Available online at www.sciencedirect.com

SciVerse ScienceDirect

Procedia CIRP 3 (2012) 453 – 458

www.elsevier.com/locate/procedia

45th CIRP Conference on Manufacturing Systems 2012

Hybrid Production Strategy Between Make-to-Order and Make-to-Stock – A Case Study at a Manufacturer of Agricultural Machinery with Volatile and Seasonal Demand

J. Köber[a,]*, G. Heinecke[b,c]

[a]*CLAAS Selbstfahrende Erntemaschinen GmbH, Münsterstraße 33, 33428 Harsewinkel, Germany*
[b]*Swiss Federal Institute of Technology (ETH), Tannenstraße 3, 8092 Zurich, Switzerland*
[c]*Corporate Technology Siemens AG, Otto-Hahn-Ring 6, 81739 München, Germany*

*Corresponding author. Tel.: +49-170-564-6685; fax: +49-524-712-2291. *E-mail address*: jonathan.koeber@claas.com

Abstract

Manufacturing companies want to implement the make-to-order (MTO) strategy to be more flexible and responsive to the volatility of demand and product variability. However, the make-to-stock (MTS) approach is an appealing concept due to its desirable performance properties: high capacity utilization, high availability and short lead times. This paper aims to define a methodology that combines the advantages of MTO and MTS. The evaluation of the production strategies is based on an industrial case of a global manufacturer of agricultural machinery and is accomplished with the help of System Dynamics.

Keywords: Hybrid Production Strategy; Customer Order Decoupling Point; System Dynamics; Industrial Case Study

1. Introduction

In the evolution of production systems, mass customization is playing a major role because markets have changed from supplier to buyer markets. Hence, manufacturing companies want to implement the strategy of make-to-order (MTO) supply chains to be more flexible and responsive to demand volatility while also providing higher product variability [1, 2]. The increasing interest in product customization is explained by the fact that customers are demanding highly customized products and services [3]. Furthermore, customization is also driven by marketing since it provides manufacturing firms with an approach that is claimed to improve its competitive position [4]. Especially, the market performance measures like high service rate and short lead times of customized products are unique selling proposition [5]. Generally, in an deterministic MTO supply chain the processes can respond to the actual customer demand when it occurs. However, firms suffer from increased vulnerability due to variations (e.g. demand fluctuations) and disturbances (e.g. material supply issues) that lead to unpredictable effects and destabilize the equilibrium of MTO supply chain. The required adaptability (e.g. flexibility) of spare production capacities to variations (e.g. seasonal or volatile demand) is limited due to the associated costs. Hence, the production concept of MTS is appealing due to its desirable performance properties: high capacity utilization and short lead times. As a result, the desired market performance of a MTO supply chain can be achieved only at the costs of the operational performance to meet seasonal and volatile demand. Accordingly, the success of the MTO strategy does not entirely reach expectations.

Consequently, the focus of this contribution lies on an evaluation of a *hybrid production strategy* between MTO and MTS to achieve market and operational performance. In the academic literature, the topic of choosing the right product delivery strategy (PDS) and the design of downstream (agile approaches) and

doi:10.1016/j.procir.2012.07.078

upstream (lean approaches) processes from the customer order decoupling point (CODP) are widely discussed [2]. However, these discussions insufficiently cover the implications of the right production strategy for companies that operate in seasonal markets with volatile demand. This contribution addresses this gap through a methodology that defines a *hybrid production strategy*.

2. Related Literature

2.1. Customer Order Decoupling Point (CODP)

The PDS is defined by the position of the CODP in a supply chain. The CODP defines the stage in the manufacturing value chain, where a particular product is linked to a specific customer order [6]. Sharman [7] defines the CODP as the point where product specifications are typically frozen. As a rule, the CODP also coincides with an important stock point from which the customer is supplied [8]. On the downstream side of the CODP the finished goods are pulled by customer orders. On the upstream side, the production is driven (pushed) by forecasts. The MTS approach is characterised by high customer anonymity in the supply chain, short order-to-delivery time, high importance of forecast accuracy, high inventory costs and high capacity utilization in the supply chain. Many manufacturers follow the vision of a CODP that allows MTO production. However, the decision of the CODP, which also implies the PDS, has to consider the variations, disturbances and capacity limits in the supply chain. In general, these aspects get too little attention in the design of supply chains and the choice for a production strategy. As a result, the dynamics of crucial parameters and the limits of adaptability have to be respected when choosing the right PDS.

