Helsinki University of Technology
Department of Industrial Engineering and Management

Evaluating the costs and benefits of merge-in-transit for distributors

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The main objective of this study is to construct a model to evaluate the applicability of merge-in-transit distribution for industrial distributors and wholesalers. Merge-in-transit is a distribution model where customer orders are centrally managed and the goods delivered from several suppliers are consolidated into single deliveries at merge points, without inventories in the delivery chain. When successful, merge-in-transit distribution can simultaneously enhance customer service level and reduce logistics costs.

However, the application of merge-in-transit has been rare due to the extensive integration efforts required to manage the consolidation process. A promising possibility to facilitate the integration is to use shipments to provide control information in electronic form. Using this 'product centric control' together with distributed programming, a flexible network can be created for managing the consolidation operations. This also reduces the investment costs needed and thus makes merge-in-transit a more attractive alternative for distribution chains.

The evaluation model in this thesis is based on a literature review of distribution channels and logistics information systems. The main topics examined are channel alternatives for distributors, characteristics of and requirements for merge-in-transit operations, logistics cost elements in distribution, requirements for logistics information systems in supply chain integration, and alternative approaches for implementing the integration. The evaluation model is tested with an industrial distributor that launched merge-in-transit operations during the study.

The result of the study is an evaluation model that is divided in four main parts. In the first part a scenario utilising merge-in-transit is constructed as an alternative for current operations in a specific distribution chain. In the second part of the model, operational costs of both the scenario and the current operations are evaluated to assess the economical feasibility of merge-in-transit in the environment. Also, potential service benefits achievable with merge-in-transit are evaluated. In the third part, the requirements for information systems in the merge-in-transit delivery chain are identified. In the last part, the costs and benefits of product centric control in merge-in-transit distribution are compared to those of a traditional integration approach.

Keywords distribution channels, merge-in-transit, consolidation, logistics costs, logistics information systems, product centric control

Teknillinen korkeakoulu	**Diplomityön tiivistelmä**
Tekijä	Timo Antero Ala-Risku
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Tutkimuksen päätavoitteena on luoda malli toimitusten yhdistelyn soveltuvuuden arviointiin teollisuuden jakelijoille ja tukkukauppiaille. Toimitusten yhdistelyllä tarkoitetaan jakelumallia, jossa asiakastilauksia hallinnoidaan keskitetysti ja tuotteet toimitetaan asiakkaille useilta lähettäjiltä siten, että lähetykset yhdistellään yhdeksi asiakastoimitukseksi kuljetusverkossa ilman välivarastointia. Menestyksekäs toimitusten yhdistely voi samanaikaisesti sekä parantaa asiakaspalvelutasoa että vähentää logistiikkakustannuksia.

Toimitusten yhdistelyä on kuitenkin käytännössä sovellettu verrattain vähän johtuen yhdistelyprosessin hallinnan vaatimuksista tietojärjestelmäintegraatiolle. Toimitusten mukana sähköisessä muodossa kuljetettava ohjaustieto on lupaava ratkaisu integraation helpottamiseksi. Tämä ”tuotekeskeinen ohjaus” yhdessä hajautettujen ohjelmistoratkaisujen kanssa mahdollistaa joustavan järjestelmän luomisen toimitusten yhdistelyn tiedonhallintaa varten. Järjestelmän vaatimat investoinnit ovat verrattain alhaiset, jolloin toimitusten yhdistelystä tulee entistä kiinnostavampi jakelumalli.

Tässä työssä laadittu arviointimalli perustuu kirjallisuustutkimukseen, jossa tarkastellaan jakelukanavavaihtoehtoja ja logistiikan tietojärjestelmiä. Keskeiset käsiteltävät aiheet ovat jakelijoiden kanavavaihtoehdot, kuljetusten yhdistelyn ominaispiirteet ja vaatimukset, jakelulogistiikan kustannuselementit, vaatimukset logistiikan tietojärjestelmien integraatiolle toimitusketjussa ja vaihtoehtoiset lähestymistavat integraation toteuttamiseksi. Luotua arviointimallia testataan yrityksessä, joka käynnisti toimitusten yhdistelyyn perustuvan jakelumallin tutkimuksen aikana.

Tutkimuksen keskeisin tulos on arviointimalli, joka jakautuu neljään pääkohtaan. Ensimmäisessä vaiheessa muodostetaan nykyisten toimintojen vaihtoehdoksi skenaario, jossa toimituksia yhdistellään kuljetusverkossa. Toisessa vaiheessa arvioidaan logistiikkakustannukset sekä nykyisten että skenaarion toimintojen osalta. Tuloksena syntyvän taloudellisen kannattavuuden arvioinnin lisäksi käsitellään kuljetusten yhdistelyyn siirryttäessä saatavilla olevia palveluhyötyjä. Kolmannessa vaiheessa tunnistetaan vaatimukset toimitusten yhdistelyyn tarvittaville tietojärjestelmille. Viimeisessä vaiheessa arvioidaan tuotekeskeisen ohjauksen ja perinteisten integrointikeinojen kustannuksia ja hyötyjä toimitusten yhdistelyssä.

Avainsanat jakelukanavat, toimitusten yhdistely, konsolidointi, logistiikkakustannukset, logistiikan tietojärjestelmät, tuotekeskeinen ohjaus

Foreword

Many people deserve my gratitude for their contributions to the completion of this Master’s Thesis.

First of all, I would like to thank Professor Kari Tanskanen at the Department of Industrial Engineering and Management for his supervision and guidance.

No less thanks go to my instructors Kary Främling and Jan Holmström. Among many other things, Kary Främling as the soul of the Dialog project has designed the software used in piloting the new ideas included in this thesis. Jan Holmström has given great support and has continuously encouraged me with fresh suggestions to improve my work.

I would also like to thank all the people in two research groups at the TAI Research Centre: Dialog and Ecomlog. The work with this Master’s Thesis has been greatly influenced by the inspiring atmosphere present in these two groups.

Last but not least at TAI Research Centre, I would like to thank my roommate Mikko Kärkkäinen, who has provided the spirit lifting “mieletön meininki” in our office. He has also been a very good counterpart in tossing around thoughts as well as other things.

Finally, a very personal thanks to my fiancée Soile Tapio, who has understood – and had the insight to remind me at times – that preparing a Master’s Thesis is not an eternal state of affairs.

Some final thoughts in the form of lyrics for a famous Finnish song (Autiotalo, *Dingo*):

Aurinko laskee selkäni taa,
se värjää mun näyttöni punaisellaan
ja Eput laulaa ”älä mene, niet niet”,
en mee, teen dippaa, se kaiken ajan vie.

Nään silmissäin Spektrin yöttömän yön,
ja pimeessä pääni taas näppikseen lyön,
en uskalla edes hetkee hengähtää
työn tuoksina vie tajuntani pimeään.

Ja kirja kädessä kuljen mä Spektriin autioon,
ja se minua niin - harmittaa,
Nämä hetket saa minut pian aivovaurioon,
kun talon aution yksin taas jaan.

Mä reppu selässä kirjoja vien,
ne sekä artikkelit tukkii koko tien
ja pöydälle minä lähdepinon teen,
yskähdän, kirjapölyä hengittäen

Joku hullu on istunut ikuisuuden,
dipan ääressä vain kahviin turvautuen,
ei enää reppu selkääni tuu
ja kurkkuni keijosta vihdoin kostuu.

Ja kirja kädessä kuljen mä Spektriin autioon,
ja se minua niin - harmittaa,
Nämä hetket saa minut pian aivovaurioon,
kun talon aution yksin taas jaan.

Espoo, June 2002

Timo Ala-Risku

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1 INTRODUCTION

1.1 Background and motivation

Some of the biggest challenges in customer demand fulfilment lie in the management of the physical distribution. This is especially evident in the case of e-marketplaces, where a wholesaler or distributor offers its customers a wide variety of products from different suppliers (Kärkkäinen and Holmström, 2001; Seideman, 2000; Brooksher, 1999). Due to high inventory carrying costs, it is often not feasible for a wholesaler to stock all the offered products in its own warehouse. Direct deliveries from the product suppliers remove the need for excessive ownership transactions and warehousing in the delivery chain, but result in several individual deliveries at the customer, thus raising her receiving costs.

Efficient means for reducing both the need for warehousing and the number of customer deliveries have been found in several merge-in-transit cases (Kärkkäinen et al., 2002; Norelius, 2002; Richardson, 1999; Dawe, 1997). Merge-in-transit is a delivery model, where shipments of multiple suppliers are consolidated as one customer delivery at merge points that operate without inventory. However, the current merge-in-transit applications typically include only a few large partner companies and a limited number of products in the process.

One of the reasons for this is the increasing complexity of material flow control, when a multitude of suppliers is included in the merge-in-transit process. As the number of consignments in process increases, matching the material flow with the respective information flow becomes very challenging (Johnston and Yap, 1998). Each of the individual consignments must be identified and information on the associated customer order must be available at all the terminals, where consolidation is taken care of. Thus, one of the main challenges for the logistics service provider in multi-company shipment consolidation is to receive exact information from all the involved parties.

With current practises of varying messaging formats, including paper documents, the delivery information management for the logistics companies is itself a challenge (Carbone, 2001). It results in unnecessary manual work that is prone to errors, and varying formats make the merge-in-transit process inflexible and hard to scale up. The automation of information transfer is essential for merge-in-transit, to ensure correct and up-to-date information on the availability and movement of goods (McLeod, 1999). Electronic Data Interchange (EDI) and other message-based services provide automated means for point-to-point communication (Linthicum, 2001, pp. 9-15), but do not sufficiently support the needs of multiple organisations participating in merge-in-transit.

A proposal studied at Helsinki University of Technology, described in the following section, is to solve the difficulties in managing the merge-in-transit process by using the products to provide control information (Kärkkäinen et al., 2001) in combination with distributed programming (Främling and Holmström, 2000). The resulting 'product centric' system focuses on controlling deliveries from the material flow perspective, instead of the traditional approach of inter-linking several centralised company applications for transaction processing.

There is very little published research on the merge-in-transit concept, perhaps due to the complexity of its implementation in larger scale. In particular, there are no studies on how to evaluate the applicability of merge-in-transit for different business situations. With a potential solution to the management of delivery information available, new research is needed to assess the benefits of the concept in general.

This thesis presents a model for evaluating the applicability of merge-in-transit operations for a specific distribution chain. The model has four parts. In the first part a merge-in-transit scenario is constructed for the current business environment of a distribution chain. In the second part the costs of physical operations and achievable service benefits are assessed. The third part constructs a product centric approach to implement the communications necessary for the operations. And finally, in the fourth part the costs of implementing and operating the communication systems as well as potential service benefits resulting from the product centric approach are evaluated.

This work is a continuation of recent studies at the Helsinki University of Technology (Främling and Holmström, 2000; Kärkkäinen et al., 2001; and Kärkkäinen et al., 2002). It links also with development at other research institutes, for example the Auto-ID Center of MIT (Brock, 2001) and the Distributed Systems Group of ETH Zurich (ETH Zurich, 2002).

1.2 Product centric control in the delivery chain

The management of control information related to the material flow in a delivery chain (or in any network of individual companies) focuses traditionally on how to transfer the information from a company application to another (Linthicum, 2001). This requires a communication link to be created between all parties needing to exchange data. With a large number of parties in a network the result is numerous links that need to be set up, before the entire communication network is operational.

Another, often separated, issue to be solved is to correctly identify the materials in each of the involved companies, which is necessary to be able to control the correct items with the transferred information. The problem here is that companies typically have a proprietary identity scheme for materials flowing through their organisation.

An alternative to the transactional company centric view is to take a product centric approach to controlling the delivery chain (Kärkkäinen et al., 2001). The idea is to use the objects themselves to transfer control information in the delivery chain. This can be done by giving objects an identity on the Internet. Relevant information of each object can then be linked to the identity to form a virtual counterpart for the object (Kärkkäinen et al., 2001; Brock, 2001). Thus, each partner (or partner application) would only need to know the virtual identity of the object to access its data on the Internet. No separate connection set-up is required.

There are two important issues in making the product centric approach operational in a delivery chain. The first and key issue is a uniform identification system for all shipments. The second issue is that all participants have means for accessing the data over the Internet. Both of these are addressed in the Dialog project at the Helsinki University of Technology (http://dialog.hut.fi/dialog/index.html). The Dialog project develops distributed software for supply chain use and conducts pilot implementations in real business situations.

The proposals designed in the Dialog project for solving these requirements are described in the following two sections. In the third section, based on the development in the Dialog project, a prototype application for merge-in-transit is presented.

