased responsiveness. To synchronize supply chains with market demand, collaboration and improved information sharing are necessary (Holweg et al., 2005). Measures that can lead to improvements in these areas include the introduction of a sales and operations planning process, the use of cross-functional teams, pull-based replenishment techniques, as well as the already mentioned measures VMI and CPFR.

Sharing real-time information generally facilitates decision synchronization. Demand can be fulfilled quicker and flexibility is improved by providing superior visibility and time to respond to change (Simatupang/Sridharan, 2005). Information sharing has to start within the own organization. Much has been written on functional silos and the traditional isolation of demand and supply processes which result in frequent mismatches (Esper et al., 2009; Croxton et al., 2001; Lambert et al., 1998; Taylor, 2000). Introducing sales and operations planning (S&OP) can lead to improved communication, information sharing and planning between the demand and supply sides within a firm (Esper et al., 2009). S&OP aims at cross-functional coordination between sales & marketing, operations, and finance. By implementing S&OP, improvements in linking corporate strategic plans to daily operations as well as the cross-functional exchange of real-time market demand and aligned reactions to it are enabled (Grimson/Pyke, 2007). It specifically aims at enabling the organization to respond effectively to demand and supply variability (Muzumdar/Fontanella, 2006).

Improving internal coordination is also in line with Duclos et al. (2003). They state that the amount of flexibility that a specific node in the supply chain can achieve depends on the flexibility of its workforce and organizational structure, business practices and culture. Deep organizational hierarchies can hinder flexibility and layers of bureaucracy slow down communication between departments. What is needed is a culture and organizational setup where the organization, operational procedures, performance measures, and even office layouts are designed to enhance quick and efficient decision making and transaction processing is simplified (Ferdows et al., 2004). Success stories of fast, responsive organizational configurations have one commonality: they all involve some type of cross-functional team design, composed of personnel with interdisciplinary capabilities, all focused on a common objective, and given incentives through joint KPIs (Gattorna, 2011).

While S&OP focuses on improved cross-functional planning, reactive pull-based replenishment techniques are a more operational measure to improve SCF by synchronizing replenishment processes with real market demand. Buffer inventories at different stock points are replenished based on actual demand. Shipments and production are stopped once preset inventory levels are reached. By doing so, the right products are produced based on real-time demand information. Both, production and logistics are freed up from managing products that are not demanded and therefore are able to respond faster to real changes in demand (Garber/Sarkar, 2007). Tichon/Fumero (2010) describe the use of the following pull planning techniques to replenish inventory at a chemical firm. Kanban is responsive and used to replenish materials in multiples of a fixed quantity. This approach provides self-management and flexibility. Where variability is too high for Kanban, re-order points are used. This technique is also responsive, but just uses one re-order quantity. For very low-volume products with high demand variability, campaign management can be used.

Many companies have invested in systems to streamline internal processes, but fail to extend these systems to their supply chain partners where approximately 80 percent of the information needed to orchestrate the supply chain lies. Tighter collaboration, the use of VMI and CPFR as well as the application of state-of-the-art technologies, such as cloud information platforms, allow visibility into real-time sales-order and inventory data (Garber/ Sarkar, 2007). In order to commit to information sharing, trust and collaboration needs to be improved. Close relationships increase the willingness to share information and cope with change and thus provide one dimension of flexibility (Stevenson/Spring, 2007). Centralized decision making as for example through VMI has benefits, as described above, but from a supply chain dynamics perspective, nothing fundamental is changed. Still two decisions are made individually from each other at the supplier, replenishment decisions and production decisions. The next step is to fully synchronize demand with the supplier's own production and inventory control process to increase SCF and reduce lead time. However, even with sophisticated CPFR systems, few companies have been able to exploit these advantages. With centralized structures, collaboration benefits are often diluted (Holweg et al., 2005).