2.2. Approaches to Define a PDS

This subsection illustrates three approaches for defining a PDS by considering selective criteria. First, the model from Olhager [6] defines the PDS based on two criteria: relative demand volatility (coefficient of variation, CV) and the ratio between production lead time (P) and delivery lead time (D). The CV is an indicator for the predictability of demand. Thus, in order to ensure high operational and market performance, a low CV favours a MTS strategy while a high CV leads to a MTO strategy. On the other hand, the ratio of production lead time (P) and delivery lead time (D) indicates that a product could be produced in less time than the customer desired delivery time. If the ratio is less than one, then the PDS is driven by customer orders. If not, then the PDS follows a MTS approach. Figure 1 shows that Olhagers's framework essentially defines whether a product will be MTS or MTO. In-between those two strategies products can also follow the strategy of ATO, which means to hold inventory of components and to assemble the final product once a customer order arrives.

The second classification approach for choosing a PDS is based on the Pareto Law, which states that 20% of the products make 80% of the total demand. The way in which these 20% of products are managed differs considerably from the remaining 80% [9]. Those 20% of products generally show high and stable volumes that makes them more predictable and, hence, more adequate for the MTS principle. The other 80% of products are more exotic with intermittent and erratic demand that caused by highly volatile demand behaviour [10]. In this case, these products are more suitable for a MTO production.

Third, a *hybrid production strategy* based upon separating demand patterns into "base" and "surge" elements has been proposed [9, 11]. Base demand can be forecasted, whereby surge demand is typically characterised by unpredictable, volatile demand behaviour. The advantage of this separation is to produce base demand on stock during slack periods to achieve a robust scheduling of production capacities, reducing the need for flexibilities. It has been shown that MTO is an adequate principle for surge demand [11]. As a result, the approach of base-surge-demand can balance the target set of production controlling, high capacity utilization, low inventory, short lead times and high service rates. In a nutshell, this approach combines the advantages of MTO and MTS production.

However, there are still gaps in regard to the applicability of the approaches i) in case of seasonal and volatile demand and ii) when considering capacity constraints while defining the production strategy. In summary, the model of Olhager, the Pareto Law and the base-surge-demand approach together create the base framework for this contribution. The following Section 3 illustrates the practicability of the approaches by applying them to an industrial case. The goal is to determine their suitability and demonstrate the necessity for a *hybrid production strategy* between MTO and MTS, which considers also the utilization of production capacities in cases of seasonal and volatile demand.

3. Case Study

The case study is based on data from the supply chain of a global manufacturer of agricultural machinery that produces combine harvesters, forage harvesters, balers, forage harvesting machinery and tractors. These markets are characterized by a series production, low and seasonal demand volume, increasing product variety and globalization of operations. Due to the competitive landscape, the market of agricultural machinery has especially high requirements on customized products, quality, service, price, delivery reliability and short delivery times to generate customer satisfaction and enterprise profitability. A benchmark of a representative market found that the MTS production leads to higher costs regarding both factors: costs of inventory and product reconfiguration, as well as to lower price realisation than MTO because stocked products do not match customer requirements. As a result, there is a potential to increase the customer satisfaction and profitability by producing what customers want. Hence, MTO is the desired production paradigm. However, the limitation of available production capacity downstream from CODP has to be considered because an adaption of the capacities to the actual consumer demand requires a high responsiveness of the production system.

3.1. Practicability of the Model of Olhager

The customer desired delivery time has been ascertained through a customer survey of over 420 customers in a reference market. The result of the survey shows that the customer wants their customized tractor on mean average in 12 weeks. The standard deviation is 1.9 weeks. The production lead time including the shipping time for a product is on average nine weeks. In respect to the model of Olhager all products could be produced to an order-based approach because the ratio of production lead time and the customer desired delivery time is smaller than one. All products are placed on the left hand corridor in the matrix of Olhager. The relative volatile demand (y-axis) is equal to the coefficient of variation (CV), which is the quotient of the standard deviation divided by the average of the demand. Typically, a lower relative demand variation correlates with a higher demand volume. That means, vice versa, products with low volume demand have a higher CV. This has also been shown empirically in [12]. As a result, the production system is suited for a MTO or ATO principle, where every production job is triggered by a customer order. There is only the differentiation that products with a high relative CV are produced MTO and those with a lower CV follow an ATO strategy. However, the parameters are continuously influenced by changes. For example, if the actual customer demand (e.g. seasonal demand peaks) is higher than the available production capacity for a time period then the ratio between production lead time and desired delivery time is bigger than one. Additionally, demand volatility, which is calculated over a certain time period, leads to oscillation of a products position in the matrix. Furthermore, it was observed that a spontaneous demand increase (e.g. sales campaign) leads to a diagonal movement of the product position. There is a correlation between longer production lead times and higher CV by an oscillation of the demand volume.