1.2.1 Identification System

The essential requirements for the identification scheme are uniformity and uniqueness. The requirement for uniformity means that all participants use the same structure for presenting an identity, while uniqueness means that there are no two identities that are exactly the same. Additionally, in order to make the system scalable, the identification should be based on a coding system that is easy to adopt across organisations, and the coding system should provide unambiguous information on how to access the delivery information stored elsewhere.

A solution to satisfy these demands is to create a two-level coding system making use of the existing uniqueness of the IP-addresses and URIs (Uniform Resource Identifiers) on the Internet. Each company sending shipments can store delivery-related information on their own server connected to the Internet, and thus having an IP-address. The company can then allocate for each of its deliveries a globally unique code consisting of the IP-address or URI of the server combined with a delivery ID of free choice, for example consecutive numbering. Thus, the concept is analogous to the Serial Shipment Container Code of the EAN-UCC (EAN International, 2002), but the EAN-allocated unique company code is replaced with an ISP-allocated unique IP-address.

By no coincidence, this solution to the uniqueness of the parcel identity encoding simultaneously solves the problem of how to connect the network identity to the physical parcel. The identity of the delivery is at the same time the exact address on the Internet, where all additional information can be found. The physical attachment of the identity on the parcel can be done by writing it on an RFID-tag or, more traditionally, by printing it as a bar code.

1.2.2 Access to the Delivery Data

The other element needed for a product centric application is software capable of accessing the parcel’s data at another company over the Internet. The solution offered by the Dialog project is based on Java-programmed software agents operating as background services at each member company in the distribution chain. The agent connects to existing databases of the company using Java Database Connectivity (Linthicum, 2001, pp. 215-229), meaning that no modifications to the existing business applications are needed.

The software agents come in two forms, a server agent that integrates with the delivery information database at the supplier, and a client agent that operates at the parcel identity reading points where information on the parcel is needed. Thus, every time the identity of a parcel is registered, up-to-date data can be obtained from the source application with no need for copies of the information stored in applications of other members of the distribution chain.

The connection between agents for transferring delivery data to the reading point is created in a peer-to-peer fashion. This means that no intermediate service providers are needed between the communicating parties, as the connection is formed over the Internet. Another benefit of the object identity coding system described above is that when the URI is part of the identifier this can also be used to notify the reader agent of the protocol to use with the supplier agent.

If such distributed applications really are superior compared to message-based transactions between business applications, why are they not commonly used already? The recent development of distributed programming and the extending use of the Internet are the main technological drivers for the emergence of truly distributed software. On the other hand, the business needs for enhanced information sharing between companies and distribution of control have also been emphasised only lately (Euwe and Wortmann, 1998; Edwards et al., 2001). And there still are plenty of challenges to be solved regarding the investment and benefit sharing for operation modes based on such applications, and of course security issues.

1.2.3 Prototype solution for merge-in-transit

In this section, based on the current results of the Dialog project, a prototype solution for merge-in-transit is presented. The solution is designed for the business environment of an industrial distributor offering its customers products from several suppliers.

As suggested above, each parcel can have an identity in the logistics network. Delivery or product specific data can then be connected to this network identity and accessed over the Internet. If an identity is created also for each customer order, we can access the Bill of Materials for each consolidated customer delivery through the Internet. This gives us a parcel that knows its destination and the customer order it belongs to, and can thus also provide access to its consolidation needs. The network identities with related information are illustrated in Figure 1.

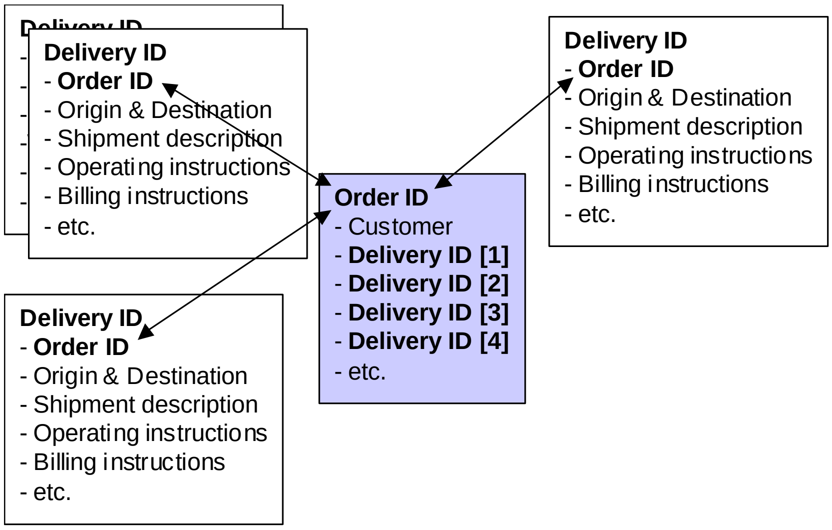


Figure 1 Network identities for deliveries and orders

For merge-in-transit this means that it is not necessary to create EDI-connections between all suppliers and the logistics service provider, as the application in a distribution centre can access the delivery information of each parcel at its origin whenever needed. By having unique identifications for both delivery parcels and customer orders, such an application can take care of correct integration of material and information flows.

We can now build applications capable of monitoring the entire consolidation process at the logistics service provider. As a parcel arrives at a distribution centre of the transportation company and its identity is registered, the application can provide information on whether the parcel should be stored shortly to wait for consolidation or sent forward to the next depot or customer on its own. Similarly, the application would notice when the last piece of a customer order has arrived, and it could trigger the order-picking process at the depot.

The actual distributed application taking care of the information exchange is composed of several software agents operating at various points of the distribution chain, displayed as shaded areas at parent applications in Figure 2. The needed transactions (orders) are depicted as solid arrows in the figure. The software agents take care of other necessary information flows.

As the wholesaler gets a customer order, he processes the order with his ERP software. Delivery-related information in the initial customer order is made available to the wholesaler's agent software. The wholesaler then sends all suppliers a normal product order appended with the customer order's Internet address. Correspondingly, the wholesaler informs the logistics service provider of the customer order's critical advance information (e.g. customer delivery date, involved suppliers, pick-up dates, SKUs, and quantities), and states the virtual identity of the customer order.

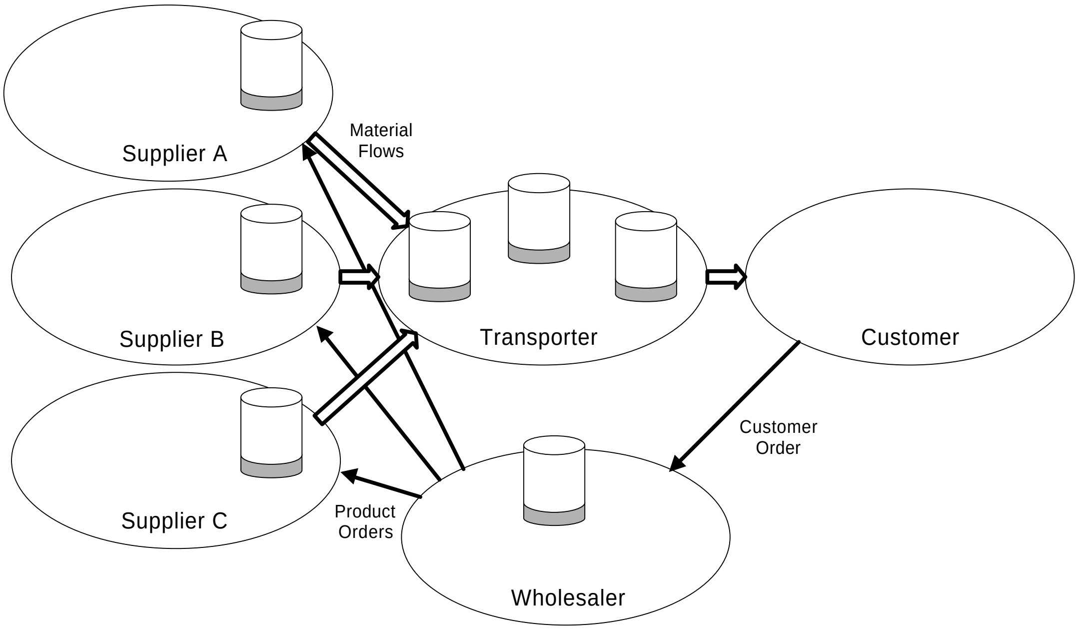


Figure 2 The distributed application (shaded areas) in co-operation with other software

When the suppliers are sending the ordered products, they record the delivery data of each parcel in a database accessible for their agents and attach on the parcels a bar code or RFID-tag with the Internet address of the parcel data. As the parcel is handed over to the transportation company, the identity of the parcel is read and the agent of the transportation company accesses the delivery data at the supplier. Since the supplier's delivery data includes the identity of the wholesaler's customer order, the transportation company now has all the necessary information available to accomplish its task of consolidating several parcels as one final customer delivery. The customer delivery is ready to be shipped, when all items in the customer order have arrived at the consolidating depot.

After the delivery to the customer, the software agent at the last distribution centre – or alternatively, in the delivery truck – receives information of a completed customer delivery. The wholesaler's agent immediately knows that the customer has received his delivery, and the wholesaler can send an invoice for the delivered products.

1.3 Research problem

The wholesalers' seemingly contradictory goals to provide a wide assortment of products for their customers while simultaneously lowering the need for central warehousing require efficient distribution networks. Merge-in-transit distribution may offer a solution to achieve both of these objectives. However, the application of merge-in-transit has been rare due to the extensive integration efforts required in setting up the process. With a proposal available to facilitate the integration of multiple organisations, the focus of this study is on the potential benefits of merge-in-transit distribution. The first research problem of the study is:

> *How to assess the costs and benefits of merge-in-transit distribution for a business situation?*

As the proposal for solving the application integration challenges in merge-in-transit is based on an application under constant development, a relevant second research problem is:

> *How to assess the costs and benefits of implementing the product centric model in multi-company distribution situations?*

Since both the merge-in-transit and the product centric approach are emerging alternatives to organise the distribution network, and there is not much research on either subject, it is necessary to carefully set the objectives and scope for a master's thesis in these topics.

1.4 Objectives

The aim of this thesis is to provide tools for assessing the potential cost and service benefits of using merge-in-transit distribution channel in the business-to-business environment. This includes the assessment of the new enabling technology based on product centric information systems.

Specifically the objectives are:

- Define a quantitative model to assess the potential delivery cost benefits of merge-in-transit distribution

- Present qualitative tools for assessing the service benefits of merge-in-transit distribution

- Define a quantitative model to assess the implementation and operation costs of the product centric model in merge-in-transit

- Present qualitative tools for assessing the service benefits of the product centric model in merge-in-transit

1.5 Scope

The business environment studied in this thesis is business-to-business distribution. This definition is essential, as the distribution alternatives in business-to-consumer environment have very different characteristics, and treating all alternatives would greatly disperse the focus.

The operational focus of this thesis is on the material flow, that is physical distribution and necessary execution information flows. The order flow elements related to business transactions are touched where appropriate, but are not included in the assessment models constructed.

The perspective used in evaluating the costs and benefits of merge-in-transit distribution is that of the delivery chain from the supplier to the customer. Although the central player is the industrial distributor, also the other players in the delivery chain are covered.

The challenges related to international merge-in-transit are omitted in this thesis, due to the wealth of legislative issues that would require special attention.

1.6 Research methods

This master's thesis is constructive in nature. First, the current knowledge on merge-in-transit concept is reviewed. Second, based on findings a model is formulated to assess the costs and benefits of the concept. And finally the usability of the model is evaluated in a case company situation.

The current knowledge on merge-in-transit distribution is reviewed and the requirements, enablers, and effects are discussed. After understanding the channel structure in merge-in-transit distribution the logistics cost elements are identified. Based on the elements, a costing model is created for the operational costs. In addition, qualitative tools are designed for assessing the service benefits.

To assess the applicability of the proposed solution for merge-in-transit distribution, the requirements and alternative approaches for integrating logistics information systems are identified based on a literature review. After perceiving the necessary components of integration, a quantitative model is designed to address implementation and operations costs of the approaches. Potential service benefits of the proposed solution are discussed qualitatively.

Both the model for operational costs of merge-in-transit and the model for implementation costs of the application integration are tested with a case company.

1.7 Structure of the thesis

Chapter 2 of this thesis comprises of a literature study on the distribution modes available for wholesalers and industrial distributors, and the ways to manage logistics information flows necessary to control the distribution. The merge-in-transit concept is compared to the other modes and the attainable benefits and requirements found in literature are discussed. Similarly, the product centric approach is compared to other business-to-business application integration alternatives.

In Chapter 3 an evaluation model is constructed to analyse the cost and service benefits of the merge-in-transit distribution mode. The model is divided in four parts: In the first part a merge-in-transit scenario is constructed as an alternative for current distribution operations in the delivery chain under review. In the second part the costs and benefits of the physical distribution are assessed both in current operations and in the merge-in-transit scenario.