Flexible capacity allocation

The above detailed concepts behind supply chain synchronization are simple and powerful, but they are not broadly implemented in the industry. Information sharing can be a challenge as supply chain partners often have differing interests in the short term. Full synchronization is difficult to implement for supply chains with long lead times and volatile demand (Holweg et al., 2005). The next strategic approaches will aim at improving supply chain flexibility by the provision of flexible capacity allocation. Any changes to manufacturing processes have been explicitly excluded from this study. Therefore, measures such as accurate response (van Hoek et al., 2001; Reimann, 2012), manufacturing postponement (Sodhi/Tang, 2012; Yang et al., 2004) and capacity pooling (Jordan/Graves, 1995; Simchi-Levi, 2010) will not be discussed. Logistics postponement and virtual pooling have been highlighted above already. Their target to delay customization and use available capacities in a flexible way is supposed to increase overall flexibility to respond to changed customer demand (Lee et al., 1993; Nair, 2005). Further measures that have been identified in this area include supply chain segmentation, outsourcing, and the use of shared resources and capacity swaps.

Customer segmentation describes how a given market can be divided into different customer groups that share similar needs (Harrison/van Hoek, 2008). Its goal is to find the appropriate supply chain processes and policies to meet each customer segment's needs while maximizing customer service and profitability (Thomas, 2012). Using customer segmentation can reduce the impact of demand variability on the supply chain and increase its responsiveness at the same time. Resources are freed up from standard demand in peak times and allocated to those customer segments that require (and pay for) increased flexibility. Rexhausen et al. (2012) regard this measure as a key resource for improved demand management performance.

Outsourcing reduces the own need for flexibility. In times of excess demand, the contract manufacturer's capacity can be used or the production of goods with high demand variability can be completely outsourced. Using contract manufacturers can also help reducing cycle time by moving production closer to customer plants (Garber/Sarkar, 2007). Contract manufacturing is specifically important in the pharmaceutical chemicals and agrochemicals segment where it represents a major part of the manufacturing capacity (Lambert, 2008). Logistics service providers are another lever for increased supply chain flexibility. Negotiating flexible contracts regarding transportation and warehousing capacities can significantly speed up distribution processes (Reichhart/Holweg, 2007). Swapping capacities between competitors is another strategy to potentially improve demand response. Two firms producing the same commodities in geographically distant locations can swap their capacities. With shorter lead-times, response to demand changes can be improved. Swapping production capacity is most common in the electricity, oil and gas industries and is also applied by chemical firms (McKinnon, 2004; Kosansky/Schaefer, 2010).

Reducing lead times
The speed of response to customer needs is another important dimension of supply chain flexibility (Ng et al., 1997; Closs et al., 2005). Long cycle times freeze cash in inventories and hinder quick response to changing market conditions (Schmid/Mandewirth, 2011). De Treville et al. (2004) found that lead time reduction is very powerful for increasing supply chain performance. Reducing manufacturing lead times is out of scope for this paper, thus only transportation lead time reduction will be investigated.

Overview on demand management measures
We have identified a number of measures that aim at improving the fit between flexibility need and flexibility potential. Figure 2 provides a summary of these measures, including estimated effects on variability reduction and flexibility increase, as well as their potential applicability in the chemical industry.

