

Networked inventory management systems: materializing supply chain management

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Networked inventory management information systems: materializing supply chain management

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Introduction

This article discusses the driving forces for networked inventory management and outlines information systems for this particular type of supply chain management. While logistics management is concerned with the planning, implementation and control of the movement of physical objects and associated information in general[1], supply chain management focuses on the ultimate customer, who creates the demand, which in turn supports the existence of the supply chain to provide the customer with the product[2]. Supply chain management is defined as an integrative approach to dealing with the planning and control of total materials flow from suppliers to end-users[3]. The concept encompasses several fields, such as inventory management, operations management and capacity management. In this article we will elaborate on the inventory management issue, which is in line with the statement that supply chain management is an integrative approach to using information to manage inventory throughout the channel, from source of supply to end-user aiming at improved customer service at reduced overall costs[2].

Our contribution to the supply chain management research aims at the development of so-called networked inventory management information systems (NIMISs). Those are information systems for integral inventory management across networked organizations. For this networked inventory management, information systems are vital resources, because huge amounts of complex information have to be transformed, stored and communicated inside and across the co-operating organizations. So far, the research into supply chain management has mainly resulted in global concepts, because the broad perspective and coverage of supply chain management make the subject difficult to study[2]. By concentrating on NIMISs, we intend to elevate the research from global concepts to some tangible information systems for inventory management in practice.

The first objective of this article is to explain the driving forces for networked inventory management. For that purpose, we will discuss major developments with respect to customer requirements, networked organizations

and networked inventory management. Our second objective is to present high-level specifications of NIMISs. To that end, we will first review some decision systems for inventory management and compare traditional inventory management to networked inventory management. These insights are then used to outline NIMISs for several types of inventory management decision systems. Finally, we will summarize the results of our study and provide an outlook on further research.

Driving forces for networked inventory management

Increasing customer requirements result in the need for networked organizations, which in turn leads to the opportunity of networked inventory management. These three interrelated developments make up the driving forces for networked inventory management and are explained below.

Increasing customer requirements

The trend of increasing customer requirements can be explained by stronger competitive pressures due to the world-wide phenomenon of the opening of markets. More and more markets have been liberalized in recent years, resulting in a global marketplace with increased competition. Because of falling trade barriers, manufacturers, wholesalers and retailers experience the entrance of new players in regional markets, who either have their origins in the region or come from abroad. In the open markets just one superior performer can raise the competitive threshold for companies around the world, while good performers drive out the inferior, because the lowest price, the highest quality, the best service available from any one of them soon becomes the standard for all competitors[4]. Competitive pressures are now forcing all major firms to become global in scope, to decrease time to market, and to redouble their efforts to manage risk, service, quality and cost on a truly international scale[5]. Competitive pressure in a global marketplace has greatly altered the nature of customer choice, as Japanese producers have shown that it is possible, indeed essential, to compete on price, quality, delivery lead time and reliability simultaneously, and that the reward for doing so is vastly increased market share[6]. The intensified competition, as a consequence of the opening of markets, has in turn influenced the balance of power in supply chains.

The increased competition between the numerous players in the open markets has resulted in a relative shift of power from suppliers to customers. The previous “seller’s market” has turned into the current “buyer’s market”. In this new situation customers tell suppliers the specifications of the products they need, the delivery dates they accept and the prices they allow. Customers demand products and services designed for their unique and particular needs, so the mass market has broken into pieces, some as small as a single customer[4]. In consumer goods especially, customers like to be offered a wide choice of items, easily available at attractive prices and certain to perform to specification[6]. These increased customer requirements have forced the market players to improve their customer service and to shorten their product life

cycles[5]. In general, both higher customer service and greater product variety are observed, while prices are not allowed to rise. These increased customer requirements have led to increased complexity of processes[7], which is hard to deal with for a single organization. To meet the increased customer requirements networked organizations emerge.