Downstream of the CODP, processes ideally follow customer demand behaviour and their fluctuations. If an unpredictable supply chain event (e.g. demand change, production strike or supply issue) occurs, then the production lead time increases. Hence, the product positioning in the matrix of Olhager moves horizontally. In a nutshell, from one moment to another the PDS can change dramatically. Consequently, desired market performance is not achieved and sales people lose their trust in the production. A typical reaction is that sales people then start to place “sales orders” - instead of end customer orders - based on their personal forecast and judgment to achieve availability and delivery reliability.

An ex post analysis for a reference product shows that its position moves as anticipated (Figure 1). The position of the product in the matrix moves diagonally due to the monthly ups and downs that result from seasonal demand behaviour. This demand variation leads to a higher CV and higher ratio between the production lead time and desired delivery time. Furthermore, in November a supply chain event (supplier strike) led to an unpredictable increase of the production lead time and the ratio quickly increased above one that demands a strategic change from MTO to MTS.

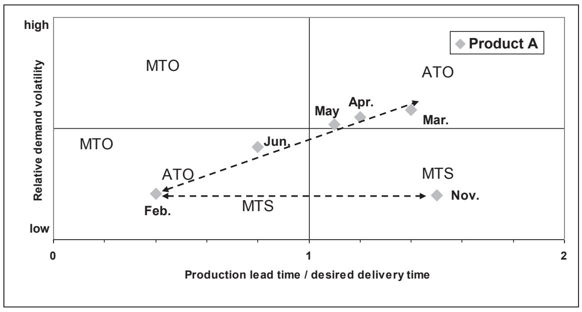

Fig. 1. Dynamics of product positioning in the matrix of Olhager

The model of Olhager includes important criteria to define a PDS like the CV, the desired delivery time and the production lead time. However, the example in Figure 1 shows that these parameters exhibit a dynamic behaviour that demand volatility changes of production strategies. Since production systems are limited in their adaptability, manufacturers have difficulties in realizing an order-driven approach in practice.

Furthermore, if we make the assumption that a MTO production is the ideal PDS for a product family like in the industrial case, then the last inventory point lies upstream of the manufacturing process of the OEM. Consequently, all supply chain events (i.e. demand volatility, issues of just-in-sequence suppliers and production strikes) have to be absorbed through the adaptability of processes downstream from the CODP. Hence, production capacity is the forecasted demand volume plus a multiple of its standard deviation to ensure high responsiveness and desired market performance. From the operational perspective, however, over-sized capacities are uneconomical. Furthermore, in practice the flexibility to adapt to actual demand are very limited and costly.

In a nutshell, capacity constraints and their adaptability along the downstream processes from the CODP have to be considered when defining the right PDS. As a result, the model of Olhager helps to give an indication of what is the right PDS for a product. However, the approach neglects capacity constraints and the influence of supply chain events downstream of the CODP. The case in Figure 1 shows that the dynamics of the parameter coupled with capacity limits have a significant impact on the position of the CODP.

3.2. Classification of the PDS in MTO and MTS

Christopher and Towill [9] used the Pareto Law to classify products into two groups that either supports a lean (MTS) or agile supply chain (MTO) design. Products with high demand volume are more adequate for MTS than products with low volume demand. A correlation between demand volume and the CV showed that products with high demand have a low CV making them more predictable. Figure 2 shows the results of the Pareto Curve of the products in the industrial case. The products are ranked according to demand volume. In practice, this intuitive approach helps prioritizing products into two product delivery classes, i.e. MTO and MTS, depending on their forecasted demand volume. This classification matches the base-surge-demand approach and provides a crucial base framework for a *hybrid production strategy*. Products with base (high and stable) demand can be allocated to a MTS production and products with surge (low and volatile) demand to a MTO production.