In the third part the requirements for enabling automated communication of delivery information for merge-in-transit distribution are evaluated, and the product centric control approach is suggested as an alternative for traditional communications. And finally, in the last part of the model the costs and benefits of the necessary application integration are evaluated. The third chapter presents also results of using the evaluation model in the business situation of a case company.

Chapter 4 is devoted to conclusions and the discussion of further research needed.

2 LITERATURE REVIEW

The traditional view of competition as a company-to-company battle has slowly given way to a more holistic view of competition as a contest between supply chains. This includes the notion that no single company can succeed unless it co-operates with other companies in the chain. It has also further proliferated the outsourcing of functions not seen as core competences of the company. Supply chain management has thus become a critical success factor for all businesses. (Christopher, 1992, pp.12-16)

In this chapter, the broad subject of supply chain management will be approached from a wholesaler's viewpoint in two ways. In the first section, the issue of how the supply chain is structured in terms of distribution channel alternatives is discussed. In the second section, the requirements for managing the supply chain and enabling technologies are reviewed.

2.1 Distribution channels

Distribution channels are a topic hard to press into one profile. There are a number of ways how to arrange the transportation and marketing efforts needed to take care of providing a customer with a product or service of a supplier. The American Marketing Association gives a definition for distribution channels as:

> *"The structure of intracompany organisational units and extracompany agents and dealers, wholesale and retail, through which a commodity, product, or service is marketed."* (Baker, 1990)

Bowersox and Closs (1996, p. 94) present a functional approach to explain the requirements for the distribution channel to take care of the distribution process. The basic functions are grouped in three entities: Exchange functions, physical distribution functions, and facilitating functions. The exchange functions consist of activities related to buying and selling, while physical distribution functions comprise transportation and storage activities. The facilitating functions include standardisation, market financing, risk bearing, and market information and research. In the scope of this thesis the exchange functions and physical distribution functions are of most interest and will be referred to as order flow and material flow, respectively.

A very essential element for many distribution channel arrangements is the creation of assortments, i.e. collections of products desirable for a customer (Bowersox and Closs, 1996, pp. 97-100). From the viewpoint of the customer, it is convenient to acquire as much of the necessary goods as possible with one visit to a marketplace, be it a physical location, a paper catalogue, or an e-marketplace. From the suppliers' point of view there is a strong interest to utilise economies of scale in the distribution channel and reduce duplicated operations in distribution to as few as possible. In other words, there is a need for a demand and supply aggregator in many distribution channels, illustrated in Figure 3. This is the justification for wholesalers in business-to-business environments and retailers in business-to-customer trade.

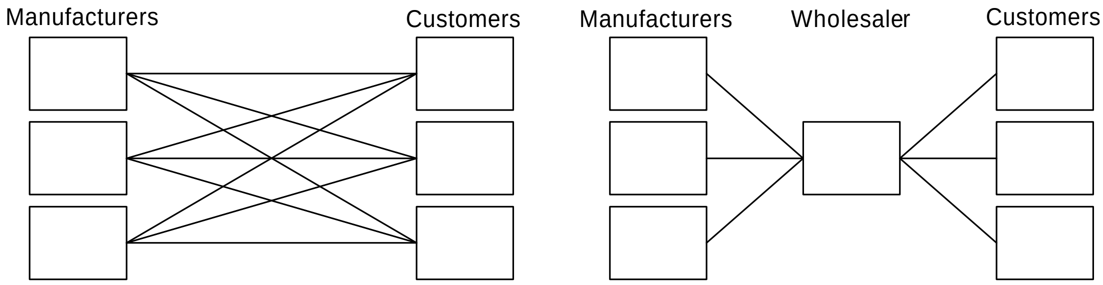


Figure 3 Principle of minimum transactions (Bowersox and Closs, 1996)

Traditionally, the wholesalers have taken care of both the order and material flow. That means, they have first purchased products from suppliers, stored them in their own warehouses, and then sold them further to their own customers. With the progress in information technologies, more sophisticated arrangements have been developed. This is the case with, for example, some e-marketplaces, where a distributor provides products from several suppliers, but never comes in physical contact with the goods sold. The physical distribution is outsourced to a logistics service provider.

In the next section, the basic alternatives for wholesaler distribution channels are discussed. The section after that takes a closer look at the merge-in-transit distribution channel. Finally, the distribution channel structures are reviewed to identify the essential cost elements.

2.1.1 Alternative distribution strategies for distributors

The typical alternatives for distribution channels in business-to-business commerce are illustrated in Figure 4. The customer may procure its supplies directly from the producer or a selling agent of the producer located more conveniently. The third alternative is a wholesaler or distributor, who in turn has its inventories replenished by either the producer or its local representative. In the below configurations, material and order flows are integrated, as the participant who sells the goods also stores and delivers them.

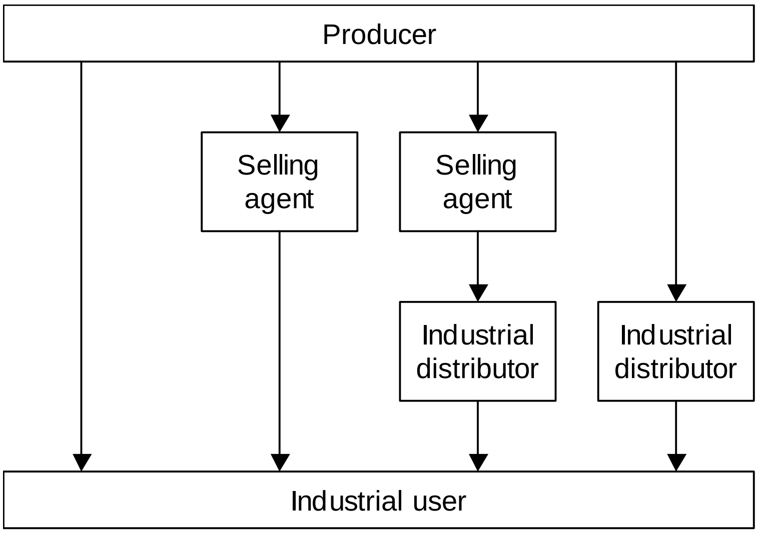


Figure 4 Typical channel structure alternatives in industrial-goods distribution (applied from Bowersox and Closs, 1996, p. 118)

As stated in the previous section, from the viewpoint of the customer the distributors offer the most attractive channel for ordering goods. They generally are able to provide a better assortment than a single producer. On the other hand, the logistics executives tend to often prefer the direct delivery alternative, as it reduces anticipatory inventories and intermediate product handling (Bowersox and Closs, 1996, p. 484). It is apparent that none of the typical channel arrangements are ideal for both the order and material flows.

The solution to these diverging requirements is called channel structural separation. It means that the marketing channel, the order flow, can be separated from the logistical channel, the material flow, in respect to both time and performer (Bowersox and Closs, 1996, p. 479). The industrial distributor can thus offer its customers also goods it does not store and deliver itself. This is illustrated in Figure 5, where dotted arrows are used to represent order flows, and solid arrows for material flows. The strong arrows are related to customer orders, while the thinner arrows depict inventory replenishment of the channel members.

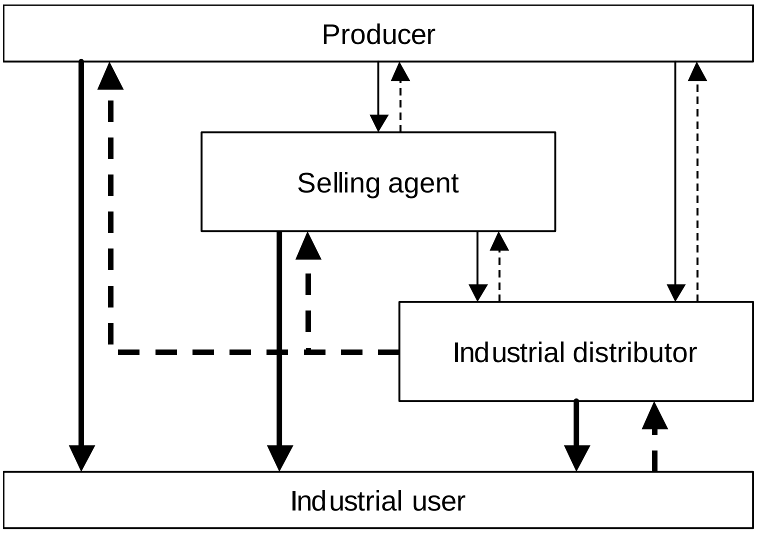


Figure 5 Structural separation of order and material flows in industrial goods distribution

A problem with this approach is that it results in multiple deliveries to the customer, which increases the costs in reception activities (Kärkkäinen et al., 2002). And in cases, where the component deliveries form an entity, for example a pc-mainframe and a monitor, an unsynchronised delivery is hardly good customer service. The solution is to merge the individual deliveries in distribution centres while they are in transit, without having to store all goods in one place. This merge-in-transit structure is presented in Figure 6.

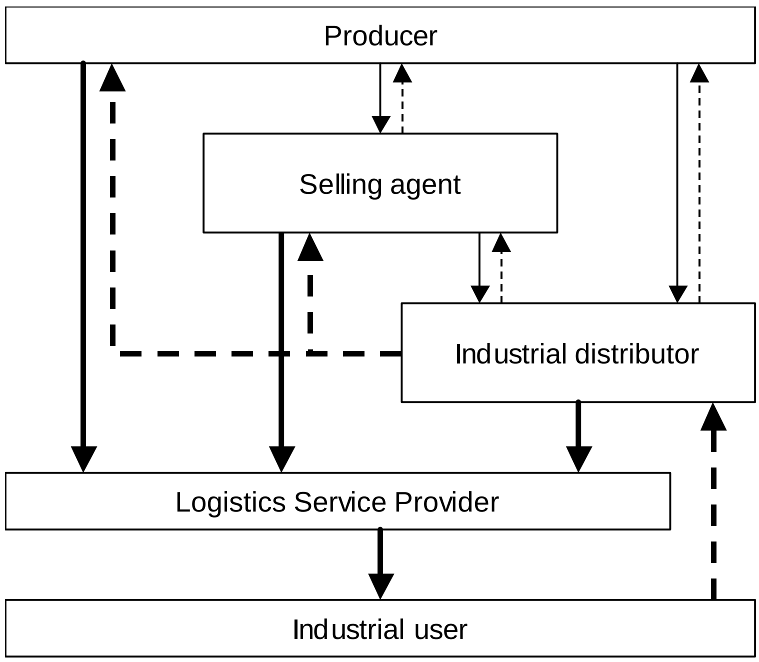


Figure 6 The merge-in-transit distribution channel

Benefits of structural separation result from channel participants being able to specialise in their own areas (Bowersox and Closs, 1996, pp. 479-482). In merge-in-transit distribution the logistics service provider takes care of the logistical channel with services such as transportation, material handling, and consolidation of customer orders. Meanwhile, the industrial distributor can specialise in providing marketing services, such as negotiating sales, credit, and advertising. This arrangement reduces the distributor's need to have products stored in its own warehouse, as it can provide the same customer service with merge-in-transit as with consolidated deliveries from its own warehouse.

However, not all product deliveries can benefit from the merge-in-transit arrangement. Warehousing products is justified for the wholesaler, if the producer of the goods does not have a local selling agent with inventory, thus making the response time too long to enable the merge-in-transit process.

Direct deliveries from the supplier to the customer are the most cost efficient distribution mode for bulky products that easily make up full truckloads, as the transportation through a merging distribution centre cannot add any further value to the delivery. Another benefit of direct deliveries is the shortest possible lead-time from supplier to customer (Simchi-Levi et al., 2000, p.113), since the goods are not stored in the distribution chain and the delivery is not dependent on the lead-times of other goods in a consolidated delivery.

As a summary, there are three basic alternatives for a wholesaler to arrange the distribution: Direct deliveries from the supplier to the customer, deliveries through its warehouse, and merge-in-transit deliveries. The optimum distribution strategy is most likely a combination of all these, depending on the individual goods.

The aim of this thesis is to provide tools for assessing the operational costs of logistics and the costs of the needed information technology infrastructure in merge-in-transit. Although the operational costs are not the only criteria for selecting the appropriate distribution strategy for each product, they play a very essential part in making well-founded decisions. An in-depth discussion of the strategic aspects of distribution logistics management can be found in Korpela (1994). Lambert, Stock, and Ellram (1998, p 559) present three basic requirements for logistics strategies planning, that indicate the significance of the cost analysis:

> *"(1) A thorough grasp and support of corporate strategy and supporting marketing plans in order to optimise cost-service trade-offs, (2) A thorough understanding of how customers view the importance of various customer service elements, and the performance of the firm compared with its competitors, and (3) A knowledge of the cost and profitability of channel alternatives."*

The next section discusses the current knowledge in merge-in-transit distribution. In the section after that, methods for analysing the logistics costs are presented.