Need for networked organizations

Current organizational concepts may be hopelessly inadequate to meet the challenges of the turbulent environments ahead[8]. New organization forms, including strategic partnerships and networks, are replacing simple market-based transactions and traditional bureaucratic hierarchical organizations[9]. A networked organization is an organization (company or business unit) with its own strategic control unit, that co-operates with other organizations, on the tactical and operational level, within its strategic constraints, in order to gain mutual benefits. A network in this context refers to two or more organizations involved in long-term relationships, which due to the intensity of their interaction, constitute a subset of one or several markets[10]. Such an inter-organizational network is the intermediate between on the one hand the vertical integrated, single firm and on the other hand the open market. Networked organizations have much in common with value adding partnerships and lean enterprises. A value adding partnership (VAP) is a set of independent companies that work closely together to manage the flow of goods and services along the entire value-added chain[11]. The lean enterprise is a group of individuals, functions, and legally separate but operationally synchronized companies[12], in which "lean" means that it uses less of everything compared with mass production[13]. Characteristic for these networked organizations is the sharing of, among others goals, decision making, responsibility, accountability and trust[5]. As customers and suppliers feel increasingly comfortable with the idea of co-destiny, relationships of trust are likely to develop[14].

The networked organization is regarded as a promising alternative to withstand the changing business conditions. The network paradigm is built around the assumption that small is better, that each part or process or function should be the responsibility of a specialized, independent entity, effectively organized and managed, that has world class competence[9]. Networks are key to managing effectively the interdependence across organizations, that in turn is needed to improve performance areas such as service, quality and cost[5]. Because networks of co-operating organizations take the best of both market and hierarchy, they are capable of managing the additional complexity of business processes that is associated with increased product variety, higher customer service levels and affordable prices. The power of the networked organization (VAP) is undeniable as it combines the co-ordination and scale associated with large companies with the flexibility, creativity and low overhead usually found in small companies[11]. As the networked organizations aim at a continuous value stream that creates, sells, and services

a family of products, the performance of the whole can be raised to a dramatically higher level[12]. After all, the co-operation between organizations in a network is a means for the individual companies and business units to survive the increased competition. Ideally, the networked organizations form a virtual corporation, in which the goal of suppliers will be to produce products instantaneously in response to customer demand, so that producers will have no finished goods inventory[14]. This brings us to the opportunity of networked inventory management.

Opportunity of networked inventory management

Networked inventory management is the integral management of inventories in the stock points and intermediate processes that are spread out over different networked organizations. These stock points and intermediate processes in a network together make up the supply chains through the networked organizations. Networked inventory management deals with the inventory aspect of supply chain management in the domain of networked organizations. Based on the discussion on supply chain management and networked organizations presented earlier, networked inventory management can be described as the integrative approach to the planning and control of inventories in the supply chains through a network of co-operating organizations, from source of supply to end-user, focusing on the ultimate customer demand, aiming at improved customer service, higher product variety and lower costs.

Networked inventory management is one of the opportunities for networked organizations to gain mutual benefits. It is an old truth that inventory management may be the decisive factor in determining whether a firm makes profits or losses[15]. In general, supply chains are plagued by three sources of uncertainty: supplier performance, manufacturing (and distribution) process and customer demand[16]. These uncertainties have to be managed effectively to meet the increased customer requirements. For that purpose networked organizations can apply networked inventory management. Supply chain management across networked organizations is a promising field of co-operation. A European-wide study commissioned by the Coca-Cola Retail Research Group Europe showed that by a fully collaborative relationship between just suppliers and retailers the supply chain cost for European grocery retailers could be reduced from about 9.5 per cent to 7.5 per cent of retail sales[17]. Even more spectacular effects are attainable, because the more complex the network of suppliers, manufacturers and distributors, the more operational efficiencies can be gained by attending to networked inventory management[18].

Networked inventory management requires a lot of information processing within and between the networked organizations. The transformation, storage and communication of information about the inventory in the stock points and in the intermediate processes across the network is highly complex. Therefore, automated information systems are essential to succeed in networked inventory management. Because of the typical features of networked inventory

management, as compared to traditional inventory management within organizations, special information systems for networked inventory management are needed. In the remainder of the article we will present some high-level specifications of these so-called networked inventory management information systems (NIMISs).

