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REAL-TIME, INTEGRATED SUPPLY CHAIN OPERATIONS: AN EXAMPLE FROM DISTRIBUTION OF PHARMACEUTICALS

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ABSTRACT

Integrating and coordinating supply chain operations is today widely considered a prerequisite for achieving high efficiency and competitiveness. This paper focuses on real-time control of integrated supply chain operations. A case from the pharmaceutical industry is used to illustrate the challenges of supply chain operations, and how control based on real-time information can be applied to improve performance, and reduce inventory and resource consumption in the supply chain. A set of principle for the development of real-time, integrated supply chain operations is developed and described based on the control model methodology.

INTRODUCTION

Integrating and coordinating supply chain operations is today widely considered a prerequisite for achieving high efficiency and competitiveness. Focusing on the performance and competitive situation for the entire supply chain rather than a single company is a trend in several industries. The supply chain perspective implies an increased need for orchestrating a broad set of activities, resources and companies, often with decentralised geographical structure and high complexity (Busi and Dreyer, 2004; Chopra and Meindl, 2007; Cooper and Gardner, 2003; Jonsson and Mattsson, 2003; Rudberg and Olhager, 2002). Several collaborative models for orchestrating supply chain activities have developed. The aim of these models is to achieve seamless inter-organisational interfaces, and to tie and adjust supply chain activities to demand and customer requirements based on make-to-order principles (MTO). Efficient supply chain control is dependent on access to real-time information that is critical for controlling the flow of products, services and information between suppliers and customers, and recent developments in technology and standards has enabled more efficient solutions for data capturing, storing and sharing in a supply chain setting.

There are few know examples of implementations of fully integrated, real-time collaboration models across several actors in a supply chain. Thus, there is still a need to explore in more detail the underlying principles of such models and their possible application in a real-life setting. This paper highlights the control principles a unified and real-time supply chain control model should consist of, and how real-time information can be applied in order to realise improvements. The scope of the paper is on the planning and control principles involved in the replenishment and inventory process of the supply chain, and on how these should be integrated with the manufacturing and retailing processes. The underlying premise is that all these processes should be highly integrated and based on end customer demand. The application of the proposed principles of an integrated control model is illustrated using a case from the pharmaceutical industry consisting of a manufacturer, a wholesaler and a retail chain.

The paper starts with an overview of the relevant theoretical background from logistics, operations management and supply chain management (SCM) and a brief description of the paper's research methodology. Next, seven principles for an integrated, real-time supply chain control model are outlined and then their application illustrated in a supply chain, before the conclusion sums up the paper's contributions, limitations and suggestions for further research.

THEORETICAL BACKGROUND

A control model for real-time, integrated supply chain operations is enabled through recent developments in a number of areas. The following sections contain a brief overview with regards to supply chain control, collaboration models, real-time information, automated control and decision support, and visualisation.

Supply chain control

In operations of supply chain systems the planning and control process is vital. Planning and control ensures efficient utilisation of resources when fulfilling demand from customers (Vollmann et al., 2005). The aim is to decide how much to produce and deliver when, and how products and information should flow throughout the supply chain, as well as defining processes for monitoring, performance measurement and event management. Important characteristics of supply chain planning and control activities include (Alfnes et al., 2006):

- Control principles; defining main principles for how operations are controlled (e.g. pull, push, ordering)
- Customer order decoupling point (CODP); dividing the supply chain in one part based on forecasts and one part based on customer orders/demand
- Key performance indicators; defining parameters for monitoring and evaluating performance of the supply chain and its actors
- Control/responsibility areas; defining areas or processes that share specific outputs and are controlled as one unit
- Differentiation criteria; defining criteria for identifying products or processes that should be controlled in the same way

Today most of the planning and control systems used in supply chain operations are based on traditions of make-to-stock (MTS) and MRP/MRP where forecasts and expectations of future demand are the main inputs. In addition, economics of scale arguments are frequently used when dimensioning and controlling processes like manufacturing, warehousing and transport. Still the main planning and control logic of ERP-systems is based on aggregation, optimal batch sizes, order quantities, transport frequencies, and sequencing, etc. (Alfnes and Strandhagen, 2000). 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.