2.1.2 Merge-in-transit distribution

Definition of merge-in-transit. There is very little published research on the merge-in-transit concept, although several companies have successful implementations with some of their partners (e.g. Richardson, 1994; Dawe, 1997; Norelius, 2002). The most extensive study related to merge-in-transit I managed to come across is a recent licentiate thesis by Hans Norelius (2002). He suggests the following definition for merge-in-transit:

> *"Merge in Transit is the centralised co-ordination of customer orders where goods are delivered from several dispatch units consolidated into single customer deliveries at merge points, free of inventory"*

His definition covers well the descriptions of merge-in-transit processes found in other sources.

Consolidating deliveries to gain cost savings in transportation is not a new idea. Deliveries from several local producers have long been consolidated in the region to have full containers transported to international markets (Christopher, 1992, pp.116-118). The difference in merge-in-transit is that volumes are much smaller, as the consolidated deliveries are formed for one customer order. The operations required in the merge points are actually very similar to those needed for cross-docking. As Norelius (2002) states, *"The emerging distribution structure Merge in Transit is a further development of the cross-docking concept"*.

In the literature, no clear distinction between cross-docking and merge-in-transit seems to be available. A general description for cross-docking can be found in (Simchi-Levi et al., 2000, p. 112):

> *"In this strategy, items are distributed continuously from suppliers through warehouses to customers. However, the warehouses rarely keep the items for more than 10 to 15 hours."*

The cross-docking concept was created by Wal-Mart (Stalk et al., 1992). Today typical implementations of cross-docking are between manufacturers and retailers (Aichlmayr, 2001) or sub-contractors and manufacturers (Witt, 1998). This reveals perhaps the most significant structural difference to merge-in-transit: In cross-docking the distribution network between suppliers and customers is static, while in merge-in-transit the orders come from individual customers not integrated to the distribution channel. Another major distinction is the difference in transportation volumes and frequencies: Cross-docking often involves full pallets flowing from manufacturer to retailer, whereas in merge-in-transit the handled units may be individual products.

Examples of merge-in-transit. Although implementations of in-transit merging of products may have been done somewhat earlier, one of the first articles where operations of merging shipments in-transit are described is written by E. J. Muller

(1992). He reports of “Merge Centres”, where Skyway configures orders for Hewlett Packard in-transit. Dell was also among the first companies to utilise merge-in-transit distribution (Richardson, 1994), and is probably the best known example due to frequent citations to their business model. Richard L. Dawe (1997) presents another early example of a global enterprise with merge-in-transit distribution, Cisco Systems.

Both the Hewlett Packard and Dell distribution models are described also in (Norelius, 2002), along with the merge-in-transit model of Ikea that is studied more thoroughly. Ikea developed its distribution channel to respond to customer requests for home-delivery and assembly. The famous Ikea cash and carry concept could not provide these services efficiently. In the new customer distribution channel the roughly 2,000 suppliers of Ikea deliver to one central warehouse, from which the products are delivered to customer orders via one of seven Local Service Centres. Six of the producers manufacture customer specific products that are delivered directly to the LSC and merged with the standard products coming from the central warehouse. The customer then receives one delivery for her order. This arrangement means that there are in fact only seven dispatching units for the merging process.

The central similarity in the above case descriptions is that they are all manufacturer-managed merge-in-transit systems. On the supplier side of the delivery chain there are a limited number of fairly fixed partners and own production units of the company. The situation is somewhat different when a distributor sets up a merge-in-transit channel. The number of suppliers is likely to be much bigger, as it is in the interest of a distributor to provide a wide product assortment to its customers.

Norelius (2002) presents also a merge-in-transit case of a retailer: Bokus.com, the Nordic Internet bookstore that was merged with Bol.com in year 2000. Before that, Bokus had 1,6 million book titles from more than 10,000 suppliers on offer, with no own inventory. The merge point was in Arlöv, Sweden, where the Swedish Post took care of the operations. After the consolidation of a customer order was ready, the final delivery was done with the Post’s normal flow of letters and parcels. The difference to industrial distribution is the size of the parcels to be consolidated. In this case the work in the merging centre was done mostly manually.

Effects of merge-in-transit reported in the literature. The following cost and service benefits are described both by Norelius (2002) and a study prepared by Jan Fransoo and Laura Kopczak (Bradley et al., 1998; Anon., 2002).

- *Reduced inventory and warehousing costs*. Upstream centralisation of inventories reduces the required safety stock level and eliminates stock keeping activities.
- *Increased or reduced transportation costs*. Smaller shipment sizes increase the transportation costs, but this can be substantially compensated by consolidation and shorter distances.
- *Delivery of one complete shipment to the customer's premises*. This is enabled by coordination of order and material flows.
- *Increased supply chain visibility*. Manufacturers can utilise Point of Sales data, which pushes the information decoupling point further back upstream and enables postponement both in time and form. These further reduce uncertainty and cost of forecast calculation.
- *Reduced cycle times from customer order receipt to delivery*. The removal of inventory in the chain allows manufacturers to benefit from postponement.
- *Improved customer service*. Improved coordination of the distribution chain and removal of inventories increases flexibility to meet changes in demand patterns. It is also possible to offer customer specific products and a wider variety of goods from a larger pool of suppliers without increasing inventories.

The first three items have an immediate impact on the distribution chain, meaning that they result directly from the merge-in-transit operations. The latter three items are only potential effects, in that they require additional changes in operations to benefit the distribution chain partners.

In addition, Norelius (2002) states the following effects:

- *Reduced administrative costs*, due to elimination of administrative activities and use of scale economies.
- *Increased complexity*, due to requirements for coordination of order and material flows

- *Increased customer order lead time for accessible products* (i.e. products available in stores), due to additional activities in the customer order cycle compared to customer pick-up from stores.

The first two effects may counteract each other, if the complexity is not managed with a reasonable level of automation. The last effect can be found mainly in retail business, as customers of wholesalers and distributors seldom prefer picking up their goods themselves.

The actual cost and service impact of all the listed merge-in-transit effects depend on the channel structure, and they must be evaluated for each case separately.

Drivers and enablers for merge-in-transit. The reasons for merge-in-transit gaining attention are both economical and technological. Competition drives companies to seek cost and service benefits whenever possible, while the technological development enables new operational models.

The need to reduce costs related to inventories is the key driver for many industries. Especially in the high tech industry, high product costs mean high inventory costs and the rapid technological changes result in high obsolescence costs (Anon., 2002). For such industries, form and time postponement available with merge-in-transit distribution can be especially beneficial (Pagh and Cooper, 1998).

Increasing profits through increased customer service is another major driver. Deliveries of complete shipments and increasing available product variety without investments in inventories are the value proposals of merge-in-transit distribution sought for in most of the above example cases. And, some customers do not just expect deliveries to be complete; they require it (Anon., 2002).

The main technological enablers presented in (Anon., 2002) are the development of global tracking and tracing and the development of integration technologies for different IT applications, both essential for a merge-in-transit system to be functional (Norelius, 2002; McLeod, 1999).

Requirements for merge-in-transit. Setting up a merge-in-transit distribution channel involves several challenges that need to be considered. The challenges can be divided in three categories: Technical requirements, business relationships, and implementation project planning.

The main technical requirements are merge point operational capabilities, reliable shipment tracking, and information systems capable of providing correct and up-to-date information for all parties (McLeod, 1999; Dawe, 1997; Norelius, 2002). The requirements and alternatives related to information systems are further discussed in section 2.2.

The time critical nature of merge-in-transit operations requires partner dependability for the wholesaler, as she makes the customer a promise the other channel participants need to fill. The suppliers must be able to make the ordered goods available on time, and the logistics service provider must be able to consolidate and deliver the shipments on time (McLeod, 1999; Schaffer, 1997). Another reason for tight cooperation with the suppliers and logistics service providers is the changing cost structure (Schaffer, 1997). Wholesaler inventory is pushed back in the chain, the suppliers need to deliver for individual customer orders, and a new activity of consolidation operations is added to the distribution chain. The resulting savings for the entire supply chain have to be allocated properly to make all participants realise the benefits of merge-in-transit distribution. In this context, it is again particularly useful to be aware of the cost structure of the operations.

The merge-in-transit implementation project requires careful planning and management, including the following aspects (Anon., 2002):

- Detailed business process analysis
- Project planning, including activity definition and allocation
- Frequent communication and project status updates
- Careful management of changes to the scope of the project
- Detailed performance metrics to measure the effectiveness of the entire supply chain, including transport, merge and delivery activities.

2.1.3 Identifying cost elements in distribution

In (Anon., 2002) and in (Norelius, 2002) benefits achievable with merge-in-transit are discussed, but studies on how to evaluate the applicability of merge-in-transit in different business situations are not found in the literature. This section discusses the activity-based costing model for assessing the operational costs of merge-in-transit.

The difficulty of assessing costs of distribution is mainly due to the shortcomings of traditional accounting operations that do not provide enough detailed information. Bowersox and Closs (1996, p. 642) claim that the use of activity-based costing is the most promising way to identify and control logistics expenses. This approach is especially well suited for assessing total costs over organisational boundaries, as the fundamental concept of activity-based costing is that expenses are assigned to the activity that consumes a resource rather than to an organisational or budget unit. In the case of logistics, the key event is a customer order that requires certain activities to be performed to fulfil the order. The costs of these activities, independent of where performed, form the total logistics costs of the order.

At the VTT (Technical Research Centre of Finland) logistics processes research, the logistics costs are defined to result from these operations (Manunen, 2000): Transportation, forwarding, customs operations, warehousing, purchasing, ordering, payment transactions, materials management in production, sales, and recycling.

Manunen further identifies seven cost elements relevant in assessing costs for wholesalers and manufacturers:

- Purchasing costs
- Transportation costs
- Warehousing costs, divided in
    - Inbound logistics costs: receiving inspection, and shelving
    - Outbound logistics costs: picking, packaging, and shipping
    - Storage costs: equipment and space
    - Inventory holding costs
- Sales: the costs of receiving orders

While the first and last of the above operations are related to the order flow, the remaining five elements are relevant in the scope of this thesis, the costs of material flow in wholesaler distribution.

The cost calculation models for each of the activities are presented in detail in Appendix 1, and the application of the calculation model is presented in section 3.2.1.

2.2 Logistics information systems

In the first section, requirements for the information systems integrating supply chain partners are reviewed. The focus is on the information flows necessary for the execution of customer delivery. In the second section, the alternatives for implementing the integration are discussed, and the relationship between traditional alternatives and the suggested product centric approach is explained.

2.2.1 Supply chain integration

Historically, companies have thought they have to compete with others in order to be profitable. This mindset extended to encompass also suppliers and customers, with whom the competition took place in the price negotiations for the supplied items. Presently the concept of supply chain management has addressed these conflicts to create a more holistic view of the operations needed to fulfil the final customer demand.

Christopher (1992, p.13) presents four differences between supply chain management and the classic materials and manufacturing control. First, the supply chain is viewed as a single entity. Second, management of the supply chain calls for strategic decision-making. Third, inventories are viewed as a balancing mechanism of last, not first resort. And finally, supply chain management requires integration between the partners, rather than mere interfaces.

The three first aspects were discussed in the previous section. The fourth aspect, integration, places specific requirements for logistics information systems, which are reviewed in the following from the merge-in-transit distribution viewpoint.

Bowersox and Closs (1996, pp. 194-201) present the general architecture for logistics information systems. They make a distinction between coordination and operation information flows, as illustrated in Figure 7. Coordination flows include activities necessary to schedule procurement, production and logistics resource allocation, whereas operating flows deal with transaction activities needed to fulfil customer orders. The focus in this thesis is in the requirements of distribution and transportation operations highlighted with a dotted line in Figure 7.

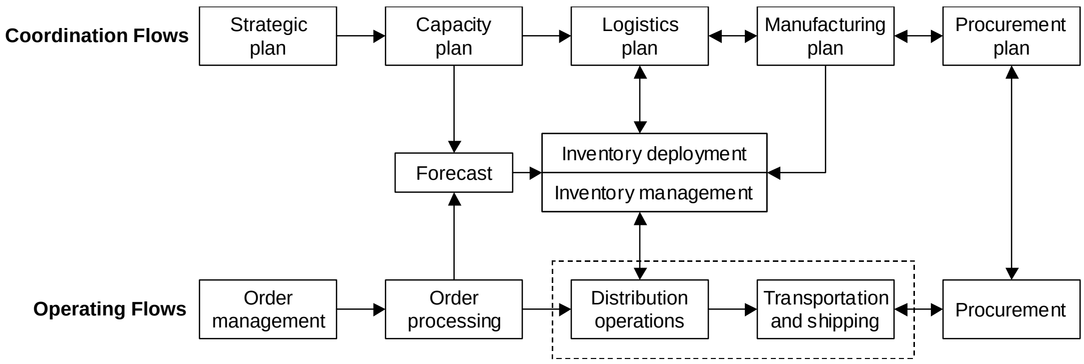


Figure 7 Logistics information system architecture (Bowersox and Closs, 1996) and the focus in this thesis.