Figure 2: Overview on identified demand management measures

Measure	Applicability	Variability effect	Flexibility effect
Vendor managed inventory	Application in line with general product and SC characteristics	Reduced variability due to information availability, central decision making, and stable replenishment prices	Faster response to demand change due to superior and advance demand visibility; reduced out-of-stock
Collaborative planning, forecasting and replenishment	General supply chain characteristics pose challenges for successful application; no track record in the industry	Reduced variability due to fully synchronized supply chain wide decision making based on a single forecast, planning and demand data	Fast response to demand change due to full synchronization of demand with production and inventory process, reduced out-of-stock situations
Supply contracts	Application in line with general product and SC characteristics	Better forecasts and advance information shared with manufacturer	n/a
Dynamic pricing	Application in line with general product and SC characteristics; immature pricing processes in the industry might hinder its use	Shape demand by the application of pricing mechanism to ensure that available capacities are used in the most profitable way	n/a
Logistics postponement	Application in line with general product and SC characteristics	Shipment is postponed until demand is better known; risk pooling therefore reduces demand variability of the portfolio	More flexible response by postponing the final localization of a product until demand pulls; responsive transportation needs to be ensured
Virtual pooling	Application in line with general product and SC characteristics	Virtually risk pooling is enabled, multiple warehouses can be used to fulfill demand	More flexible response to unplanned demand at a specific location due to back-up inventory from virtual pool
Sales and operations planning	Application in line with general product and SC characteristics	n/a	Cross-functional exchange of real-time market demand and aligned reactions to market demand potentially improve responsiveness and flexibility
Cross functional teams	Application in line with general product and SC characteristics	n/a	The organizational setup and culture have a strong influence on overall flexibility of a firm
Pull-based replenishment	Application in line with general product and SC characteristics	n/a	Reactive inventory and replenishment techniques synchronize demand with supply chain operations
Customer segmentation	Application in line with general product and SC characteristics	n/a	Resources are freed from standard demand in peak times and allocated to customer segments that demand and pay for flexibility
Contract manufacturing / Logistics service provider	Application in line with general product and SC characteristics	n/a	Flexibility is outsourced to the contract manufacturer / logistics service provider who operates flexible capacity
Capacity swaps	Application for commodity/standardized chemicals possible; not for customized/innovative products	n/a	Chemical manufacturers can swap production capacities between distant plants to reduce lead times; not necessarily improving flexibility
Transportation lead time reduction	Application in line with general product and SC characteristics	n/a	More flexible response to demand by faster customer delivery; flexibility in the mode of transportation

3. CASE STUDY

Contingency theory claims that there is no single best way on how to manage an organization that is effective in all situations (Fiedler, 1964) and that no optimal set of choices that is true for any firm exists (Ginsberg/Venkatraman, 1985). Differences in the strategies applied, therefore, exist from firm to firm and are dependent on the firm-specific environmental demands (Trkman/McCormack, 2009). In line with this view, a case study approach, investigating a specific, real-world chemical supply chain, appears the sensible choice to test the applicability of the measures identified above.

This research method allows in-depth insights into the investigated field and seems to be especially appropriate for dynamic and complex phenomena as well as emerging research fields (Seuring, 2005;

Golicic et al., 2005; Stuart et al., 2002). Both are true for this investigation. Yin (2009) states that the single case methodology is applicable in various circumstances. Amongst others, representative and revelatory cases are mentioned. Demand management challenges of the case supply chain were assessed to be representative for many other chemical supply chains. In addition, in-depth quantitative and qualitative analyses were conducted during a six months on-site research project. To our knowledge, access to such in-depth analyses of the phenomenon has not been available before.
A classical research approach, as proposed by Stuart et al. (2002), has been applied. This included instrument development, data gathering, data analysis and dissemination. Data gathering fulfilled the concept of triangulation. Data was collected and interpreted from existing company reports, interviews and workshops, as well as in-depth data analyses. With the aim to identify those demand management measures that can improve fit between flexibility need and flexibility potential, the following three project steps were conducted: analysis of status quo, selection of improvement measures, and evaluation of implementation effects.