Information sharing and utilisation of demand information backwards in the supply chain can be an instrument for both workflow processing and 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 shorter the time span between information generation and utilisation in the planning and control processes, the more value and impact the information will have on the efforts for reducing demand variability. The ability to utilise real-time information in supply chain operations will therefore be a significant contributor for improving performance through the application of new planning and control principles. Real-time information is this context refers to immediate and continuous access to information without time lag.

An important enabler for the realisation supply chain operations based on real-time information will be technology such as radio frequency identification (RFID), sensor technology and Electronic Product Code Information System (EPCIS). These technologies and standards will allow easier access to real-time information than existing solutions. RFID tags can for instance contain information that can be read from a distance, thereby increasing the number of points where data can be obtained throughout the supply chain considerably compared with today's barcode system. Combining RFID technology with sensor technology further enhances the intelligence of such data capturing technologies and will support the development of intelligent and automated planning and control concepts.

Collaboration models

Integrated supply chain operations based on real-time information requires a collaborate environment which builds trust, secure transaction and relationship specific investments, and a unified set of principles for how operations should be performed. Efficient consumer response (ECR), quick response (QR), vendor managed inventory (VMI), collaborative planning, forecasting and replenishment (CPFR), and automated replenishment programs

(ARP) are examples of collaborative models that are based on a unified supply chain approached where the exchange of more or less real-time demand information is a main fundament (Christopher, 2005; Danese, 2006; Sabath et al., 2001; Skjoett-Larsen et al., 2003). Information such as inventory levels, forecasts and plans, point of sales (POS) data, is shared between the customer and supplier and used to estimate future demand in order to prevent stock out situation or excessive inventory.

Supply chain collaborative models are characterised by their reliance on access to and sharing of demand information, and they require formalised control principles for how materials and information should flow between customer and supplier. The models clearly specify how, how much, and when to deliver to the customer, as well as how inventory level information should be shared. Thus, unified control models and the utilisation of demand information are key elements in orchestrating and enabling integrated supply chain operations.

Most of the demand information used in collaboration models is semi-real time information arriving from POS data systems and continuously updated inventory records. With the application of advanced information and data capturing technology, access to real-time information can be created to enable automated supply chain planning and control systems and advanced decision making.

Real-.time information

ICT developments have led to innovations in data capturing technologies such as RFID and information processing systems such as EPCIS (Electronic Product Code Information Systems), BI (Business Intelligence) and more advanced ERP systems. RFID and supporting IT systems make access to a vast amounts of real-time information on material flow and supply chain events possible. As RFID tags today are getting better and cheaper and EPC standards are evolving, new possibilities for using RFID-captured information for planning and controlling supply chain operations in real-time are many. For supply chain control activities this could imply a paradigm shift towards real-time control and decision making, closing the time gap between events and corrective actions.

Automated control and decision support

Methods and tools for advanced decision support have seen tremendous developments over the last decades (Power, 2002), supporting decision makers in strategic, tactical, and operational decision making (Semini et al., 2008; Simchi-Levi et al., 2008). At the operational level, well-known examples include production scheduling included in today's Manufacturing execution Systems (MES), and vehicle routing and scheduling systems within different transport systems. Common for these applications is that they are still mainly used off-line, creating plans daily or hourly. In areas like inventory control the common practice is still the application of simple, product-by-product calculations supporting managers in determining purchase or shipping quantities.

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 (Turban et al., 2007). Such systems often make decisions without human intervention, and they are used for decisions that must be made frequently and very rapidly, using on-line information (Turban et al., 2007). Opportunities for decision support with a very short (immediate) planning horizon include (Sodhi, 2001):

- Improving deployment of finished goods inventory
- Minimising transportation costs
- Real-time tentative rescheduling of production to check whether requested dates for orders can be met
- Reconfiguring orders to meet request dates

Major challenges still exist with regards to setting the right optimisation goals, selecting the and handling the large amount of information, and dealing with uncertain and lacking information, for instance due to less than 100 % reliable track and trace facilities.

Visualisation

Even though formidable amounts of information is created in a supply chain there is still is a challenge related to the utilisation and understanding of the information. Visualising, tracking and managing supply chains becomes all the more complicated as firms pursue outsourcing strategies and delivery systems become increasingly global (Cooper and Gardner, 2003). As humans we are subjected to bounded rationality which means we are endowed with a limited but powerful analytical and data processing apparatus. However, this does not imply irrationality. Instead, although bonded rational agents experience limits in forming and solving complex problems and in processing information, they otherwise remain "intendedly" rational (Williamson, 1981). Thus in order to grasp large and complex amount of information, there is a need for processing instruments and ways to represent and visualise information (Liff and Posey, 2004). Visualising involves graphically representing information in the form of pictures, maps and illustrations in order to clarify and easily abstract, transfer and exchange knowledge. Emphasis should be put on what to visualise, how to visualise, and to clarify the specific information elements and the holistic picture.

