Principles for Real-Time, Integrated Supply Chain Control: An Example from Distribution of Pharmaceuticals

Heidi C. Dreyer, Jan Ola Strandhagen, Anita Romsdal, Annette Hoff

Principles for Real-Time, Integrated Supply Chain Control: an Example from Distribution of Pharmaceuticals

Heidi C. Dreyer[1], Jan Ola Strandhagen[2], Anita Romsdal[1], Annette Hoff[2]

[1] Norwegian University of Science and Technology, Department of Production and Quality Engineering, NTNU – Valgrinda, N-7491 Trondheim, Norway
[2] SINTEF Technology and Society, Department of Industrial Management, S.P. Andersens veg 5, N-7465 Trondheim, Norway
Heidi.c.dreyer@sintef.no, jan.strandhagen@sintef.no, anita.romsdal@sintef.no, annette.hoff@sintef.no

Abstract. This paper investigates how to control an integrated supply chain based on demand-driven principles and sharing of real time information. A set of principles to support a unified supply chain control model is proposed based on theory and previous and ongoing research and illustrated in a case example from the pharmaceutical industry. Essential elements include application of pull-based control principles, automated decision support, advanced visualisation, and automated replenishment concepts. Expected effects include improvement of supply chain speed and reliability, and reduced resource consumption. However, implementation challenges associated with financial, political and trust issues in supply chain relationships remain.

Keywords: Supply chain control, real-time information, demand-driven

1 Introduction

Integrating and coordinating supply chain operations is today widely considered a prerequisite for achieving high efficiency and competitiveness. Focusing on the performance and competitiveness for the supply chain rather than the single company is a trend in several industries. Operating supply chains is challenging due to the heterogeneous system characteristics, the diversified product and material flow structure, the trade-off situations, and the conflicting interests and goals of the participants. Products vary in value, volumes and shelf life. Offering high customer service either means maintaining a high inventory level or frequent deliveries. In order to deal with these trade-off situations and challenges, and to be able to adjust the supply chain according to customer demand, supply chain approaches have become more focused on utilising real-time information and modern information and communication technology (ICT). The research challenge of this paper is therefore *how to control an integrated supply chain – based on the assumption that all relevant information is made available to all partners in real-time.* The objective is to establish a set of principles to be applied in the related control processes. Based on a number of Norwegian research and development (R&D) projects including Automed, Norman, Smart Vareflyt and Origo, this conceptual paper addresses real-time supply chain operations and the control principles which should support a unified and real-time supply chain control model. The scope of the paper is on the replenishment and inventory processes of the supply chain and on how these should be integrated with the manufacturing and retailing processes. The paper builds on a concept for intelligent and real-time supply chain control and proposes a number of principles which are illustrated through a case supply chain in the pharmaceutical industry.

2 Methodology

This paper combines the insights from an R&D project called Automed with practice and theory from operations management, logistics and supply chain management (SCM). Data from the case has been gathered through personal participation, observation, discussions with industrial and academic participants, project reports and presentations, secondary documentation, other R&D projects, and relevant literature. Following an action research strategy building on the perspectives of Coughland and Coghlan [1] and Greenwood and Levin [2], focus and activities in the project were determined and carried out in close cooperation between practitioners and researchers based on the specific challenges facing the participating organisations and their supply chain. New solutions in the project were developed using the *control model methodology* (Alfnes, 2005). A control model is a formalised way to describe the material and information flows in a supply chain and can be used as a foundation for reengineering and improvement processes. The model describes resources, materials, information, processes, organisation, and the detailed principles and rules used to control material flows. The control perspective describes how operations are organised and controlled in manufacturing and distribution, outlining control principles and methods, main processes, buffers/inventories, operations areas, and material and information flows. Initially, an AS IS control model describing the starting point for the supply chain was developed in order to make all involved actors aware of and agree on the structures and policies currently used to control the supply chain. After an analysis of the AS IS control model and a mapping of improvement opportunities, a TO BE control model was collaboratively developed specifying how the supply chain could be controlled in the future.