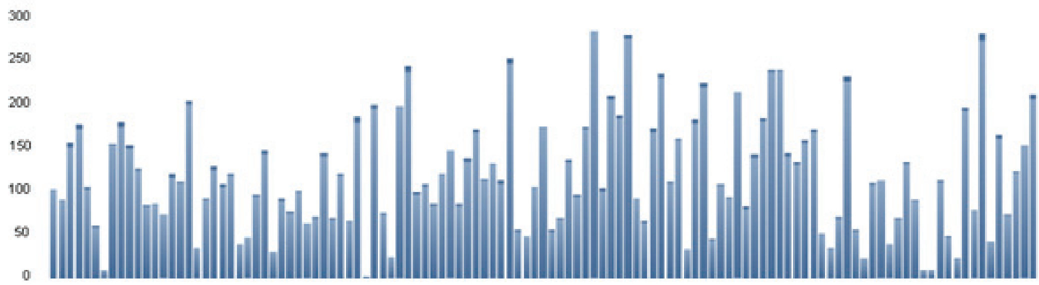
3.1 Company and supply chain overview

Our case company (referred to as CHEMCO in this paper) is a Fortune 500 company with a large portfolio of chemical products. Due to diverse demand management challenges based on individual products and geographical markets, the scope of the case study has been limited to one product and one regional market (Asia-Pacific). The company's business challenge can be summarized by a misfit between a relatively inflexible supply chain and highly volatile demand patterns. The chemical product in scope serves as a precursor for the food industry. While demand for the end product is stable, demand for the precursor is very volatile. Production takes place in Europe. Shipping to Asia is done by sea. This results in long transportation lead-times. To remain capable to act in such an environment, traditionally, large stocks of finished products are held. However, high intra-company transfer prices for the product are complicating this situation. Inventory that is held in the regional and local warehouses is valued at significantly higher rates than at the production site. Therefore, it has been one of management's goals to reduce its local inventories as much as possible. The misfit between flexibility need and flexibility potential manifests in low customer service levels and lost sales.

3.2 Analysis of status quo

In a first step, we analyzed the status quo of the supply chain's demand management capabilities. Expert interviews were conducted and workshops were held from which we drew the data to analyze demand variability as well as its effects on supply chain performance. This included in-depth analyses of forecast, demand, production, inventory, and delivery data. Figure 3 shows the weekly sales volumes for the region. The chart reveals operation's continuous struggle with highly variable demand. A coefficient of variation of 55 percent was calculated for the reference period. No demand patterns, such as seasonality, were identified.

Figure 3: Weekly sales volumes (indexed with week 1 = 100).



XYZ-analysis classifies goods according to their demand predictability. Z-goods are most difficult to handle due to erratic demand and generally low forecast accuracy (Kummer et al., 2009). According to Schulte (1999), all products with a coefficient of variation in demand higher than 25 percent are considered z-goods. Clearly, CHEMCO's product in scope falls into this challenging category.

Root cause analysis showed that market dynamics, driven by own pricing strategies, competitor behavior, expected price changes and highly speculative behavior of the immediate customers was a main driver for variability. So far, little attention has been given to supply chain operations when pricing decisions were taken. For CHEMCO this has resulted in significant challenges in operating the supply chain in an efficient and effective manner. Forecast accuracy showed low values. To further complicate the situation, production was inflexible to volume changes and transportation lead-times were long. Inventory analysis showed that low forecast accuracy, long lead-times and the restrictive inventory policy has led to significant out-of-stock problems in the regional distribution center as well as the local warehouses. Low customer service levels were the apparent consequence. No records existed on lost sales, but sales experts did describe this as a weakness of the current supply chain setup.

3.3 Selection of improvement measures

A portfolio of potentially beneficial measures has been identified in the literature review. The applicability of each measure was then evaluated for this particular supply chain. To do so, the use of scoring models has been identified as an efficient and effective multi-criteria decision making tool (Cooper et al., 2001). In our case, a constrained weighted factor scoring model (Meredith/Mantel, 2012) was used which was based on firm specific decision parameters. Constraints were first formulated that needed to be fulfilled in order for an individual measure to be applicable. Once a measure has passed all of the constraints, the actual scoring began based on company specific evaluation criteria. This included financial, environmental, and implementation aspects. Individual measures were ranked based on their individual total scores. The measures with the highest ranks were selected for a further investigation. This phase resulted in the selection of the following measures: transportation lead-time reduction and virtual pooling. Increasing local safety stocks was a third measure promoted by CHEMCO as a baseline scenario.