The distribution operations control the activities in distribution centres. The operations use batch and real-time assignments. In a batch environment, instruction and task lists are created to guide the material handlers in the warehouse. In a real-time environment information-directed technologies provide more operation flexibility and reduce internal performance-cycle time requirements. This is essential in the time critical merge-in-transit operations, where each incoming parcel should be identified and merged directly to the correct outbound consolidated delivery.

The transportation and shipping operations include functions to plan, execute, and manage transport and movement activities. In the merge-in-transit distribution, these functions require information from all the parties related to the activities: suppliers, the logistics service provider, and the wholesaler. The minimum information to be shared includes orders, shipment notifications, and transport documents. The large amount of these types of information to be transferred makes automated and exception-based communications a necessity. It is also essential to be able to track the shipments to be consolidated (McLeod, 1999).

The current experiences with merge-in-transit and the very similar cross-docking operations show that the essential requirements for the information exchange are availability, accuracy, and timeliness (Aichlmayr, 2001; Richardson, 1999; McLeod, 1999; Pedler, 1994). Bowersox and Closs (1996, pp. 190-193) give extensive definitions for these logistical information requirements. Availability means the ability to access and update necessary information, such as order status, regardless of managerial, customer, or product order location. Accuracy is defined as the degree to which available information reflects the actual physical counts or status. Timeliness refers to the delay between when an activity occurs and when the activity is visible in the information system.

In the next section, available solution strategies are reviewed with regard to the requirements presented here. The applicability of the solutions for merge-in-transit is also discussed.

2.2.2 Alternative solution strategies for implementing logistics information systems for multi-company networks

Logistics information systems that cover several companies need to rely on automated information exchange, which is evident considering the requirements for the information stated in the previous section. Automation can be achieved with software solutions, called middleware, connecting the business applications between participating companies.

Traditionally, the middleware has been based on message queuing, i.e. sending messages from Company A’s application X to Company B’s application Y. This unfortunately provides only a point-to-point solution, and linking additional applications leads to a complex web of individual connections. Another disadvantage of traditional systems is that they often require changes in the source and target systems to make the data to be forwarded understandable for the specifications of the middleware. These properties significantly reduce the ability to react to changes in the company network. (Linthicum, 2001, pp. 9-15)

While there has been intense development on the field of business-to-business application integration to enable the communications between multiple parties, no individual solution with superior performance has been able to penetrate markets. This has led to the multitude of messaging standards in use, including proprietary communication mechanisms. As stated by David Linthicum (2001, p.327): “*The hodgepodge of technologies and standards that has resulted from these various in-house decisions will remain in place as we seek to address the supply chain integration problem.*”

Among the alternatives available, the best-known communication model is Electronic Data Interchange (EDI), as it has been the key technology for enabling the integration in supply chains (Angeles and Nath, 2001). Despite its rather old technology and complexity of implementation, new connections are still actively created relying on the proven and robust concept it offers. Therefore, I will use EDI as the comparison between the traditional approach and the new product centric approach presented in section 1.2 in the introduction chapter.

Two essential components need to be considered in order to enable exchange of data between applications: How to make the data in the application available to the middleware, and how does the middleware provide the communication link?

When using EDI, the applications need to provide an output message related to an event requiring data transfer (e.g. an order is input). This message is accepted by EDI translator software, which converts it to a standard EDI message.

The proposed system is database-oriented, meaning that the software agent connects directly to the database of the application participating in multi-company communication. Entry tables necessary for the merge-in-transit process can be created in the databases, meaning that the agent can access and modify the data with no need for converting any output messages.

Typically, the message-oriented EDI relies on transferring electronic documents through a specific Value Added Network (VAN) operated by an independent service provider. The messages are generally sent as batches between company-specific “mail boxes” at the service provider (Witt, 1998; Linthicum, 2001), which means that EDI does not provide true real-time communications. Various alternatives for implementing EDI are presented in the section 3.4, where the costs of implementation are assessed.

Using EDI (or any message-oriented middleware) to transfer delivery information needed in consolidation means that the information has to be sent in advance to the merging centre and later married again with the shipment. These messages are called Advance Shipping Notices (ASN). In some cases, the batch nature of the transactions makes EDI infeasible for merge-in-transit use. Such a situation occurs, if the delivery time to the consolidation centre is shorter than the interval of transmitting the EDI batches: the parcel arrives at the centre before the associated information (Tirkkonen, 2002).

The product centric system works the other way around. Data transfer takes only place, when the information regarding a shipment is needed or created. As data is accessed and modified in real-time at the original database over the Internet, accurate and up-to-date information concerning the shipment is always available, regardless of the location where it is needed.

It seems therefore safe to argue that the proposed system fulfils the requirements of availability, accuracy, and timeliness better than a traditional message-based system.

The above discussion is summarised in Table 1. The implications of the product centric approach in implementing logistics information systems for merge-in-transit are discussed closer in section 3.4.

Table 1 Summary of the characteristics of EDI and the proposed system

	EDI	The proposed system
Operational characteristics		
Information transfer mode	Push: Information sent proactively	Pull: Information retrieved when needed
Material and information flows	Separated: shipments and related information need to be linked to enable logistics operations	Integrated: information always connected to the correct logistical unit
Adding a participant to a communication network	Everyone needing to communicate with the new partner has to create a communication link to her.	No efforts necessary for existing participants
Technical characteristics		
Data access for the middleware	Message-oriented: applications need to provide output messages and accept input messages	Database-oriented: the data is retrieved from and stored in the database of the application
Communication link	Typically provided by a service provider, newer approaches use the Internet	Over the Internet
The essential requirements for information exchange in merge-in-transit		
Availability	A partner has access to pieces of information only if they have been sent to her	All authorised partners can access and update information continuously
Accuracy	Information accurate only if no changes have occurred after message transfer Several dissimilar instances of the same data may exist	Single instance of data: always up-to-date.
Timeliness	Non real-time: New information available only after sent to and received by other parties	Real-time: All new data instantly available to authorised parties

3 THE MODEL TO ANALYSE BENEFITS OF MERGE-IN-TRANSIT PROCESS

To assess the potential benefits of merge-in-transit, the new process must be compared to alternative distribution channels. This comparison needs to be carried out for specific distribution situations. In this chapter a model is presented to analyse the feasibility of merge-in-transit distribution in replacing other distribution channels. The model consists of four distinct parts.

In the first part of the model a merge-in-transit scenario is constructed as an alternative for current distribution operations. In the second part, the process is analysed from a logistical point-of-view, as to what are the operational costs of physical distribution in each of the distribution models. In addition, the potential service benefits of merge-in-transit are assessed.

Should merge-in-transit prove to be an attractive alternative from the operational viewpoint, the assessment proceeds to implementation aspects. In the third part the requirements for necessary information systems are assessed for the constructed scenario. And finally, in the fourth part the costs of traditional information system integration models and the costs of the proposed product centric control system are assessed for the merge-in-transit distribution channel, and their impacts on scalability are evaluated.

A flowchart of the model is presented in Figure 8 with the individual steps needed in the evaluation process. The numbering in the figure provides the structure for this chapter, and each of the sections is briefly described below.

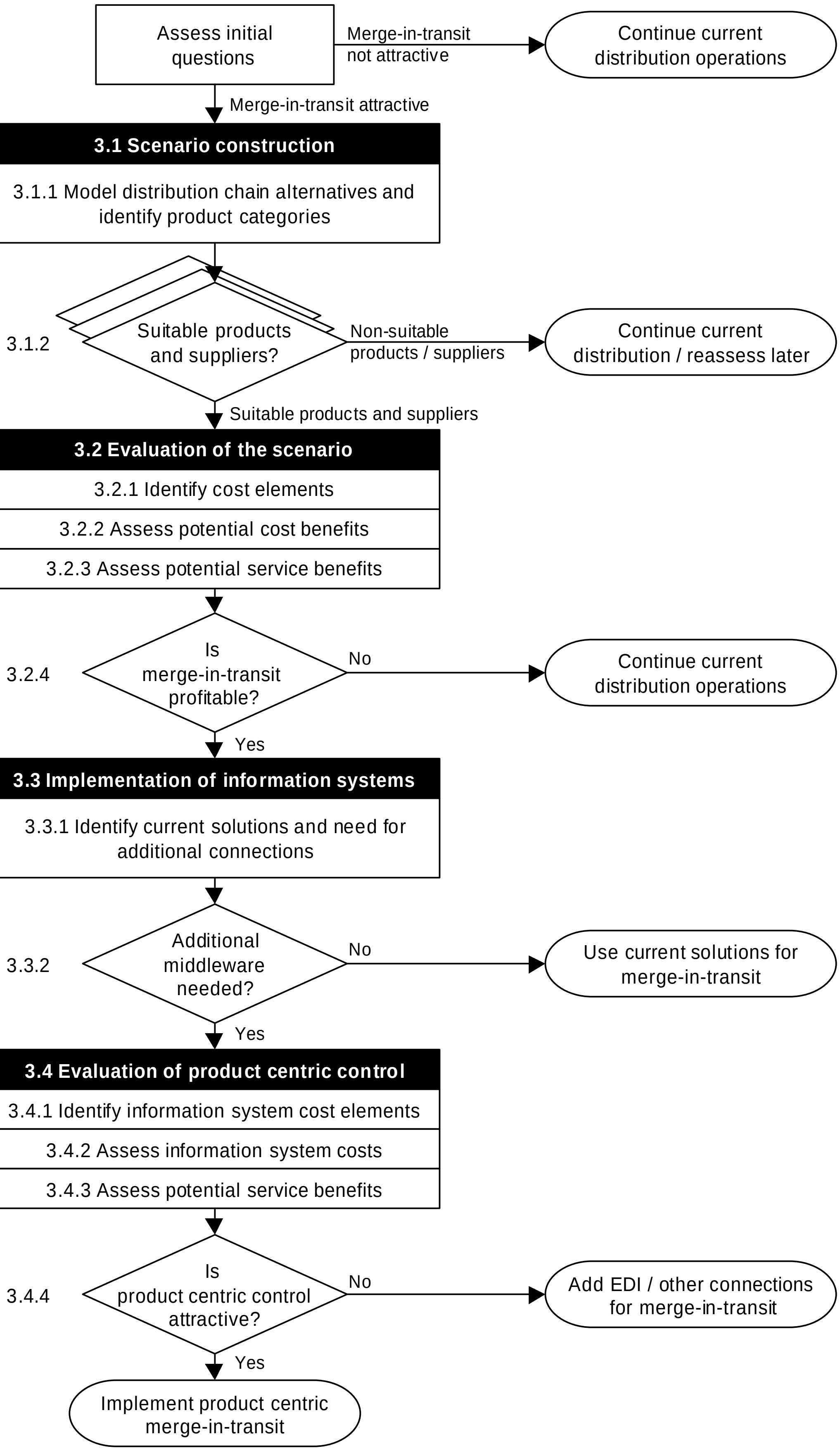


Figure 8 Illustration of the model to analyse benefits of merge-in-transit process

3.1 Construction of a merge-in-transit scenario

The distribution situation that is compared with merge-in-transit needs to be understood and the corresponding merge-in-transit scenario constructed. Suitable products and suppliers are identified for the merge-in-transit operations.

3.2 Evaluation of the constructed scenario

In order to assess the total costs of operations, the cost elements in the current operations and the merge-in-transit scenario are identified. Depending on the business situation, the costs with current operations and the merge-in-transit scenario are assessed based on total distribution costs for each fulfilled order or yearly distribution costs for one supplier.

Before making the judgement of the superiority of either of the distribution channel alternatives, the service benefits resulting from merge-in-transit are evaluated. Slightly higher operational costs may be justified, if other valuable benefits are attainable.

Finally, the merge-in-transit scenario is evaluated as a whole. The results show whether or not the merge-in-transit operations could benefit the distribution chain.

3.3 Construction of a product centric scenario for merge-in-transit

The basic alternatives for achieving the necessary integration between merge-in-transit partners are reviewed. Special attention is given to the proposed system utilising product centric control in delivery chains.

A short checklist is presented to identify the required information for assessing the potential solutions and their suitability for a distribution situation.

3.4 Evaluation of product centric control for merge-in-transit

To assess the costs of implementing and using information systems, the cost elements are identified. The costs of information system solutions are assessed based on the cost elements and required number and type of implementations. Implications of using the product centric system are reviewed to provide an outlook on the applicability of the new approach in multi-company environments.