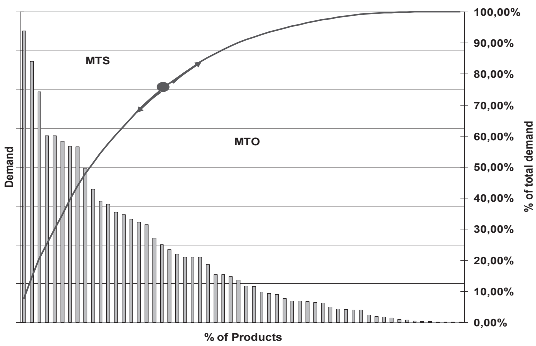

Fig. 2. Pareto Curve of the demand per product of a product family in the industrial case

This classification leads to a high performance of the market and operational targets. Consequently, MTS products with high and stable demand volume are used to level production capacities. Additionally, the MTS production increases the ability to respond to unpredictable supply chain events because late inventory buffers absorb fluctuations. It has been shown that through utilizing the presented approaches a hybrid production strategy can balance the advantages of MTO and MTS while ensuring high performance regarding to operational and market targets.

Based on the findings, the authors of this contribution demonstrate in the following chapter i) a methodology to define a hybrid production strategy between MTO and MTS by seasonal and volatile demand and ii) a generic simulation model to evaluate the performance measurement.

4. Framework

4.1. Methodology to Define Hybrid Production Strategy

Section 3.1 outlined that the model of Olhager gives an orientation for the right PDS. The model considers main criteria like relative demand volatility and ratio between production lead time and desired delivery time. As presented, the approach does not cover the dynamic of the criteria and capacity constraints. To classify products into either MTO or MTS, the Pareto Curve of the demand volume is also a proper approach. Furthermore, an applicable approach to a *hybrid production strategy* between MTO and MTS is given by the base-surge-demand approach, which leads to a balancing of operational and market performance.

Figure 3 demonstrates the methodology to define a *hybrid production strategy*, which is based on the three presented approaches. In the first phase the products are classified into the two PDS classes, MTO and MTS. If we respect limited capacities, seasonal and volatile demand behaviour then a *hybrid production strategy* is more economical than a strategy that is completely MTO or MTS. In a second phase, all products of the MTO class are ranked by their demand volume with the help of the Pareto Curve. Every point on the curve can be defined as a scenario (S), which can be evaluated in the simulation model. For example scenario zero (S 0) means that all products are dedicated to the MTO class. In scenario 1 the product with the highest demand volume is dedicated from MTO class to MTS. Finally, in scenario n all products are dedicated from the MTO class to a MTS approach. In the third phase, the operational and market performance for every scenario is evaluated with the help of a generic manufacturing supply chain simulation model. As a result, different degrees of to which the production strategies of MTO and MTS are applied can be evaluated. Details of the simulation model are described in Köber and Heinecke [13].