METHODOLOGY

The research in this paper was conducted within a perspective where operations management is viewed as a design science – where the focus has been on spotting and solving practical problems (Holmstrom and Främling, 2006) in the setting of a real supply chain. The control model and control principles that are suggested are part of a *satisficing* way forward (March and Simon, 1993), where a supply chain in the pharmaceutical industry is used as an example of a base case to search for new alternatives for how to operate and control the flow of goods and information in a changing technological environment. Based on a view of bounded human rationality (March and Simon, 1993), a number of control principles are proposed that aims at capturing the main features of a control model for integrated supply chain operations without necessarily capturing all the complexities of the specific case.

The information from the example supply chain stems from a three-year user-controlled R&D project in the Norwegian pharmaceutical industry. The project focus and activities were determined in cooperation between practitioners and researchers based on the specific needs of the participating organisations and the entire supply chain. The project provided a detailed study of a real-life situation where the design of an automatic replenishment system based on real-time demand information was in its early stages. During the project, the participating companies and researchers developed the conceptual constructions as a first step towards supply chain cooperation and integration based on real-time information and customer demand. Data was derived using the control model methodology (Alfnes et al., 2006). Solutions were developed through scientific methods (combined action research and case methodology, use of theory, literature, scientific methods for data collection and analysis, etc.), combined with practical knowledge and experiences from the pharmaceutical and pharmacy industry.

This paper combines the insights from the R&D project with practice and theory from operations management, logistics and SCM to contribute towards increased understanding of the supply chain integration problem.

PRINCIPLES FOR REAL-TIME SUPPLY CHAIN OPERATIONS

Meeting the challenges of realising real-time integrated supply chain operations requires focus and development within the following main issues:

- Development of new control principles exploiting the potential of access to real-time information

- Development of real-time information registration/data capturing sources
- Concepts and processes for combining demand information (e.g. POS-data) and inventory level information, automated decision support and creating control information for real-time control of physical flow
- Control models for unification, communication and trust
- ICT as enabling technology; visualisation, track and trace, and automated control of flow based on integrated decision support facilities

In Bjartnes et al. (2008) a concept for intelligent and demand driven manufacturing network control was proposed, of which the main elements are illustrated in Figure 1.

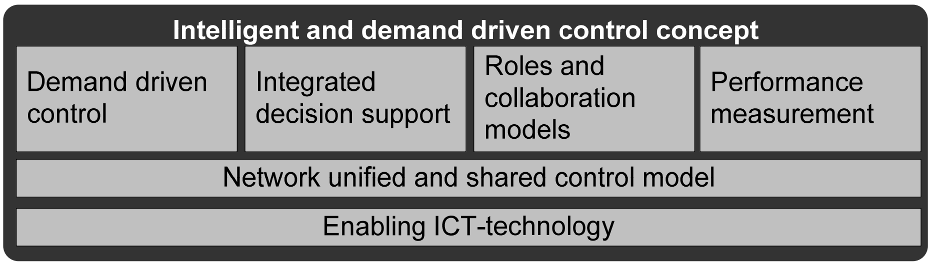

Figure 1: Concept for intelligent and demand driven manufacturing network control (Bjartnes et al., 2008)

Based on this concept and the theoretical background described above, seven principles for real-time, integrated supply chain operations have been developed; see Table 1.

Table 1: Principles for real-time, integrated supply chain operations

1	Replenishment and shipping decisions should be based on real-time information on POS-data, inventory levels, marketing plans and transport status
2	CODP should be moved as far as possible upstream in the supply chain
3	Replenishment responsibility should be moved upstream in the supply chain (supporting VMI concepts)
4	Human decision making in creating purchase order and fulfilling orders should be replaced by surveillance, status monitoring and automated decision support through visual monitoring facilities
5	Responsibilities should be organised by product or product segment instead of function
6	Information hubs should be established to collect, store and present information from the entire supply chain – integrating information from the ICT systems of each actor
7	Unified control model; agreed upon and implemented control principles and decision rules should be documented, visualised and communicated in a common model

A number of elements from the concept for intelligent and demand driven manufacturing network control are essential in the realisation of these principles. The following sections describe important aspects related to demand driven control, integrated decision support, unified and shared network control model, and enabling ICT.