Inventory management decision systems

In our study of networked inventory management, we distinguish between decision systems and information systems. A decision system represents the mathematical logic for inventory management, while an information system refers to the computers (hardware, software and communication facilities) that process the information according to the rules specified in the decision system. As compared to traditional inventory management, networked inventory management requires special information systems, because the information processing has to be distributed over the networked organizations. However, the decision systems that are valid for traditional inventory management, may also be applied in networked inventory management. For that reason, we will discuss four major inventory management decision systems that are applied in traditional inventory management:

- (1) Statistical inventory control (SIC).
- (2) Base stock control (BSC).
- (3) Materials and distribution requirements planning (MRP/DRP).
- (4) Line requirements planning (LRP).

Statistical inventory control

Statistical inventory control (SIC) systems manage the inventory level of a single stock point by coping with probabilistic demand. The four most common SIC systems are: (s, Q), (s, S), (R, S) and (R, s, S)[19]. The inventory level of a stock point is the inventory on hand plus the inventory on order minus the backorders. In the (s, Q) system a fixed quantity Q is ordered whenever the inventory level drops to the reorder point s or lower. In the (s, S) system a variable replenishment quantity is ordered when the inventory level drops to the order point s or lower, to raise the inventory level to order-up-to level S. In the (R, S) system every R units of time (periodic review) enough is ordered to raise the inventory level to the order-up-to level S. The (R, s, S) system is a combination of (s, S) and (R, S) systems. If the inventory level is below the reorder point s at the moment of review, enough is ordered to raise the inventory level to the order-up-to-level S.

A SIC system makes replenishment decisions based on the costs, lead times, service and forecasts of its own stock point[19]. A SIC system ignores the implications of decisions at one stock point for the inventory levels of other stock points. Moreover, replenishment orders tend to become progressively larger and less frequent further upstream in the supply chain. As a result it

takes a long time before changes in customer demand influence the behaviour of upstream stock points.

Base stock control

Base stock control (BSC) systems make use of the principles of the base-stock system[20], in which each stock point in the supply chain works against actual customer demand rather than against demand generated by replenishment orders from the next downstream stock point in the supply chain[19]. Instead of managing the local inventory level, BSC systems manage the integral inventory level of a stock point. The integral inventory level or echelon stock is the inventory on hand (and on order) in the stock point plus the inventory on hand in, and in transit between (on order in), all downstream stock points[21,22]. BSC systems reorder as soon as the integral inventory level drops below the base stock level, that is the norm for the integral inventory level. The most common type of BSC system is an (s, S) system, in which enough is ordered to raise the position to the base stock level S, when the integral inventory level is lower than s[19].

BSC systems are a response to the problems associated with SIC systems. In BSC systems ordering decisions at any stock point in the supply chain are made as a result of customer demand, while SIC systems trigger on orders from the next downstream stock points. There is much less variability in the customer demand than in the next downstream stock point ordering[23]. Hence, as compared to SIC systems, significantly lower safety stocks are achieved by BSC systems[19].

Materials/distribution requirements planning

Materials requirements planning (MRP) systems manage inventory in supply chains with the help of time-phased inventory levels. An MRP system consists of a set of logically related procedures, decision rules, and records designed to translate a master production schedule into time-phased net requirements and the planned coverage of such requirements for each stock point[24]. MRP systems begin with a master production schedule that provides the timing and quantities of production of all end-products[19]. With the help of the bill of materials a series of gross requirements by time period is generated for components. Then, the existing inventory levels are allocated against the gross requirements to produce a time series of net requirements. Next, the net requirements are translated to planned receipts. Finally, these planned receipts are backed off over the lead time, resulting in planned order releases. These planned order releases are translated to gross requirements for the next lower component level in the bill of materials. For the next level, the gross requirements are used to derive stepwise the planned order releases, and so on.

MRP systems seek to overcome the weaknesses of traditional decision systems in a manufacturing environment. MRP systems make use of the dependent nature of demands for components, they take into account the time varying nature of the requirements and they co-ordinate stock points that deal

with the same operation[19]. With the explosion of planned orders, MRP systems make the gross requirements known for the upstream stock points, but not the information which led to these dates and quantities. Furthermore, in a stochastic environment MRP is too rigid, resulting in nervousness of plans and rapidly decreasing performance as soon as the environment becomes uncertain[22].