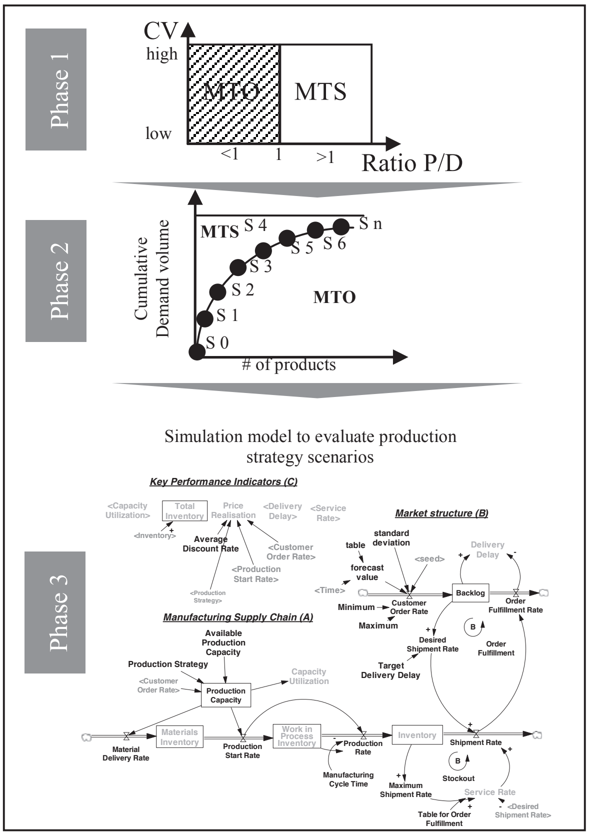

Fig. 3. Methodology to define a production strategy

4.2. Evaluation

This subsection demonstrates the performance of the model when operations follow MTO, MTS or a *hybrid production strategy*. In comparison to MTS, a MTO principle leads to lower inventory levels and a higher price realisation. The *hybrid production strategy* has the same inventory level but a significant higher price realisation as MTS (Figure 4). To achieve a high performance with a MTO production, however, requires that capacities are over-sized to the “worst” case of forecasted customer demand volume per time unit to ensure high market performance (short delivery time and on-time delivery). As a result of the simulation study, the utilization of the available capacity is circa 50% lower when compared to a MTS production (Figure 4).

Furthermore, in practice the capacities and adaptability to changes are limited and costly. A *hybrid production strategy*, where products with volatile demand are dedicated to MTO and those with stable demand to MTS, allows high capacity utilization.

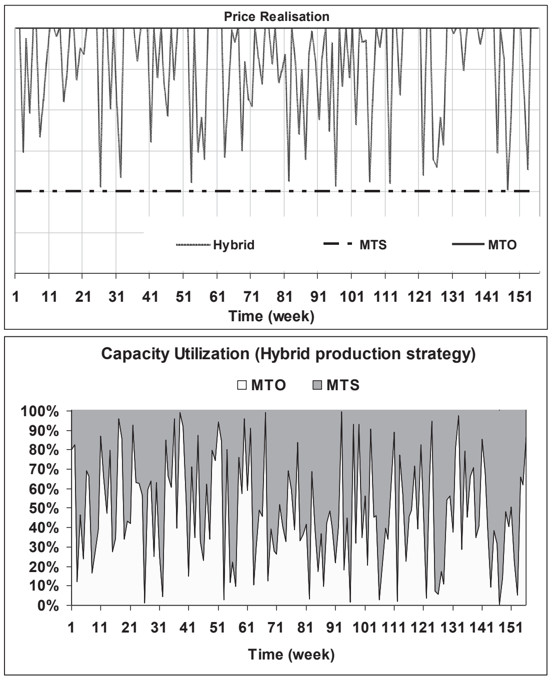

Fig. 4. Comparison of the price realisation and capacity utilization between the MTS, MTO and hybrid production strategy

Compared to the MTS, the final price has been raised about 60% strategy and achieves nearly the same level as the MTO strategy. A disadvantage of a hybrid production system is a higher inventory level than for a MTO strategy. However, this inventory results in an optimized utilization of production capacity and allows sales to sell available standard products. The other two KPI, service rate and delivery time, are stable for all strategies. As a result of the simulation study, a *hybrid production strategy* resulted in the most preferable performance through balancing the respective advantages of MTO and MTS.

In summary, a MTO strategy achieves the highest market and operational performance when the production capacity is not limited and very adaptable. A MTO supply chain requires a high availability of the production capacity in a volatile and seasonal demand environment that is not achievable and uneconomical in industry. Hence, in practice the desired market and operational performance of a MTO production is out of reach. Uncertainty of demand fluctuations or disturbances, however, can be absorbed with standard products, which are dedicated to a MTS strategy. The inventory of products gives the supply chain time to adapt to unforeseen supply chain events (e.g. demand changes, production strikes, supplier issues) within an adequate time span. Based on the Pareto Law, products with low and volatile demand volume have to be classified as MTO and the products with high and stable volume demand are adequate when allocated to MTS. In a nutshell, a *hybrid production strategy* between MTO and MTS, which implies two CODP, achieves a high market and operational performance.

5. Conclusion and Outlook

As a result of this contribution, there will not be a single off-the-shelf solution to define the right production strategy. The authors propose a methodology to evaluate the performance of different production strategies that also considers the dynamics of parameters and capacity constraints. In a perfectly deterministic world, a company would opt for a MTO production strategy by default because it guarantees low inventory levels for manufacturers and highly individual products for customers that are sold at premium prices. However, as it was shown earlier, strategies with late CODP in general and MTS in specific are still the most prevalent production strategies found in industry [1]. They offer, in contrast to MTO, some security against erratic customer demand, supply problems and other disruptive occurrences while still guaranteeing adequate lead times. They are an insurance against unforeseen disturbances and high capacity utilization in the supply chain. If the degree to which a company tends more towards MTO rather than MTS largely depends on the production and market stability that surrounds the examined product, however, then the criteria of the literature review do not capture the full story of the decision between MTO and MTS. As argued in Section 3, there is no doubt that the dynamic of the criteria (e.g. demand volume, capacity limits, etc.) play a very important role. However, it is more important to first examine i) the available capacity and stability of the production processes, ii) the stability of supply processes and iii) customer demand behaviour before considering further criteria. Thus, a holistic view on the supply chain behaviour and the resulting performance for operational and market targets are essential. The elaborated simulation model is a suitable tool to understand the behaviour of a manufacturing supply chain and to simulate the performance of the different production strategies. At the end, the presented *hybrid production strategy* leads to two positions of the CODP: one for MTO products and another for MTS products. Figure 5 illustrates the position of the two CODP in a *hybrid production strategy*.