According to literature, it is advisable to first reduce demand variability as much as possible. Only then, supply chain flexibility should be used to cater for the remaining demand uncertainty. Variability in this supply chain was mainly driven by pricing decisions and a lack of coordination. However, measures aiming at reducing these root causes were not deemed applicable by CHEMCO. Changes to the current pricing strategy were not regarded as feasible. Measures aiming at improved cross-functional coordination were also not chosen for a further investigation. All measures aiming at improved coordination and cooperation with customers were deemed inapplicable due to the commodity character of the product and the price sensitivity of the customers. CHEMCO expected that as soon as a competitor offers a more favorable price, customers would turn towards the competitor. Accordingly, it is not expected that they would accept any form of cooperation that binds them to just one supplier. The exclusion of these measures means that instead of addressing the root cause of the problem, only reactive measures remained on the list for implementation.

3.4 Evaluation of implementation effects

In the next step, the previously selected measures were analyzed in terms of their implementation effects. By means of a business case, we captured all relevant information for final evaluation. In order to be able to incorporate the business dynamics into the business case, we applied Monte Carlo simulation. Uncertain variables, such as sales prices and volumes, production cost, and available inventory levels were modeled using a probability function.

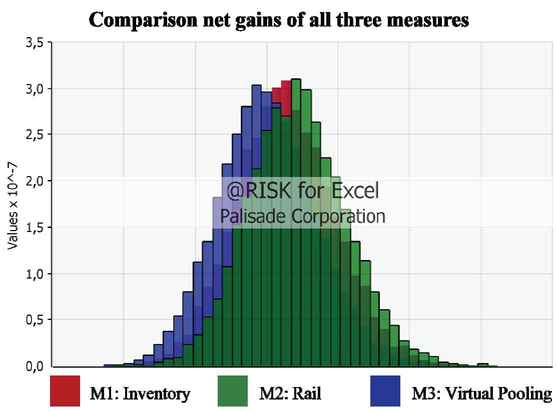
Increasing local inventory levels by 10 percent was the first measure. The evaluation showed that, on average, sales volumes could be increased by 5.2 percent. Theoretically, increasing inventory by an even higher percentage would be beneficial. However, not all dynamics of the market were incorporated into the business case. For example it is not clear which amount of sales are really lost due to the non-availability of inventory. Dependent on buyer intentions as well as competitor behavior, buyers might be willing to accept a backlog.

The second measure, the reduction of transportation lead-times to Asia-Pacific, was addressed by proposing to switch to other transportation modes, such as rail transportation (via the Eurasian land bridge), sea/air multimodal transportation, or air transportation only. Air transportation showed to increase transportation costs by a factor of 40 and was therefore dropped immediately. In the case of rail transportation, our estimates showed that transportation costs would double. In terms of lead-time reduction, we settled on a conservative estimate of a reduction of 15 days. This simulation revealed significantly higher demand fulfillment and that the higher transportation costs could easily be compensated by the expected increase in sales.

Virtual pooling, the third measure in scope, extends a warehouse beyond its physical inventory. Transshipments of inventory between the warehouses or direct delivery to the customer in another sub-region could be used to fulfill demand. While in theory this measure seems to be a good fit for CHEMCO, its practical performance is less powerful as it was expected. Demand variability is driven to a high degree by the firm's pricing strategy. The market for the product is characterized by globally transparent prices. High demand is expected at times when CHEMCO offers a favorable price compared to global competition. In such a situation, demand increases significantly across all sub-regions. In the past, this has led to a number of stock-out situations across all warehouses. Therefore, in times of increased demand, little inventory will be available for transshipment across the regions. Transshipment costs and costs for system adaption absorb the rather low revenues from additional sales.