Distribution requirements planning (DRP) systems are twins of MRP systems. DRP is simply the application of the MRP principles and techniques to the management of inventories in distribution[25]. In DRP systems for each downstream stock point a master schedule with its gross requirements is developed. Through allocation of existing inventory levels, net requirements for the stock point are obtained. These net requirements are translated to planned receipts and planned orders respectively. The planned orders are translated to gross requirements for the next upstream inventory points. DRP is a very natural extension of MRP that addresses the drawbacks of using independent control of the same product at different locations[19].

Line requirements planning

Line requirements planning (LRP) systems[22] can be regarded as a mixture of BSC and MRP. Similar to BSC systems, LRP systems make use of integral inventory[26] or echelon stock[21]. LRP systems work with time-phased inventory levels, as is the case in MRP systems. In LRP systems, the reorder level s in BSC systems is turned into a dynamic reorder point $s(t)$ based on a time series of forecasted demand or planned requirements[22]. Not only order suggestions for the current period are generated, but also a time series of planned orders is made. As opposed to MRP, LRP explodes not only information on expected requirements, but also information on inventory levels in downstream stock points to upstream stock points.

LRP systems have the advantage over BSC systems that they exploit the dependent nature of component demand. As compared with MRP systems, the main advantage of LRP systems is the fact that the distortion of information with respect to requirements and inventories (due to, for example, lot-sizing) is minimal, because LRP systems explode inventory levels and requirements separately and in their basic form to upstream stock points. Requirements for components are directly derived from the requirements for final products, so it is easier to see how requirements are built up. In a stochastic environment, LRP systems result in robust plans, but sometimes LRP systems may be too rough[22].

Classification of inventory management decision systems

The four decision systems for inventory management can be classified with the help of two criteria. The resulting classification, comprising four classes, is shown in Figure 1[27].

The first criterion is inventory focus, divided in two classes: local or integral. SIC systems as well as MRP systems both manage local inventory levels, i.e. the

inventory on hand (and on order) in a stock point. In contrast, BSC systems and LRP systems manage integral inventory levels, i.e. the inventory on hand (and on order) in a stock point plus all the inventory present in downstream stock points and processes.

The second criterion is time focus, also divided into two classes: instantaneous or time-phased. In SIC systems and BSC systems the time focus is instantaneous, i.e. only the current inventory levels are managed. However, in both MRP systems and LRP systems the planning is time-phased. These systems deal with the management of current and future inventory levels.

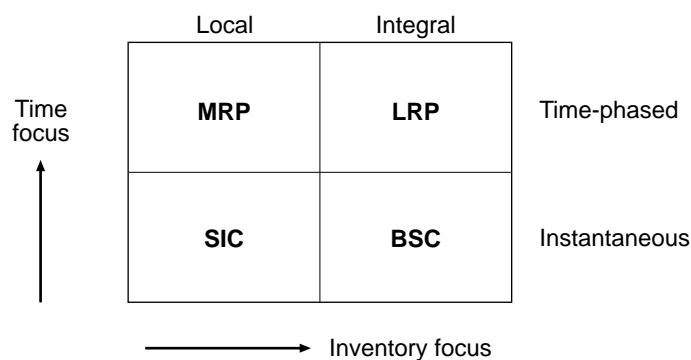


Figure 1.
Classification of
inventory management
decision systems

Decision systems in traditional versus networked inventory management

The four inventory management decision systems presented above, may be applicable for both traditional and networked inventory management. With traditional inventory management, we mean the currently observed inventory management with a scope that is limited to one organization, whereas in networked inventory management we deal with integral inventory management across co-operating organizations. Next we will first discuss how the inventory management decision systems are applied in traditional inventory management. Then we will show how the decision systems can be applied in networked inventory management.

Decision systems in traditional inventory management

In traditional inventory management the scope of control, and accordingly the coverage of the decision system, is limited by the organization boundaries. Thus, each organization has one or more inventory management decision systems covering the stock points in its own organization. In Figure 2 we show a supply chain through four organizations, and we suppose that each organization has two stock points and two intermediate production or distribution processes. In this situation of traditional inventory management, it may be that organization A manages its inventories with SIC systems, organization B uses a BSC system, organization C applies an MRP system and organization D has an LRP system as inventory management decision system.