Demand driven control

In order to shorten lead times, reduce inventory levels, increase inventory turnover, and increase market responsiveness, the overall planning and control concept should strive for *"buy one – produce and deliver one"*. Pull and replenishment based solution are therefore an important part of future control concepts for integrated supply chain control. This implies that supply is effectuated based on knowledge of actual demand, and insight into the customer's inventory level. This is in line with concepts like ARP and VMI. What is missing in these concepts today is the use of real-time information automatically captured by for instance RFID and sensor technology. RFID information is continuously captured and stored and is therefore up-to-date and automatically collected and processed, increasing focus on real-time demand information in future control concepts. Real-time planning and control models will differ from the more traditional models in a number of ways:

- Automatic and product individual decision making
- Abandonment of issues of frequency (for order placement)
- Determination of supply quantities based on a holistic perspective (sales, inventory levels, transport routes, substitute products, etc)
- Simultaneous handling of information on history, current status and forecasts

Integrated decision support

The emphasis on intelligence in future control concepts implies that decision support is an integrated part of the control model. This integrated decision support will explicitly address strategic as well as operational uncertainties and risk, and help decision makers cope with the dynamicity and complexity of manufacturing systems through a combination of automatic handling of routine tasks, exception alerts and on-line, real-time simulation capabilities. Systems will be dynamic and react on the continuously updated flow of information from sources such as customers, company specific plans, forecast and sale activities, and RFID systems. Visual, intelligent and interactive information presentation is a key to enable proper comprehension and control in this context.

Unified and shared network control model

The essential task of supply chain planning and control is to efficiently manage the flow of material, the utilisation of people and equipment, and to respond to customer requirements by utilising the own and supplier capacity and resources to meet customer demand. Planning and control across organisational boundaries is a sensitive task due to conflicting interest and objectives (Vollmann et al., 2005). This emphasises the need for a unified design of the control principles, and the planning and control model should be carefully defined in order to avoid conflicting interest.

One approach to developing a common understanding and execution of operations is through the use of an operations model (Alfnes et al., 2006). The operations model can be seen both as a way to structure and formalise operation activities, and as a fundament for reengineering and improvement processes. The model proposes six views regarding enterprise operations that should be mapped and modelled; *resources* (products, components, documents, etc.), *materials* (material flows between resources) *information* (how information is accessed, stored, processed, and transferred), processes, *organisation* (organisational entities, responsibilities and authorities). *Control* is the key perspective of the model, also constituting a fundamental for unified and shared control in demand driven and intelligent control concepts. The control perspective is a representation of how operations are organised and controlled in manufacturing, describing building blocks such as CODP, control principles and methods, main operation processes, operation areas, material flows and information flow (Strandhagen et al., 2006).

Enabling ICT

RFID technology enables automatic and real-time acquisition of data regarding the material flow, which gives access to information vital to the intelligent and demand driven control concept. Planning and control in the supply chain has to be performed in a setting where relevant information from several ICT systems is integrated, up to date, and can be accessed in real-time from anywhere in the network. This information visibility depends on the exchange of critical data required for the efficient management and control of the flow of products, services and related information between members in the supply chain. Each node should ideally be able to see the real-time situation in the supply chain, downstream as well as upstream, from boardroom to shop floor, enabled by automatic data acquisition. Although very few networks have actually achieved information visibility and system integration, these elements are regarded as keys for enabling collaboration and network efficiency.

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 above described control principles. Information about the AS IS and potential TO BE situation in the supply chain has been derived from a three-year R&D project called AUTOMED (automated replenishment of medicine), which ended in 2008. The project's objectives were to develop a control model for automatic replenishment from manufacturer through wholesaler to pharmacies and a control dashboard prototype. The following sections describe the case in general and the situation at the start of the project (AS IS), before the main challenges of the AS IS control model are outlined. Next, the main changes from the application of the above described control principles are highlighted and illustrated as part of a TO BE control model for the AUTOMED supply chain.