3 Theoretical Background

Supply chain operations extend the control span and increase the complexity of the planning and control task which emphases the need for coordination, integration and collaboration among companies. A holistic and unified manufacturing planning and control (MPC) approach should therefore be applied in order to guide the flow of products and information through the supply chain. The MPC task in a supply chain involves determining what, who, when and how to act in order to meet customer demand with exact supply in a coordinated chain [3, 4]. Each node in the chain cannot be managed in isolation [5], and the MPC system must support cross-company processes in a manner that avoids increasing amplifications, inventory levels, and lead and response times [6]. Most planning and control systems used in supply chain operations today are based on the traditions of make-to-stock (MTS) and MRP/MRP II, where forecasts and expectations of future demand are the main inputs [7]. Additionally, the main planning and control logic of ERP systems is still based on aggregation, optimal batch sizes, order quantities, transport frequencies, sequencing, etc. [8]. The consequences are that a number of supply chain operations are decoupled from actual end customer demand and that inventories are used as a buffer against uncertainty and fluctuating demand.

The next generation supply chain MPC models, however, are derived from the principle of sharing demand information with all actors in the supply chain, changing the planning and control processes towards more make-to-order (MTO) strategies. Access to and sharing of information contributes to reduced demand variability and uncertainty in the supply chain and consequently reduction of the bullwhip effect. The more actors in the supply chain that have an undistorted and near real-time view of the consumer buying behaviour, the more responsive the supply chain as a whole is [9].

In order to develop demand-driven MPC models, several models for orchestrating supply chain and network activities have developed. The aim of models such as collaborative planning, forecasting and replenishment (CPFR), vendor managed inventory (VMI) and automated replenishment programs (ARP) is to achieve seamless inter-organisational interfaces by specifying control principles and operations models for the flow of materials and information [see e.g. 10, 11, 12]. The main principle is to tie and adjust network operations to customer demand and MTO strategies instead of the traditional forecast and MTS approaches.

The ability to utilise real-time information in supply chain operations will be a significant contributor to improving performance. Real-time information in this context refers to immediate and continuous access to information without time lag. An important enabler for the realisation of real-time supply chain operations will be technology such as radio frequency identification (RFID), sensor technology and Electronic Product Code Information Services (EPCIS). Performance monitoring is essential to ensure efficient optimization of operational processes and over the last few years focus has shifted to incorporate a supply chain perspective [e.g. 13, 14]. Supply chain performance measurement requires a consistent and comparable holistic hierarchy of indicators, based on agreed upon strategies, performance targets and priorities. Both reactive and proactive indicators are required [15, 16].

Methods and tools for advanced decision support have seen tremendous developments over the last decades [17], supporting decision makers in strategic, tactical, and operational decision making [18]. Common for these applications is that they are still mainly used off-line, creating plans daily or hourly. As data processing capabilities are constantly increasing, and modelling capability pushed forward by research achievements, the possibilities for on-line and automated decision support based on real-time information is increasing. Recently, so-called automated decision systems have appeared, making decisions in real-time after weighing all the relevant data and rules [19]. Such systems often make decisions without human intervention and are used for decisions that must be made frequently and very rapidly, using on-line information [19]. Opportunities for decision support with a very short (immediate) planning horizon include [20]: improving deployment of finished goods inventory, minimizing transportation costs, real-time tentative rescheduling of production and reconfiguring of orders to meet date requests.

Building on theory and previous research a number of elements have been identified as essential in the creation of real-time and demand-driven supply chains. In order to capture a more holistic picture of supply chain planning and control that will support future developments in industrial business cases a conceptual framework and methodology for intelligent and demand-driven supply chain control have been developed. The main elements of the concept are shown in Fig. 1.

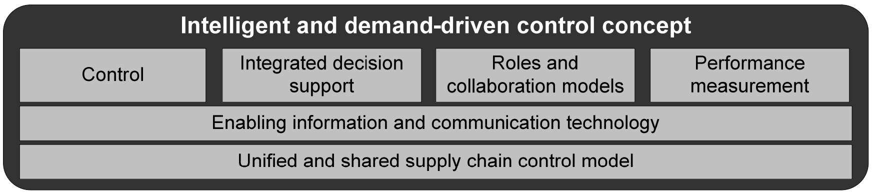

Fig. 1. Concept for intelligent and demand-driven supply chain control [adapted from 21]

4 Example: The Automed Supply Chain

In the following, the simplified case of a supply chain in the Norwegian pharmaceutical/pharmacy industry is used to illustrate the control concept described in Fig. 1, leading to a set of principles for its realisation. The case stems from a three-year R&D project called Automed (automated replenishment of medicine), which ended in 2008. The project's objectives included development of a control model for automatic replenishment from manufacturer through wholesaler to pharmacies and a control dashboard prototype.