Irrespective of the kind of decision system that an organization applies, in traditional inventory management the decision systems work inside but not across the organizations in the supply chain.

As can be seen in Figure 2, in traditional inventory management the decision systems of different organizations work separately, because they are cut off at each organization boundary. For SIC systems by definition the scope of control is limited to one stock point and the next upstream process. The separation of decision systems in traditional inventory management has some major disadvantages. Inventory management with separated decision systems results in amplification of demand and supply between organizations. Amplification is a non-technical term implying a response from some part of the supply chain which is greater than would at first seem to be justified by the causes[23]. Often, for technological reasons lot-sizes become larger further upstream in supply chains, resulting in lumpy demand in upstream stages.

Furthermore, in many forecasting procedures growth rates are extrapolated, while this is not justified. Also, there is a tendency to order ahead when deliveries slow down or during price rises. Moreover, production orders may differ from sales orders for inventory accumulation, to fill supply pipelines and for speculation. The amplification results in high and unreliable inventory levels in the supply chain. Especially when increasing product variety and customer service have to be satisfied, the amplification and its negative effects are likely to occur. Therefore, it is hard to meet the increasing customer requirements with the help of traditional inventory management, without significant rise of costs and prices.

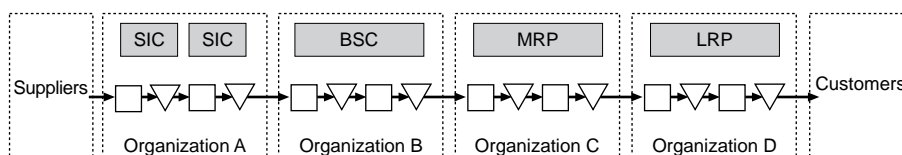


Figure 2.
Decision systems in
traditional inventory
management

Key
 □ Decision system
 ▽ Stock point
 □ Production or distribution process
 → Products

Decision systems in networked inventory management

As contrasted with traditional inventory management, in networked inventory management the scope of control, and so the coverage of the decision systems, is expanded to the domain of the networked organizations. Thus, each decision system covers at least two networked organizations. In Figure 3 we show a

supply chain through four networked organizations. In this situation of networked inventory management all four networked organizations make use of the same decision system for the management of the inventories in this supply chain. The integrated decision system can be a BSC system, MRP/DRP system or LRP system. Because the scope of a SIC system is limited to one stock point and the next upstream process, it is not applicable to networked inventory management. A decision system in networked inventory management works both inside as well as across the networked organizations.

In Figure 3 it is shown that in networked inventory management one decision system covers several networked organizations, because it is allowed to cross the organization boundaries. Although in general it will require quite some effort for the organizations to create such a co-operative setting, the application of one integrated decision system in networked inventory management has some major advantages. Networked inventory management takes away the amplification of demand and supply between organizations in the supply chain, because the integrated decision system exploits the dependence between the stock points in different organizations. This reduces the uncertainty of inventory levels in the stock points, so safety stocks can be decreased without affecting customer service levels. A BSC system for networked inventory management triggers on customer demand. Because the variability in customer demand is less than in upstream ordering, the inventory levels can be decreased. An MRP/DRP system exploits the dependent nature of demand, the co-ordination of operations and the opportunities of time-phased inventory levels, resulting in uncertainty reductions and hence lower inventories. An LRP system for networked inventory management contributes to a higher transparency of the supply chain. This results in more robust planning as compared to MRP/DRP and further reduction of inventory levels. So, networked inventory management can cope with the dynamics that go along with greater product variety and higher customer service levels. Therefore, it has much potential for satisfaction of the increasing requirements at affordable prices.