Case overview

Norwegian pharmacy legislation is among the most liberal in the worlds, and a new law in 2001 opened up for extensive vertical and horizontal integration. Today, the Norwegian pharmacy market 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 owned by one of the world's largest pharmaceutical suppliers and most of the products for the Norwegian market are manufactured in one plant located in the vicinity of Oslo. The plant manufactures prescription and non-prescription drugs (tablets, mixtures, sprays, lotions, etc.), as well as 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 product variants, 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 variants in inventory.

AS IS control

At the start of the project each pharmacy placed daily orders to the wholesaler, for delivery the next day. Orders were mainly based on daily sales and current inventory levels. The wholesaler 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 make-to-stock 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. Figure 2 illustrates a simplified version of the AS IS control model for the supply chain.

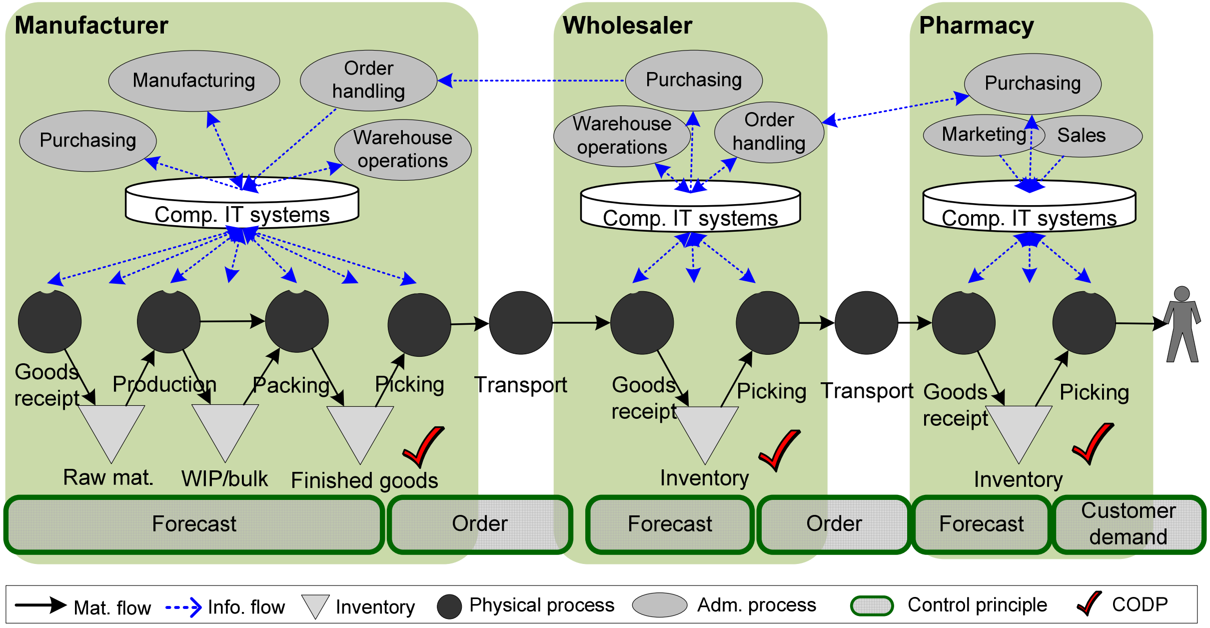

Figure 2: AS IS control model in the AUTOMED supply chain

Challenges

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 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 (typically nine months from raw material to consumption), 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.

TO BE control

During the project, a number of possible improvements to the AS IS situation were developed. Table 2 describes how each of the principles in Table 1 was addressed through a new control model for the supply chain. Some of these were implemented during the project, while others reflect the ideal real-time, integrated control model for the AUTOMED supply chain.

Table 2: Principles for TO BE control in the AUTOMED supply chain

1	Fixed-frequency, manual order placement and confirmation replaced by automated replenishment and shipping based on real-time information of POS, inventory levels, marketing plans and transport status
2	CODP at manufacturer moved back to packing (no government regulation on batch sizes in packing). Replenishment of wholesaler inventory based on information on POS, downstream inventory levels and marketing plans.
3	Wholesaler responsible for pharmacy replenishment, manufacturer responsible for replenishment of wholesaler.
4	Traditional purchasing and order fulfilment replaced by automated replenishment systems. Human decision making changed to status monitoring and exception handling facilitated by supply chain control dashboard
5	Roles in sales, marketing, forecasting, replenishment organised by product groups. Extensive cooperation within product groups across company boarders.
6	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 regarding POS-data, inventory levels, marketing plans and transport status for all participants in the chain.
7	The agreed upon TO BE control model containing principles and decision rules for the entire supply chain established, documented (text, illustrations, ICT systems) and communicated.