Finally, the product centric control system for the merge-in-transit scenario is evaluated as a whole. The result is whether or not to seek an implementation utilising the proposed system.

Through this chapter a case company is used as an example distribution situation for assessing the potential benefits of merge-in-transit with the model. The case company is a distributor that offers its customers some 2,500,000 different products from 500 individual suppliers. The number of stock keeping units is so vast, that the distributor could not possibly store all the products in its own warehouse. A large number of the products have therefore been delivered directly to the customer by their respective suppliers. The result has been that the customer receives several deliveries to have one order fulfilled. To improve its customer service, by providing a single delivery for a single order, and to reduce the units flowing through its warehouse, the distributor launched a project to employ merge-in-transit with selected suppliers. In order to evaluate the effects of replacing direct deliveries with merge-in-transit distribution, a calculation model was designed for the company (Kärkkäinen, Punakivi, and Ala-Risku, 2002). In this thesis, the model has been completed to include cost assessment for replacing warehouse deliveries. The calculation model is presented in Appendix 1. A summary of the company case is presented in section 3.5.

Some initial questions to assess the attractiveness of merge-in-transit in a specific distribution chain are listed in Figure 9 below. Should the questions receive positive answers, it is worthwhile to have a closer look on the potential benefits of the merge-in-transit concept for that distribution chain. If the benefits prove not to be attractive or feasible with the distribution situation under evaluation, it may be that merge-in-transit distribution is an unsuitable solution for the specific situation.

Could merge-in-transit be beneficial for a specific distribution chain?
Does the distribution chain include warehouses other than those of suppliers and customers? If yes, • Are products transported to the warehouse only to wait for the eventual customer delivery, with no value added services in the warehouse? • Do the products in the warehouse suffer from markdown or obsolescence? • Do the products in the warehouse have suppliers or importers capable of delivering within the lead-time of customer orders? ⇒ Merge-in-transit distribution can reduce inventories in the chain **Warehouse deliveries from the customer service viewpoint:** • Do customers request products that are not available in current assortment? • Is the narrowness of assortment due to inventory carrying costs? • Would the requested products be a valuable addition to the assortment? ⇒ With merge-in-transit distribution a wider range of products can be offered **Are suppliers commonly delivering less than truckload deliveries directly to customers?** If yes, • Are these suppliers delivering to all customers, not only to their local geographical area? • Do customers constantly receive multiple deliveries for their orders? ⇒ In merge-in-transit distribution one delivery is made for one order **Direct deliveries from the customer's viewpoint:** • Do some products have high variability in stock level due to infrequent orders resulting from high delivery costs? • Would smaller, more frequent deliveries be desirable? • What would the effect be on the stock levels? ⇒ In merge-in-transit distribution deliveries are consolidated to reduce the delivery costs **Direct deliveries from the supplier's viewpoint:** • Are more than one delivery sent daily to fulfil customer orders of the distributor or wholesaler? • Could these deliveries all be made with one daily delivery, if delivered to a single distribution centre or picked up once a day? ⇒ With merge-in-transit distribution a delivery schedule can be set up **Is order status information hard to obtain?** If yes, • Do customers often make inquiries about the progress of their order? • Are such events frequent? ⇒ Merge-in-transit distribution promotes tracking of deliveries, as it is an integral part of the distribution process

Figure 9 Questions for assessing the potential benefits of merge-in-transit.

3.1 Construction of a merge-in-transit scenario

In this section the construction of a merge-in-transit scenario is described. The goal is to model the current distribution chain and to construct an alternative distribution channel utilising merge-in-transit. A checklist is provided as a summary of the decisive elements in the scenario construction.

3.1.1 Modeling the distribution chain alternatives

The three basic alternative distribution chain structures for a wholesaler or distributor are direct deliveries from suppliers, deliveries from own warehouses and merge-in-transit deliveries (see section 2.1.1).

Direct deliveries are the most cost-effective solution for high volume orders, where the ordered amounts are big enough to form a full or near full truckload for a single supplier. Warehousing is necessary, when products have long lead times compared to required customer delivery times, e.g. imported products. Warehousing can also be justified for durable low-cost products with low warehousing costs. For less than truckload deliveries of products with high value, substantial depreciation for obsolescence, or high warehousing costs, merge-in-transit distribution is a competitive solution.

The first thing to do when building a merge-in-transit scenario as an alternative for current operations is to identify the product categories for which the operations would be suitable. The products that are imported by the distributor should be excluded from the merge-in-transit scenario, if there are no alternative importers or suppliers available inside such a range that transportation to a consolidation centre is feasible within customer order lead-time. Correspondingly, bulky products delivered directly from the suppliers in full truckload quantities can be excluded, as they need not be merged with other deliveries. However, if there is a need to reduce lot sizes for such products, they should be included in the scenario.

After sorting out the unsuitable products, the current delivery chain for the remaining products is modelled. This includes identification of the suppliers, their geographical locations and sales volumes. Additionally, the locations of distributor warehouses, their product-specific inventory values and inventory turns need to be discovered. And finally, the geographical distribution of customers and sales volumes is estimated.

The implementation of merge-in-transit can be started with only a few supplier partners. For the selection of the first suppliers several criteria must be considered. The selection can be based on supplier characteristics such as sales volumes, geographical locations, capability to deliver customer order sized lots, delivery accuracy, or capability and motivation to participate in distribution chain development efforts.

Another important selection concerns the logistics service provider. The most important criterion is, of course, that the logistics company needs to provide consolidation services at reasonably located distribution centres. The service provider also has to commit to the development efforts of the merge-in-transit process.

After identifying the potential suppliers and products for merge-in-transit, the delivery chain for current material flows is modelled. Correspondingly, the merge-in-transit scenario is constructed with the material flows through the consolidation centres.

Sorting out the non-suitable products and suppliers for the case company, the remaining material flows with potential for merge-in-transit distribution are illustrated in Figure 10. The case distributor has one central warehouse, to which the majority of suppliers deliver. Some suppliers deliver only directly to the customers and some both to the customer and to the warehouse. Currently, it is estimated that about twenty percent of the material flow will remain outside the merge-in-transit operations in direct delivery mode, as some products have special requirements for their distribution.

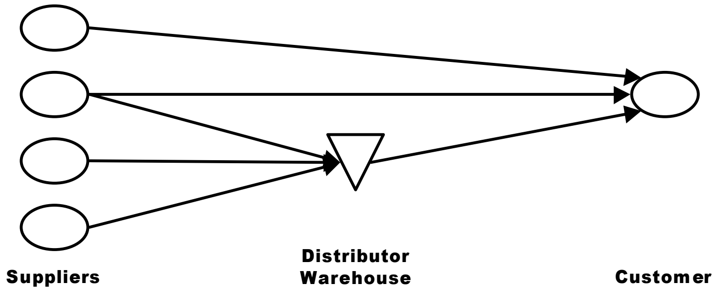


Figure 10 The original material flows for the case company

The constructed merge-in-transit scenario for the selected products and suppliers is illustrated in Figure 11. The distributor warehouse is modelled as one of the suppliers, since there are products that remain warehoused by the distributor for the time being.

The merge-in-transit distribution has now been started with a few suppliers that benefit from the possibility to perform high volume deliveries to one distribution centre regardless of the individual customers' locations. However, the target of the merge-in-transit implementation project is to eventually remove the distributor warehouse from the distribution chain by moving all the warehouse suppliers to the merge-in-transit process.

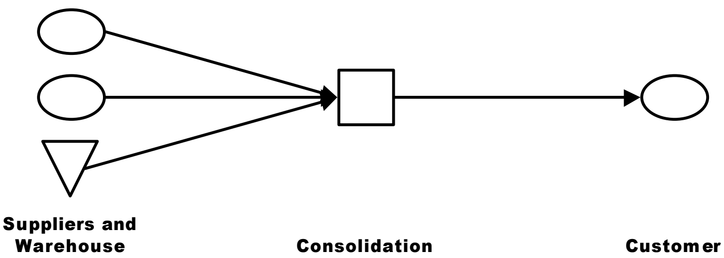


Figure 11 The constructed merge-in-transit scenario for the case company

3.1.2 Checklist for the merge-in-transit scenario

The following checklist provides a summary of the central criteria for selecting products and suppliers with potential in benefiting from merge-in-transit distribution.

CHECKPOINT

Do warehoused products have suppliers or importers capable of delivering to a consolidation centre within the customer order lead-time?

- If yes, merge-in-transit may be a beneficial distribution channel.
- If not, merge-in-transit distribution is infeasible for those products

Are suppliers capable of delivering customer order sized lots?

- If yes, merge-in-transit may be a beneficial distribution channel.
- If not, it may be necessary to deliver the products through a distributor warehouse.

Are products delivered directly from suppliers in less than truckload quantities?

- If yes, merge-in-transit may be a beneficial distribution channel.
- If direct deliveries are made in full truckload quantities, and smaller lot sizes are not desired, merge-in-transit distribution cannot provide cost benefits.

If the majority of products offered by the distributor are imported products, there may be little point in arranging a merge-in-transit distribution channel for the smaller part of the product assortment. Correspondingly, if the majority of the products are sold in full or near full truckload quantities with no requirements for smaller lot sizes, merge-in-transit probably cannot provide reasonable benefits.

For the potential products and suppliers, the current operations and the merge-in-transit scenario are modelled as described above. The next step is to evaluate the costs and benefits of merge-in-transit by comparing the current distribution chain with the constructed scenario.

3.2 Evaluation of the constructed scenario

In this section a model to evaluate costs and benefits of merge-in-transit distribution is presented. First, the activities in the alternative distribution channels are identified and their respective costing models are presented. Second, the usage of the costing models is illustrated with the case company. Finally, the service benefits achievable with merge-in-transit are examined.

3.2.1 Cost elements of the merge-in-transit scenarios

In this section the activities and cost elements of distribution are presented. Six distinctive activities can be identified in the three distribution channel alternatives of direct deliveries, warehouse deliveries, and merge-in-transit deliveries. These activities are illustrated in Figure 12. The picking activity at each supplier and the receiving activity at the customer are common to all distribution channels. Consolidation and warehousing activities are characteristic to merge-in-transit and warehouse delivery channels, respectively. Although present in all the channels, the transportation activities depend on the channel structure.

Seven logistics cost elements relevant for wholesaler supply chains are presented in section 2.2. In addition to the five in scope of this thesis (outbound and inbound logistics costs, transportation costs, storage costs, and inventory costs), one more cost element has to be included in order to assess the costs of the merge-in-transit distribution channel: Consolidation costs.

The cost elements can be assigned to the activities of Figure 12, as follows:

Order picking: Outbound logistics costs

Collection and customer delivery: Transportation costs

Consolidation: Consolidation costs

Warehousing: Inbound and outbound logistics costs, storage and inventory holding costs

Receiving: Inbound logistics costs

The calculation model for each of the cost elements is presented in Appendix 1.

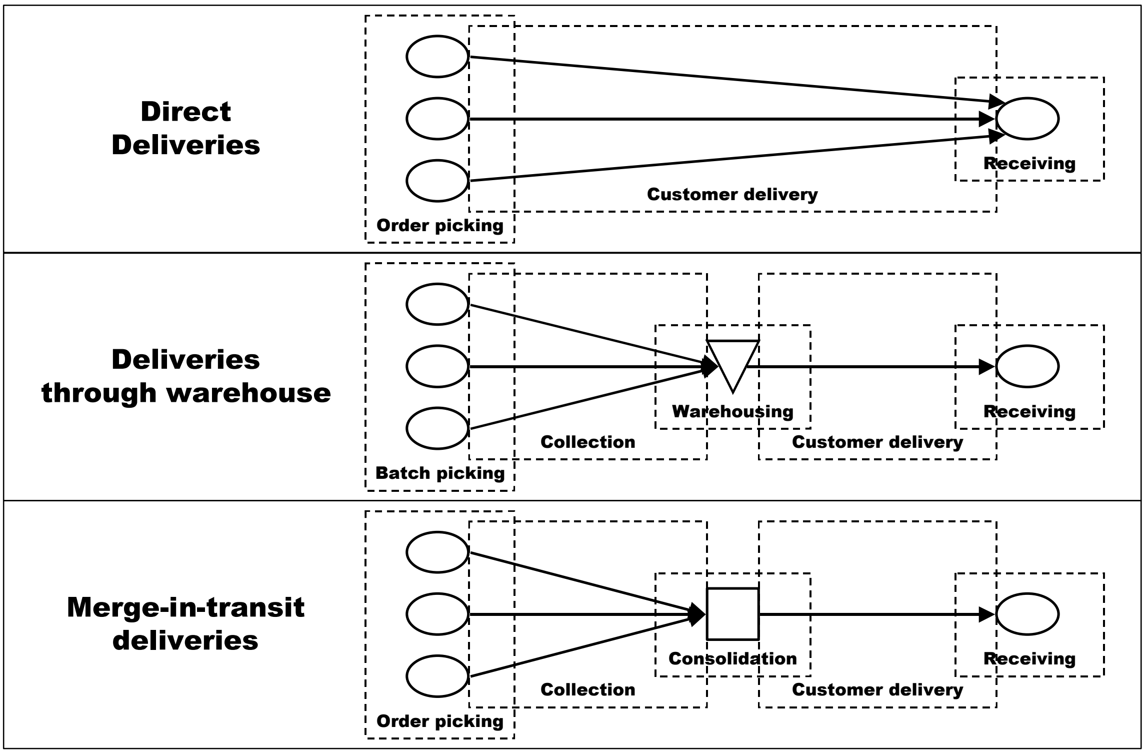


Figure 12 The activities needed in the different distribution channels

For the model, two types of data are needed. The data of the first type are external to the evaluated situations, i.e. they do not depend on the distribution models. These are:

- Transportation pricing table of a chosen logistics service provider
- Consolidation pricing table of a chosen logistics service provider
- Outbound logistics costs at suppliers (or on average in industry / warehouses)
- Inbound logistics costs at customer (or on average in industry / warehouses)

The second type data are internal characteristics of the case situation under consideration. The data includes figures such as:

- Number of suppliers for an average order
- Number of order lines in an average order
- Shipment weights
- Transportation distances
- Storage and inventory costs for stock-keeping units
- Order quantities
- Warehouse replenishment quantities
- Sales values of order lines

The required internal data depend on the situation to be evaluated.