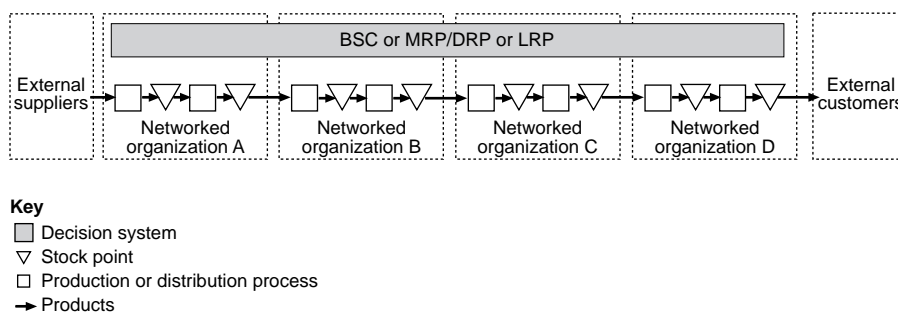


Figure 3.
Decision systems in
networked inventory
management

Networked inventory management information systems

Above, we showed how BSC systems, MRP/DRP systems and LRP systems can be applied in networked inventory management. These decision systems represent the mathematical logic for integral inventory management across networked organizations, which requires intensive information processing. Here, we will outline the networked inventory management information systems (NIMISs), that take care of the information processing for the networked inventory management. We will start with an explanation of networked information systems and continue with the high-level specifications of NIMISs for the decision systems BSC, MRP/DRP and LRP.

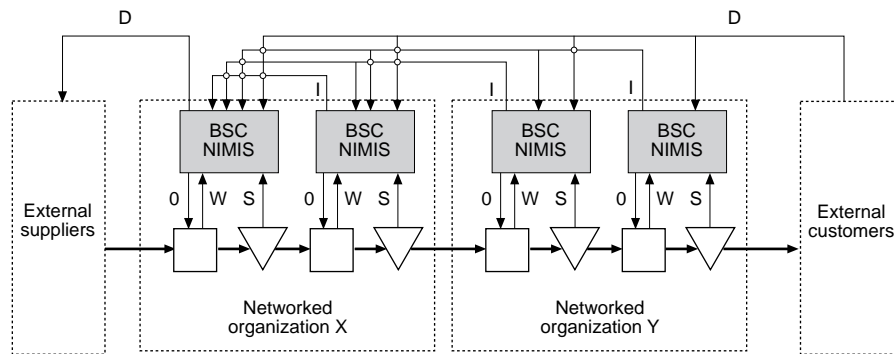
Networked information systems

For the transformation, storage and communication of information across the networked organizations, an inter-organizational information system (IIS) is needed. An IIS is an information system that is jointly developed, operated or used by two or more organizations that have no joint executive[28]. To ensure the autonomy and flexibility of the networked organization, we pursue distributed information processing. As a consequence, a central and monolithic IIS is not appropriate. Instead, we work on networked information systems. These systems are distributed over a network of co-operating organizations, are interconnected via telecommunications and co-operate for a common goal of the networked organizations.

NIMIS specification

Networked inventory management information systems (NIMISs) are networked information systems which are applied to networked inventory management. Each NIMIS provides for a part of the information processing that is needed for the decision system in the networked inventory management. Together, a group of NIMISs perform as one integrated decision system for the integral inventory management across the networked organizations. It is typical for the NIMISs that, with respect to inventory management, the information exchange between the networked organizations is similar to the information exchange within a networked organization.

For the decision systems BSC, MRP/DRP and LRP, we will give high-level specifications of the needed NIMISs. These specifications show the distribution, interconnection and co-operation of the information systems. In our outline of NIMISs, we will focus on the processing of dynamic information. All static information (concerning bills-of-material, distribution structures and inventory level norms), that is relevant to a particular NIMIS, is supposed to be available in that information system. Furthermore, in the specification of the NIMISs we do not take into account the capacity aspect of supply chain management. A networked organization may have a capacity management system that manipulates the incoming information to deal with limited availability of resources.



Key

- | | |
|--|---------------------------------------|
| □ Information system | D Instantaneous demand (requirements) |
| ▽ Stock point | I Inventory level |
| □ Production or distribution process | S Physical stock |
| → Products | O Order (production/distribution) |
| → Information | W Work in process |
| ○ Intersection of non-connecting information flows | |

Figure 4.
NIMIS for base stock control

NIMIS for base stock control

The information processing for base stock control (BSC) can be accomplished by a group of BSC NIMISs. In Figure 4 a supply chain is illustrated through two networked organizations, each having two stock points and two intermediate distribution or production, processes. The supply chain starts and ends with external suppliers and external customers respectively, that both are outside the network. The high-level specifications of BSC NIMISs in Figure 4 show how the information systems are distributed, how they are interconnected and how they co-operate.