The results of this contribution help in designing a manufacturing supply chain with volatile and seasonal demand. This production paradigm shift can be envisioned as a concept that utilizes MTS and MTO principles and consequently harnesses their respective advantages. A comparison with similar industrial cases will be relevant to verify the methodology, the generic simulation model and the presented results. Furthermore, the simulation model can be extended with a cost function and evaluated in regard to the required responsiveness for different production strategies. Further research also has to focus on the vulnerability of supply chains, their knock-on effects and their influences on the production strategy.

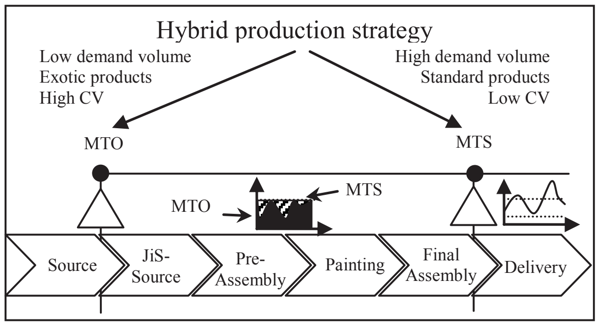

Fig. 5. Positioning of CODPs in a hybrid production strategy

References

[1] Gunasekaran, A., Ngai, EWT, 2005. Build-to-order supply chain management: a literature re-view and framework for development, *Journal of Operations Management 23*, pp. 423-451.

[2] Holweg, M., Pil, F.K., 2004. The Second Century: Reconnecting Customer and Value Chain through Build-to-Order Moving Beyond Mass and Lean in the Auto Industry, *The MIT Press*, Cambridge.

[3] Feitzinger, E., Lee, H.L., 1997. Mass customization at Hewlett-Packard: The power of postponement, *Harvard Business Review 75/1*, pp. 116-121.

[4] Kotha, S., 1995. Mass customization: Implementing the emerging paradigm for competitive advantage, *Strategic Management Journal 16,* pp. 21-42.

[5] Mason-Jones, R., Towill, D.R., 1999. Using the Information Decoupling Point to Improve Supply Chain Performance, *The International Journal of Logistics Management 10/2,* pp. 13-26.

[6] Olhager, J., 2003. Strategic Positioning of the Order Penetration Point, *International Journal of Production Economics 85/3*, pp. 319-329.

[7] Sharmann, G., 1984. The rediscovery of logistics, *Havard Business Review 62/5,* pp. 71-80.

[8] Olhager, J., 1994. On the positioning of the customer decoupling point, *Pacific Conference on Manufacturing, Jakarta*, pp. 1093-1100.

[9] Christopher, M., Towill D., 2001. An Integrated Model for the Design of Agile Supply Chain, *International Journal of Physical Distribution and Logistics Management 31/4*, pp. 235-246.

[10] Heinecke, G., Syntetos, A.A., Wang, W., 2011. Forecasting-based SKU classification, *International Journal of Production Economics*, Available online 23 November 2011, ISSN 0925-5273, 10.1016/j.ijpe.2011.11.020.

[11] Gattorna, J.L., Walters, D.W., 1996. *Managing the Supply Chain – A Strategic Perspective*, MacMillan, London.

[12] D'Alessandro, A.J., Baveja, A., 2000. Divide and conquer: Rohm and Haas' response to a changing specialty chemicals market, *Interfaces 30/6,* pp. 1-16.

[13] Köber, J., Heinecke, G., 2012. The Importance of Managing Events in a Build-to-order Supply Chain – A Case Study at a Manufacturer of Agricultural Machinery, 3rd Int. Conference Dynamics in Logistics. Bremen, Germany, paper #142.