3.2.2 Assessing potential cost benefits of merge-in-transit operations

With this step of the evaluation model, the costs of the constructed merge-in-transit scenario are compared with those resulting from current operations. To illustrate the use of the costing model based on distribution activities, a comparison of merge-in-transit distribution to both warehouse deliveries and direct deliveries is presented.

The distribution costs are viewed here from the delivery chain perspective. Even though the cost structure in the delivery chain changes when moving to merge-in-transit distribution, no recommendations are made on how to allocate the costs or savings among the participants. Eventually, the selection of the distribution channel with lowest total costs provides the entire supply chain a competitive advantage over its rivals.

To evaluate the differences in the distribution models, the costs incurred in different parts of the delivery chain are assessed. Two alternative approaches are presented to evaluate the costs:

1. Based on customer orders, i.e. what are the total distribution costs to fulfil one specific customer order, and

2. Based on individual suppliers, i.e. what are the yearly delivery costs for all the products of one supplier

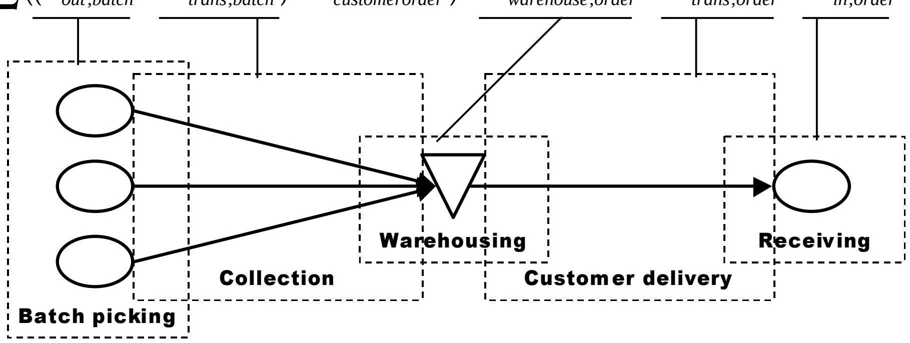
As products may differ in their suitability for merge-in-transit, the comparison of distribution models provides more useful results for distinct product categories, rather than an average of the total product assortment. For reliable results, it is necessary to compare several example deliveries inside each category, with characteristics representing the scale of various deliveries as closely as possible.

Deliveries through distributor warehouse versus merge-in-transit. If there are warehouses in the delivery chain, where products from different suppliers are gathered just to wait for the eventual customer order, the most significant benefits of merge-in-transit can be expected to arise from reducing the operational and inventory carrying costs of these warehouses. The trade-off, however, is increased outbound logistics costs at the supplier, since the supplier shifts from delivering according to aggregated demand at the warehouse to shipping individual customer orders (batch picking vs. order picking in Figure 12). Also, the logistics service provider charges a fee on the consolidation operations. The costs of the final leg, the actual customer delivery and receiving, are essentially the same in both distribution models, as both include the same products in one delivery. A slight cost difference may result from differing transportation distances to the customer.

The costs of a delivery through a warehouse are calculated as follows: First, shares of the warehouse replenishment costs for each of the ordered products are allocated on one customer delivery. This can be done by multiplying the replenishment costs with an allocation factor based on the relation of customer order quantity to replenishment order quantity (see Appendix 1, formula 3). Second, the warehousing costs are calculated for each of the products. And finally, the costs of customer delivery and receiving are added to the previous figures. Adding up the cost elements illustrated in Figure 12 and evaluated according to the model of Appendix 1 results in:

Costs of delivering a customer order through the warehouse =

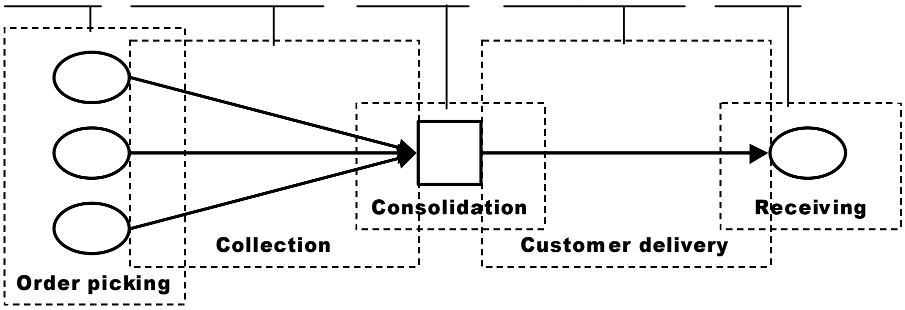
$$\sum\left(\left(C_{out,batch}+C_{trans,batch}\right)\times A_{customerorder}\right)+C_{warehouse,order}+C_{trans,order}+C_{in,order}$$



The costs of merge-in-transit distribution include order-picking costs at each supplier, delivery costs to distribution centre, consolidation costs, customer delivery, and receiving. The calculation of the cost elements for merge-in-transit is again conducted as explained in Appendix 1.

Costs of one merge-in-transit delivery =

$$C_{out,order} + C_{collection-trans,order} + C_{cons,order} + C_{delivery-trans,order} + C_{in,order}$$



If the costs of warehousing products for one order are greater than the costs to compile a consolidated delivery of the same order, it is worthwhile to consider moving to merge-in-transit operations for those products.

The second useful approach to assess the cost impact of merge-in-transit compared to warehousing is to evaluate the costs for the yearly deliveries of a supplier, since adding a supplier to the merge-in-transit distribution channel enables to process all its products through the new channel. Consequently, it is possible to remove all their stock-keeping units from the wholesaler warehouse.

The impact on yearly logistics costs by moving an additional supplier in the merge-in-transit process can be roughly estimated if the following figures are available:

- Warehouse replenishment:
  - Number of yearly replenishment deliveries from the supplier (N_{rdel})
  - Total number of order lines in yearly replenishment deliveries (N_{rlin})
  - Yearly transportation costs from supplier ($C_{trans, repl}$)
- Warehousing:
  - Storage and inventory costs for the suppliers products (C_{inv})
- Customer deliveries:
  - Number of yearly customer order lines for the products of the supplier (N_{clin})

- Number of yearly customer deliveries including products from the supplier (N_{cdel})
- Average number of order lines for the suppliers products in such a delivery ($N_{av,sol}$)
- Average number of order lines in total in a delivery ($N_{av,tol}$)
- Average weight of an order line of the products ($w_{av,lin}$)
- Average weight of a customer order ($w_{av,order}$)
- Average distance to customers for the products (d_{av})
- Distance from the supplier to consolidation centre (d_{cons})

The yearly warehousing costs can then be estimated by inserting the above figures in the costing model of Appendix 1:

Yearly costs for deliveries through a warehouse for one supplier's products =

$$C_{out}\left(N_{rdel}, N_{rlin}\right) + C_{trans,repl} + C_{inv} +$$

$$C_{trans}(w_{av,order}, d_{av}) \times N_{clin} \times \frac{w_{av,lin}}{w_{av,order}} + C_{in}\left(N_{cdel} \times \frac{N_{av,sol}}{N_{av,tol}}, N_{clin}\right)$$

The batch picking costs are calculated as a function of the number of replenishment orders and their total yearly order lines. The collection costs are assumed to be available in a bookkeeping system, as are the storage and inventory costs for the supplier's products in the distributor warehouses. The customer delivery costs are estimated as follows: First, the transportation costs of an average customer delivery are calculated and multiplied by the number of yearly deliveries including the supplier's products. And second, of these total delivery costs the share of an individual supplier is estimated based on average weights of the supplier's product order lines and of an average order. Finally, the receiving costs are evaluated as a function of a supplier's share of the customer orders including supplier's products and total yearly order lines for the products.

The yearly costs of merge-in-transit for the supplier's products are evaluated with the following elements of Appendix 1:

Yearly costs for merge-in-transit deliveries for one supplier's products =

$$C_{out}\left(N_{cdel}, N_{clin}\right) + N_{cdel} \times C_{trans}\left(w_{av,lin} \times N_{av,sol}, d_{cons}\right) + N_{clin} \times C_{cons}\left(w_{av,lin}\right) + C_{trans}(w_{av,order}, d_{av}) \times N_{clin} \times \frac{w_{av,lin}}{w_{av,order}} + C_{in}\left(N_{cdel} \times \frac{N_{av,sol}}{N_{av,tol}}, N_{clin}\right)$$

The order picking costs are evaluated with the number of yearly customer deliveries and order lines for the supplier through the distributor. Collection costs are approximated using average weights for the deliveries from the supplier to a consolidation centre. Also the consolidation cost estimation is based on average weights of customer order lines. The customer delivery costs and receiving costs at the customer are evaluated with the same elements as with warehouse deliveries, the only difference being the transportation distance.

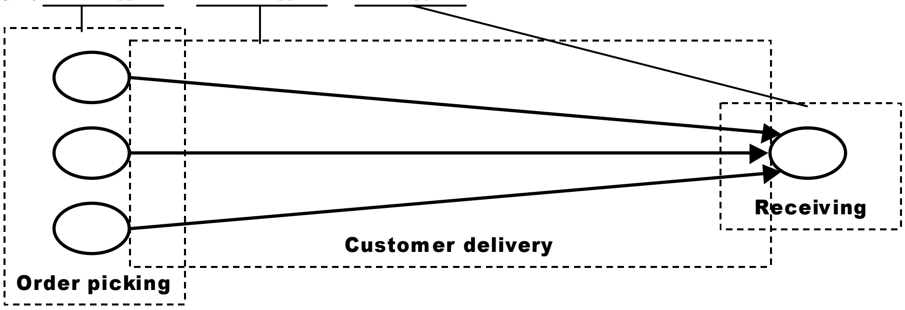
It must be noted that calculating logistics costs with average figures will not result in exact figures. However, if the merge-in-transit delivery costs are significantly lower than those through a warehouse are, the supplier should be moved to the merging process.

Direct deliveries versus merge-in-transit. If products are being shipped directly from the suppliers to the customers, but the amounts transported tend to make up less than truckload deliveries, it is possible that there are benefits to gain from merge-in-transit distribution. The potential cost savings result from reduced transportation costs and reduced inbound logistics costs by having only one delivery per order to the customer. The total order picking costs at the suppliers do not differ between these two models, as in both cases the supplier is shipping to individual customer orders.

The direct delivery costs are evaluated as the sum of all the individual order-picking, transportation, and receiving costs needed to fulfil the customer order. Using the model of Appendix 1 to present the cost elements results in:

Costs of direct deliveries for one order =

$$\sum \left(C_{out,supplier} + C_{trans,supplier} + C_{in,supplier} \right)$$



The costs of merge-in-transit for one order are assessed as presented above in the comparison to warehousing costs.