As can be seen in Figure 4, each pair of stock point and upstream intermediate process, makes use of one BSC NIMIS. The most downstream BSC NIMIS in Figure 4 (right side), measures the physical stock on hand in the stock point, monitors the instantaneous demand from external customers and calculates its local and integral inventory level. If the latter is below the norm, an order is released to the production or distribution processes, that replenishes the physical stock. The local inventory level of the most downstream BSC NIMIS is communicated to the upstream BSC NIMISs.

Besides measurement of its own physical stock, the most upstream BSC NIMIS in Figure 4 (left side), receives information about instantaneous demand from the external customers and makes use of the local inventory levels of all downstream BSC NIMISs. With the help of these inputs, the integral inventory level of the most upstream BSC NIMIS is determined. If shortages occur, the most upstream BSC NIMIS releases an order to its production or distribution process. To the external suppliers, only instantaneous demand from the most upstream BSC NIMIS is transferred. Information about the demand from external customers and local inventory levels in the network is not passed on to

external suppliers, because they are outside the network of co-operating organizations.

NIMIS for materials/distribution requirements planning

A set of MRP NIMISs or DRP NIMISs together can cover the information processing for materials/distribution requirements planning (MRP/DRP). In Figure 5 the high-level specifications of four MRP NIMISs are presented for a supply chain through two networked organizations.

In the most downstream MRP NIMIS in Figure 5 (right side), the instantaneous demand from external customers is observed and future customer demand is forecasted to derive time-phased gross requirements. The physical stock and gross requirements are input for the calculation of time-phased local inventory levels, orders and demand. Orders are released to the intermediate process to prevent the local inventory level from coming below its norm level. The time-phased demand from the most downstream MRP NIMIS is made up of the planned orders. This information is communicated to the next upstream MRP NIMIS.

In the most upstream MRP NIMIS in Figure 5 (left side), information is received about the time-phased demand from the next downstream MRP NIMIS. The time-phased demand is translated to gross-requirements. After measurement of the physical stock, net requirements and planned orders are determined respectively. Orders are released to the distribution or production process.

To the external suppliers only the instantaneous demand is communicated, as they are not part of the network. The exchange of information on time-phased demand is exclusive for the networked organizations.