Figure 4 shows the comparison of simulation results for the net gains of the above described three measures. The simulation assumed that demand variability will follow historic behavior and that the unavailability of inventory at the time demand occurs would lead to lost sales. Based on these assumptions, lead-time reduction by the use of rail transportation achieved the highest benefit, followed by increased inventory levels. Virtual pooling did not show any financial benefit. While the individual measures are not mutually exclusive, CHEMCO only chose measure 1 (inventory increase) for implementation. The firm's transportation analysts regarded the risks of theft and delay as currently still too high for the use of the Eurasian land bridge.

Figure 4: Comparison of simulation results for net gain of the three measures in Company A.



4. CONCLUSION

The ability to manage volatility is more and more becoming a requirement for sustainable success and profitability in the chemical industry. The paper has identified a number of measures that have the potential to increase the fit between flexibility need/demand variability and flexibility potential. These measures are intended to either reduce demand variability or to increase supply chain flexibility. Demand variability can be reduced by information sharing, demand shaping, and risk pooling. Supply chain flexibility can be achieved by synchronization of the supply chain with market demand, flexible capacities allocation, and the reduction of lead-times.

The underlying measures were then tested for their practical applicability in the chemical industry by case study research. The high levels of demand variability in the case study supply chain made it an interesting object for investigation. Our study benefited from privileged access to decision makers, functional experts and data. An in-depth analysis of demand management challenges and their root causes in this specific supply chain was conducted. Demand variability was predominantly caused by market dynamics, including pricing decisions, competitor and buyer behavior. Own pricing decisions were made without any attention to supply chain operations. Thus, performance problems seemed to be partly home-made.

Limited cross-functional coordination is distinctive of culturally conservative industries. Such industries are generally known for a restricted use of modern management practices. This can also be seen in the case study supply chain. To mitigate the root cause of the problem, measures aiming at improved cross-functional or even inter-organizational coordination would be needed. Instead, reactive operational measures were chosen for an implementation. This shows that CHEMCO, like many other chemical companies, still is business function oriented. Moreover, inter-organizational coordination was not regarded as feasible due to the commodity characteristics of the product.

The measures selected by CHEMCO for a more detailed evaluation of implementation effects cannot be regarded as very innovative. Prima facie, their selection appeared to be unsatisfying for our investigation. CHEMCO decided to increase local inventory levels. While this absorbs some of the variability-driven performance problems, neither demand variability is reduced, nor flexibility is increased. Does such a selection indicate that demand management measures are redundant for CHEMCO or even the chemical industry as a whole? We do not think so. We believe that an organization first has to be enabled to recognize the benefits of improved demand management. At CHEMCO, limited cross-functional coordination has led to a situation where, in spite of high demand variability, low forecast accuracy and long lead-times, inventory levels were kept at constantly low levels. Without accurate demand information and cross-functional alignment, supply chain operations were reduced to reactive fire-fighting. The project has revealed that higher inventory is urgently needed to effectively fulfill demand in this supply chain. With demand variably remaining high in the industry, additional measures will become relevant, also for CHEMCO. Even though the measure will be effective in reducing parts of the lost sales problem, wrong inventory allocations will remain threatening supply chain performance. Once this is recognized, it will be necessary to expand the firm’s scope to further demand management measures, including those that really tackle the root cause of the problem.

Further research in the area is needed. Case study research has proven to provide the in-depth insights needed for a detailed analysis. We are calling for additional in-depth case studies in different environments. With more cases, more tangible conclusions can be drawn. Differences in those sectors of the chemical industry that are operating in a less commoditized market or show different demand patterns seem to be an interesting area to direct future research to. It will be interesting to see if the statements on cultural conservativism and inter-organizational coordination will also hold for other sectors of the industry and which additional measures are regarded as applicable in different situations. Also cross-industry investigations seem interesting for future research. With more empirical insight to the use of demand management practices, also the development of a demand management maturity framework seems interesting.

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