Norwegian pharmacy legislation is among the most liberal in the world, and a new law in 2001 opened up for extensive vertical and horizontal integration. Today, the Norwegian pharmacy market consisting of approx. 500 pharmacies is dominated by three pharmacy chains – which are each owned by three major European wholesalers. Thus, the wholesaler and pharmacy chain in the Automed supply chain are owned by the same European group. The manufacturer is among the world's largest pharmaceutical suppliers and manufactures most products for the Norwegian market in a plant located near Oslo. The plant makes prescription and non-prescription drugs (tablets, mixtures, sprays, lotions, etc.), skin care products and other commercial goods sold in pharmacies, in total 750 different finished goods. The wholesaler keeps an inventory of approx. 10.000 stock keeping units (SKU), which are distributed to pharmacies in the retail chain nationwide from a warehouse in the Oslo area. Each of the approx. 140 pharmacies in the chain typically carries approx. 3-4.000 SKUs.

At the start of the project each pharmacy manually placed daily orders to the wholesaler, for delivery the next day. Orders were mainly based on daily sales and current inventory levels. The wholesaler manually placed orders with the manufacturer once a week, for delivery one week later. Orders were based on historic sales to pharmacies, forecasted demand and current wholesaler inventory levels. Manufacturing was MTS based on forecasted demand from wholesalers and current levels of finished goods in inventory. Orders for raw materials typically had a lead time of three months and were placed monthly.

A number of challenges faced the supply chain actors in Automed at the start of the project. Some were results of government regulations, while others were a result of sup-optimisation and a lack of overall supply chain control. Main challenges related to supply chain operations included traditional MTS and batch manufacturing, large inventories at wholesaler level, low ingoing service levels from manufacturers to wholesaler, limited flexibility in manufacturing due to strict government regulations regarding approval of manufacturing batch sizes, long lead and throughput times, very little value creating time, limited information sharing between actors, little focus on logistics parameters in performance measurement, and high administrative costs in order handling, purchasing and forecasting. During the project, a number of possible improvements to the AS IS situation were identified and a unified supply chain control model containing principles and decision rules for real-time integrated supply chain control was collaboratively designed. Table 1 illustrates a number of principles applied in the design of this TO BE model. Some of these were implemented during the project, while others reflect the ideal control model for the Automed supply chain.

Table 1. Principles for TO BE control in the Automed supply chain

	Topic and main principle
1	Real-time information: fixed-frequency, manual order placement and confirmation replaced by automated replenishment and shipping based on real-time information on point-of-sale (POS) data, inventory levels, marketing plans and transport status.
2	Placement of CODP: CODP at manufacturer moved back to packing with replenishment of wholesaler based on POS, downstream inventory levels and marketing plans.
3	Pull and product based control: manufacturing and shipment based on principle of “buy one – produce and deliver one”. Control by product, demand and market characteristics.
4	Replenishment responsibility: wholesaler responsible for pharmacy replenishment, manufacturer responsible for replenishment of wholesaler.
5	Automation and decision support: traditional purchasing and order fulfilment replaced by automated replenishment systems. Human decision making changed to status monitoring and exception handling facilitated by a supply chain control dashboard.
6	Roles and cooperation: roles in sales, marketing, forecasting and replenishment organised by product groups. Cooperation within product groups across company boarders.
7	Information availability: a supply chain control dashboard established for collection, communication and visualisation of relevant information from all actors. Companies can access information on appropriately aggregated levels for all participants in the chain.

Some of the elements of the TO BE control model are illustrated in Fig. 2. The most important changes involved replacing the traditional forecast-based control principles with integrated supply chain control based on real-time information on end-customer demand, inventory levels and marketing plans. Other key changes include the elimination of a number of administrative processes and the integration of IT systems across the supply chain, made possible through a supply chain dashboard.