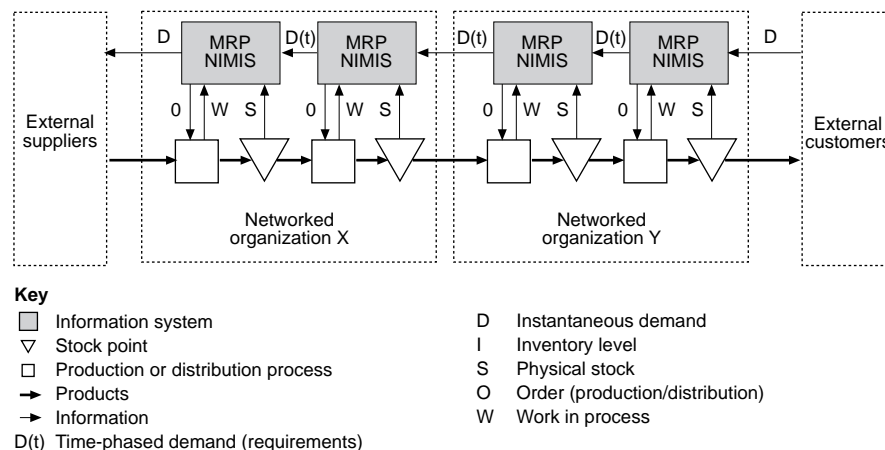


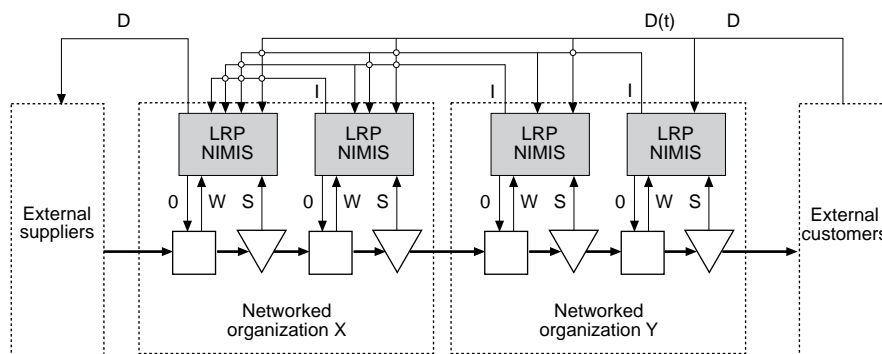
Figure 5.
NIMIS for materials
requirements planning

NIMIS for line requirements planning

The information processing for line requirements planning (LRP) can be done by a set of LRP NIMISs. In Figure 6, the high-level specifications of four LRP NIMISs are shown for a supply chain through two networked organizations. In the most downstream LRP NIMIS in Figure 6 (right side), the instantaneous demand from external customers is supplemented with forecasts for future customer demand. The resulting time-phased demand is applied by the most downstream LRP NIMIS as gross requirements in its calculations. Furthermore, the time-phased demand is communicated to all upstream LRP NIMISs in the network.

In the most downstream LRP NIMIS, time-phased demand and the physical stock on hand are inputs for the calculation of its time-phased inventory levels. Comparison of the time-phased integral inventory levels with the norms leads to time-phased net requirements, planned orders and order releases. The most downstream LRP NIMIS transfers its inventory level to all upstream LRP NIMISs.

In the most upstream LRP NIMIS in Figure 6 (left side), information on the physical stock on hand is combined with inventory levels from all downstream LRP NIMISs. Furthermore, the time-phased demand from external customers is used to arrive at time-phased integral inventory levels. These are compared with the norms, to determine time-phased net requirements, planned orders and order releases to the distribution or production process. The time-phased demand and inventory levels are not communicated to the external suppliers, because they are outside the network. Instead, only instantaneous demand from the most upstream LRP NIMIS is transferred to the external suppliers.



Key	
□ Information system	D(t) Time-phased demand (requirements)
▽ Stock point	D Instantaneous demand
□ Production or distribution process	I Inventory level
→ Products	S Physical stock
→ Information	O Order (production/distribution)
○ Intersection of non-connecting information flows	W Work in process

Figure 6.
NIMIS for line
requirements planning

Conclusion

The driving forces for networked inventory management are increasing customer requirements, the need for networked organizations and the opportunity of networked inventory management. Stronger competitive pressures due to the opening of markets result in increasing customer requirements. The networked organization is regarded as a promising alternative to withstand the changing business conditions. For such co-operating organizations integral management of the inventories in their supply chains is one of the opportunities to gain mutual benefits.

The high-level specifications for BSC NIMISs, MRP/DRP NIMISs and LRP NIMISs show the distribution, interconnection and co-operation of the information systems. Together, a group of NIMISs perform as one integrated decision system for integral inventory management across the networked organizations. It is typical for the NIMISs that the information exchange between the networked organizations is similar to the information exchange within a networked organization. NIMISs are essential resources to put networked inventory management into practice. With the help of NIMISs, networked organizations can take away amplification and its negative effects in their supply chains. In this way, NIMISs are means to satisfy the increasing customer requirements at affordable prices.

In our further research we will study the technological enablers for NIMIS, i.e. techniques for inter-organizational information systems, distributed information processing and object-oriented system development. Because facilities like open systems, object request brokers, wide area networks and Internet are becoming available at low costs, the feasibility of NIMIS is growing fast. As second research issue, we will proceed with the further development of NIMIS, including detailed design and prototyping. By using the object-oriented system paradigm we pursue autonomy and flexibility of the information systems and consequently the networked organizations. A third stream in our research addresses the applicability of NIMISs in different types of situations. We will try to establish a contingency framework which shows the relative applicability of NIMISs for the distribution of packaged consumer goods in several business sectors. Finally, our research into NIMISs should result in tangible information systems for materializing supply chain management.

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