Some of the elements of the TO BE control model are illustrated in Figure 3.

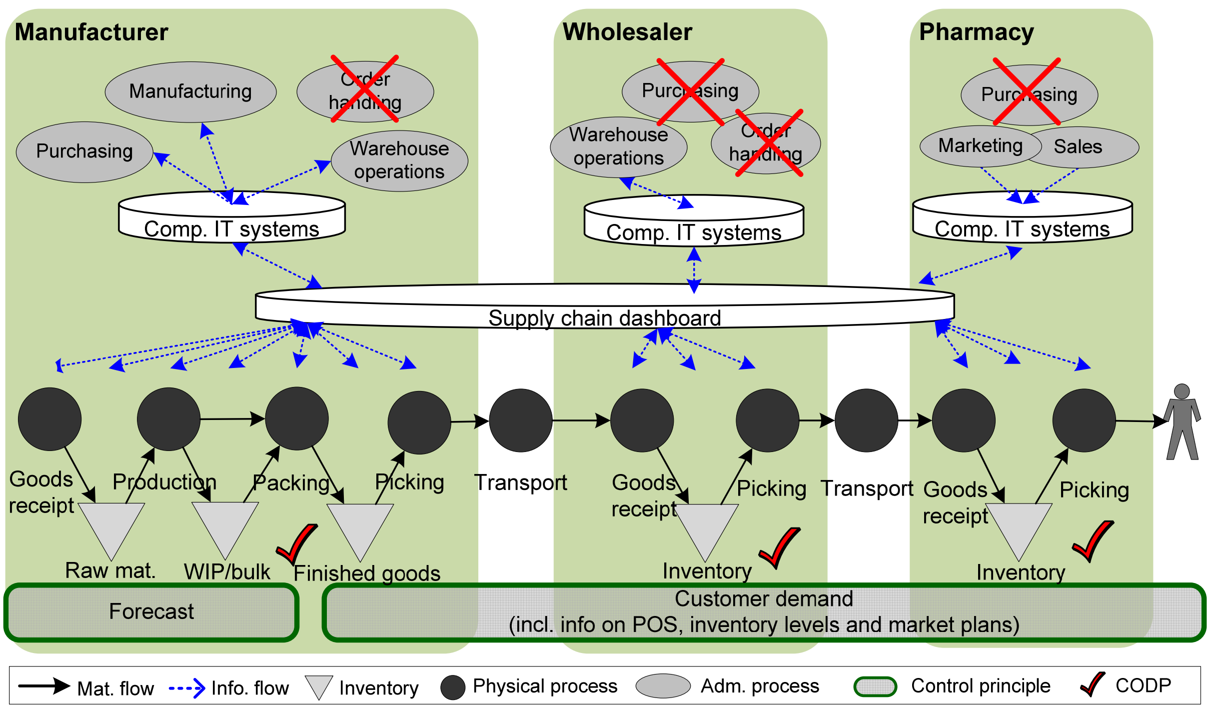

Figure 3: TO BE control model in the AUTOMED supply chain

SUMMARY REMARKS AND FURTHER RESEARCH

In this paper we have described some of the challenges related to supply chain operations and pointed to the potential effects of using real-time information to improve control. We have pointed to integration along the supply chain as an important requirement for success. The real-time integration should be supported by automated decision support systems and advanced visualisation facilities, preferably in the form of a control studio concept or dashboard.

The main achievement is the development of a set of principles for real-time operations of supply chain. These principles have been demonstrated through a case within the pharmacy industry, showing the potential of improving speed and reliability of the supply chain, combined with reduced resource consumption for the administrative processes and reduced inventory levels. The description of the AS-IS and the TO-BE situations in the paper are based on the control model methodology. This methodology was also applied in the case companies as a means to communicate and create understanding among the partners in the supply chain.

The paper has not described the implementation challenges related to these issues, nor are the detailed effects measured and evaluated as a part of this ongoing 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 information, named the supply chain dashboard.

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