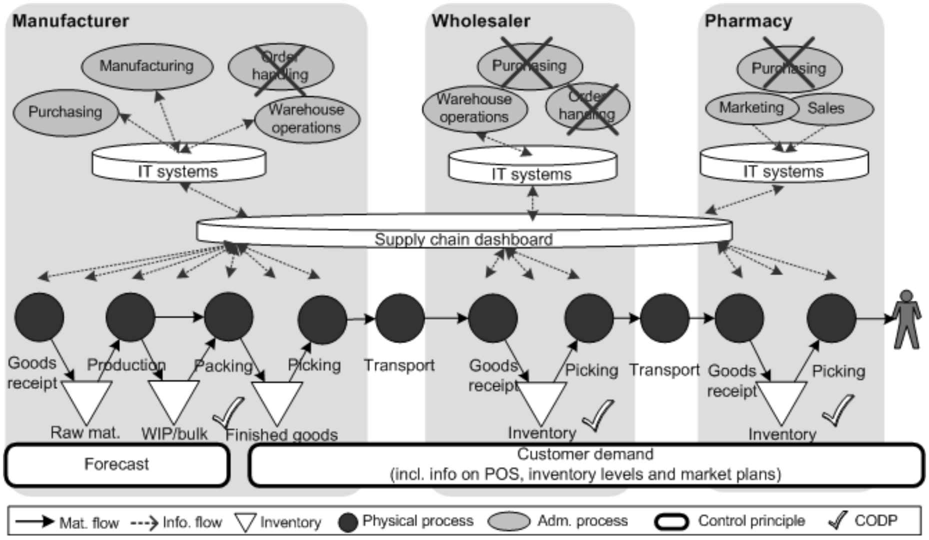

Fig. 2. TO BE control model in the Automed supply chain

5 Discussion

In terms of achievement of research objectives, the Automed project was considered successful. Important improvement areas were identified and solutions developed in order to increase integration and the use of real-time demand information to better balance demand and supply. Knowledge and new insights enriched the organisations, the relationship between the companies was strengthened and the understanding of the dynamics of the supply chain was increased.

Although the proposed solutions are technically possible to implement today, a number of other implementation challenges were identified related to the companies' interests and motivation for entering into such extensive supply chain collaboration. Implementing a new control concept such as the one proposed in this paper would require changes to a number of company processes, considerable capital investments, training and other changes that could be perceived as threatening to the companies' commercial interests and competitive advantage. Financial, political and trust issues of supply chain collaboration are well known and require development of solutions where benefits and costs are fairly distributed among the participants. Even though all participants agreed that the new control model would have led to major improvements for each company and the entire supply chain, the proposed model was not implemented. An essential element of this was the project's failure to achieve its ambition of utilising POS information in manufacturing operations control. From a scientific point of view the lack of follow-through of such implementation initiatives is an interesting aspect worth reflection.

The proposed supply chain control model assumes that real-time demand information is captured, distributed and shared among participating companies so that companies further up the supply chain gain insight into the needs of the end customer.

This would improve the manufacturing and supply processes and provide a better balance between demand and supply. At least two critical aspects related to this were identified. Firstly, the wholesaler, represented through its marketing function, was highly unwilling to make market information available to its suppliers. Sharing of this type of information was considered to weaken the wholesaler's bargaining position. Secondly, the manufacturer had limited knowledge on how to utilise real-time demand information in improving its internal planning and control processes.

Another implementation obstacle was the structure of the manufacturing industry. The vast majority of pharmaceutical manufacturers are dominant actors operating on a global scale supplying heterogeneous markets. For some products and markets the MTS model is most efficient, while for other segments a MTO model would be more appropriate. Also, the proposed control model assumes a VMI type principle where the manufacturer is responsible for the replenishment process, involving a new planning paradigm, a number of new processes and investment in ICT solutions; changes which were difficult to justify in a small market such as Norway.

6 Conclusion

This paper has demonstrated how a unified supply chain control model based on application of real-time information and changes in manufacturing operations can improve supply chain efficiency. The main contribution is the set of principles for real-time operations of supply chains. These principles have been demonstrated through a case within the pharmaceutical industry, showing the potential for improving speed and reliability of the supply chain, combined with reduced resource consumption for the administrative processes and reduced inventory levels.

The paper has not described the implementation challenges related to these issues in detail, nor are the potential effects measured and evaluated as a part of this research. These are two of the main research areas still to be pursued. A third issue for further research is the development of the detailed rules and algorithms for control as an integral part of the automated decision support facilities. A final challenge is that of integrating the control model description into the ICT architecture and infrastructure in the form of a fully operational supply chain dashboard.

7 Acknowledgements

The research in this paper was financed by the Norman project (see www.sfinorman.no) and the Research Council of Norway.

8 References

1. Coughlan, P. and Coghlan, D., Action Research for Operations Management, in Researching Operations Management, C. Karlsson, Editor. 2008, Taylor & Francis: New York, NY.

2. Greenwood, D.J. and Levin, M., Introduction to Action Research: social research for social change. 2nd ed. 2007, Thousand Oaks: Sage Publications.
3. Jonsson, P. and Lindau, R., The supply chain planning studio: utilising the synergic power of teams and information visibility, in NOFOMA annual conference for Nordic researchers in logistics: Promoting logistics competence in industry and research, O. Solem, Editor. 2002, Norwegian University of Science and Technology: Trondheim, Norway. p. 115-130.
4. Vollmann, T.E., et al., Manufacturing Planning and Control for Supply Chain Management. McGraw-Hill, Boston, 2005.
5. Shi, Y. and Gregory, M., International manufacturing networks - to develop global competitive capabilities. Journal of Operations Management, 1998. 16(2, 3): p. 195-214.
6. Dreyer, H.C., et al., Global supply chain control systems: a conceptual framework for the global control centre. Production Planning & Control, 2009. 20(2): p. 147-157.
7. Zijm, W.H.M., Towards Intelligent Manufacturing Planning and Control Systems. OR Spektrum, 2000. 22: p. 313-345.
8. Alfnes, E. and Strandhagen, J.O., Enterprise Design for Mass Customization - the Control Model Methodology. International Journal of Logistics, 2000. 3(2).
9. Mason-Jones, R. and Towill, D.R., Using the Information Decoupling Point to Improve Supply Chain Performance. The International Journal of Logistics Management, 1999. 10(2): p. 13-26.
10. Daugherty, P.J., Myers, M.B., and Autry, C.W., Automatic replenishment programs: an empirical examination. Journal of Business Logistics, 1999. 20(2): p. 63-82.
11. Sabath, R.E., Autry, C.W., and Daugherty, P.J., Automatic replenishment programs: The impact of organizational structure. Journal of Business Logistics, 2001. 22(1): p. 91-105.
12. Mattsson, S.-A. and Jonsson, P., Produktionslogistik. 2003: Lund, Studentlitteratur.
13. Chan, F.T.S. and Qi, H.J., Feasibility of Performance Measurement System for Supply Chain: A process-based approach and measures. Integrated Manufacturing Systems, 2003. 14(3): p. 179-190.
14. Lapide, L., True Measures of Supply Chain Performance. Supply Chain Management Review, 2000. July/August: p. 25-28.
15. Bititci, U.S., Turner, T., and Begemann, C., Dynamics of Performance Measurement Systems. International Journal of Operations & Production Management, 2000. 20(6): p. 692-704.
16. Neely, A., et al., Performance Measurement System Design: Developing and Testing a Process-Based Approach. International Journal of Operations & Production Management, 2000. 20(10): p. 1119-1145.
17. Power, D.J., Decision Support Systems: Concepts and Resources for Managers. 2002, Westport, Connecticut: Quorum books.
18. Simchi-Levi, D., Kaminsky, P., and Simchi-Levi, E., Designing and Managing the Supply Chain. Concepts, Strategies, and Case Studies. 3rd ed. 2008, Boston, Massachusetts: McGraw-Hill/Irwin.
19. Turban, E., et al., Decision support and business intelligence systems. 2007, Upper Saddle River, N.J.: Pearson/Prentice Hall. XXVIII, 772 s.
20. Sodhi, M.S., Applications and opportunities for operations research in internet-enabled supply chains and electronic marketplaces. Interfaces, 2001. 31(2): p. 56-69.
21. Bjartnes, R., et al., Intelligent and Demand Driven Manufacturing Network Control Concepts, in The Third World Conference on Production and Operations Management, JOMSA, Editor. 2008: Tokyo, Japan.