As with the warehousing alternative, the cost impact of adding a currently direct delivering supplier to the merge-in-transit process can be assessed by comparing the yearly costs of using each distribution channel. The following costing model for yearly direct delivery costs uses the same notation for the variables as above with the warehousing:

Yearly costs for direct deliveries for one supplier's products =

$$C_{out}\left(N_{cdel}, N_{clin}\right) + N_{cdel} \times C_{trans}\left(w_{av,lin} \times N_{av,sol}, d_{av}\right) + C_{in}\left(N_{cdel}, N_{clin}\right)$$

As with the yearly merge-in-transit costs, the order picking costs are evaluated with the number of yearly customer orders and order lines for the supplier through the distributor. The customer delivery costs are approximated with average order line weights and average distances to the customers. Finally, the receiving costs are evaluated with the same numbers as the order picking costs.

The result of the direct delivery cost evaluation is then compared to that of the merge-in-transit evaluation presented earlier. If merge-in-transit distribution results in lower costs, the supplier should be added to the merging process.

If the logistics service provider has an extensive network of distribution centres capable of consolidation operations, merge-in-transit should generally be an attractive alternative. All supplier shipments can be collected to the nearest DC, and then transported within the cost efficient service provider network towards its destination, being consolidated to the end-customer delivery along the way. Calculating the actual costs in such an environment is, of course, more challenging. However, the logistics service provider should be able to give cost estimates for its network operations as well. In the case example, for the benefit of simplicity (and this being the actual situation with the case company), the consolidation takes place in one distribution centre situated close to all participating suppliers.

3.2.3 Assessing potential service benefits of merge-in-transit operations

The difference in operational costs is not the only distinction between the alternative distribution channels. Even though the costs for merge-in-transit operations would be somewhat higher, other attainable benefits may offset this disadvantage. In this section qualitative evaluation tools are provided for assessing the potential service benefits of merge-in-transit distribution.

The first two benefits discussed can be attained when moving from warehouse deliveries to merge-in-transit distribution. The next two potential benefits exist when moving from direct deliveries to merge-in-transit. The last item discussed – tracking and tracing – is a prerequisite for merge-in-transit operations, and thus the other service benefits it offers can be employed with every merge-in-transit distribution model.

Wider product assortment for the distributor. The utilisation of merge-in-transit enables the distributor to add products in the assortment offered to customers without additional investments in warehouses or inventory. The potential customer service benefits resulting from widening the assortment with merge-in-transit can be estimated with questions such as:

- Do customers request products that are not available in current assortment?
- Do costs related to inventory prohibit the extension of assortment?
- Would the requested products be a valuable addition to the assortment in terms of customer retention?

Widening the assortment with appropriate product categories may have a significant impact on market share, as more customers will be able to make all their purchases of specific product lines with one wholesaler. While the assortment is more a strategic decision than a logistical one, it should be noted that adding new suppliers to the merge-in-transit distribution model does not affect warehousing costs of the distributor.

Point-of-sales data for suppliers. Compared to deliveries through a warehouse, the separation of order and material flows increases the visibility in the supply chain for the suppliers. Since the suppliers get the orders according to real demand, they may experience much more stable demand. The supplier may estimate the effects of bypassing the warehouse in the chain by evaluating the following:

- Are warehouse replenishment orders infrequent or with remarkable variability in quantities?
- Would actual customer orders enable postponement of assembly activities?
- Would delivering to actual customer orders enable the supply of customer configurable products?

The postponement both in time and form may help the supplier reduce its operating costs. Receiving point-of-sales data can also help forecast the demand better than with aggregated demand data from the wholesaler. Nonetheless, the actual benefits may not be very remarkable, if the marketing channel of the distributor presents only a small share of total sales for the supplier.

Frequent replenishment for customers. In contrast to direct deliveries, the utilisation of merge-in-transit offers the customers an opportunity to order items more frequently in smaller lots, as the consolidation of many small deliveries into a larger one reduces the delivery and receiving costs per item. This may enable the customer companies to reduce their stock levels and thus increase their inventory turn and reduce warehousing costs. To assess such potential benefits, the customer needs to ask herself:

- Do some products have a high stock level due to infrequent orders resulting from high delivery costs?
- Would smaller, more frequent deliveries be desirable?
- What would be the effect on the stock levels?

If ordering smaller lots results in reduced inventories, the merge-in-transit distribution model improves customer service also this way.

Supplier shipment consolidation. Also compared to direct deliveries, the suppliers may be able to take advantage of the economies of scale offered by merge-in-transit process. From the suppliers' viewpoint, their delivery address is always the same, regardless of where the end-customer is located, since they can always deliver to the nearest consolidation centre. By establishing the merge-in-transit with regular delivery windows, the supplier can arrange all shipments to be picked up with one collection. To assess the potential benefits, the supplier can evaluate the following:

- How many shipments are sent daily to fulfil customer orders of the wholesaler?
- Could these shipments all be made with one daily delivery?

According to (Aminoff et al., 2000), in addition to costs per order line, the delivery specific picking costs are € 9.60 regardless of the order size. Thus, combining several shipments to be sent at one time, these delivery-specific costs may partially be recovered. Combining the deliveries means also savings in delivery costs to the distribution centre.

Tracking and tracing. Since one of the basic prerequisites for merge-in-transit is tracking and tracing of deliveries, it is possible to use this feature for other business needs as well. Tracking of deliveries enables reacting to disruptions in delivery process by making the progress of individual parcels visible throughout the delivery chain. This enhances the controllability of the delivery process and thus can help reduce variability in delivery accuracy. To assess the benefits of this possibility, the questions to ask are:

- How frequently are shipments delayed without notice or totally lost?
- What are the costs of such events?
- Do customers make inquiries about the progress of their order?
- Is the data needed to answer these inquiries readily available?

The costs of handling the irregularities can be significantly reduced, if the shipments are constantly monitored. However, tracking has to be automated and provided as an exception-based service, as laborious manual follow-up is not desirable. It is not interesting to know the location of each parcel all the time. What matters, is to catch disruptions in the delivery process as soon as they occur, so that efficient corrective operations can be done. With a reliable tracking system, customer service is also improved, as inquiries can be answered with little effort.

3.2.4 Checklist for the scenario evaluation

After extensively evaluating the operational costs for each potential product category and supplier, the entire constructed scenario is assessed. If the scenario is deemed as attractive, strong considerations should be given to start an implementation project for the new distribution channel. However, if the scenario results in higher costs than current operations, it may be necessary to reconstruct the scenario with another composition of product categories and suppliers, or another logistics service provider.

If no realistic merge-in-transit scenario seems more attractive than the current operations, the merge-in-transit distribution channel must be discarded as unsuitable for current business situation.

CHECKPOINT

Does the merge-in-transit scenario provide cost savings compared to current operations?

- If yes, merge-in-transit distribution should be considered as a serious alternative for current distribution channels.
- If the operational cost savings are uncertain, the attractiveness of attainable service benefits should solve the applicability of merge-in-transit in the business situation.
- If the operational costs of the merge-in-transit scenario prove to be significantly higher than those of current operations and the potential service benefits cannot compensate for this disadvantage, either the merge-in-transit scenario has to be reviewed or the merge-in-transit operations deemed as inappropriate for the particular business situation.

For the case business situation, the costs of merge-in-transit were generally lower than costs of current operations, although for some of the studied deliveries the opposite was true. Nevertheless, the service benefit of having only one delivery for one customer order and the opportunity to remove own warehousing operations were deemed so important that the distributor chose to continue with the implementation project.

An example comparison between direct delivery costs and merge-in-transit delivery costs for a typical delivery of the case company is presented in Figure 13. The curves are cumulative to illustrate the accumulation of costs in the operations of the delivery chains. The values are presented as relative figures so that the total costs for delivering the products directly is indexed as 100.

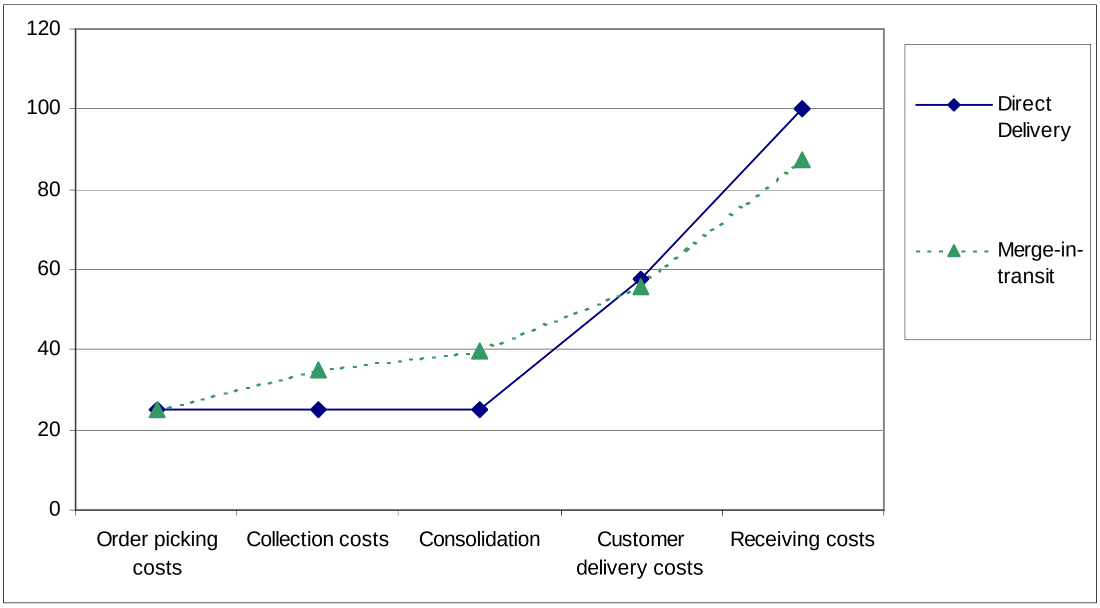


Figure 13 An example comparison of direct delivery costs and merge-in-transit delivery costs

In the next two sections, the necessary information systems for merge-in-transit are discussed. Particular attention is given to the proposed product centric system to evaluate its benefits in a multi-company business environment.

3.3 Construction of a product centric scenario for merge-in-transit

One of the key elements in setting up merge-in-transit distribution is the availability of information systems capable of providing correct and up-to-date information for all participants in the process (McLeod, 1999; Dawe, 1997; Norelius, 2002).

In this section, the alternative approaches of information system implementations for merge-in-transit distribution are discussed. A checklist is provided to construct a scenario to assess the costs and service benefits of the product centric approach in a specific business situation.

3.3.1 Modeling the implementation alternatives for merge-in-transit information systems

As presented in section 2.2 Logistics information systems the traditional way of connecting information systems across companies includes implementing a point-to-point connection between every pair of applications needing to exchange data. The proposed system standardises the delivery-related communication to be conducted over the Internet, requiring only one implementation of middleware for a company regardless of the number of participants in the delivery network.

The implementation of information systems depends on the current applications in use. If there is a single communication standard in extensive use among the potential merge-in-transit partners, it is a likely candidate for implementing the new information flows as well. This being the case, the existing and additionally needed communication links need to be modelled to evaluate the costs of implementing the required communication system in full-scale.

However, the product centric approach has some potential advantages over the traditional communications methods. These service benefits of the new approach should also be considered when evaluating the information system implementations. One of the main characteristics of the product centric approach is the scalability it offers in connecting additional partners to use the same information infrastructure.

The drawback of expanding the merge-in-transit operations with the traditional point-to-point communication is increased complexity in the distribution network. As the numbers of suppliers, shipments, consolidation DC’s, and customers grow, there are more and more messages and identifiers to be managed by the logistics service provider, and the synchronisation of varying advanced shipment notices with the actual incoming goods gets more susceptible for errors. If this multi-company network is set up with the traditional messaging approach, the resulting costs may be remarkable.

The costs can be evaluated by identifying the required connections in the merge-in-transit network. In the following subsection a checklist is provided to create a costing model of the required information system in a specific distribution network.

3.3.2 Checklist for information system alternatives

The costs of the communication systems include the implementation of necessary middleware and connections, and the operating costs resulting from conducting transactions with the system.

CHECKPOINT

Is there a standard communication method in extensive use between the distribution chain partners?

- If yes, and it easily supports the information flows needed in merge-in-transit, the costs can be evaluated with the amount of rework needed with current implementations and the need for additional implementations at partners not already using the standard
- If not, new middleware is needed. The evaluation of implementation costs for the information system is based on number of middleware implementations needed to create the necessary communication network for merge-in-transit.

The necessary questions for the evaluation are thus:

- How many and what types of middleware implementations are needed for the distribution chain partners?
- What are the expected transaction volumes between the distribution chain partners?

The costs for automated inter-organisational communications must be evaluated in two steps: First, there are investment costs associated with implementing a communication system, and second, there are operational costs resulting from using the system. These two cost categories are further elaborated in the following section. Since various EDI implementations are usually among the considered alternatives for traditional message-based communications, their implementation and usage costs will be compared with those resulting with the proposed system.

3.4 Evaluation of product centric control for merge-in-transit

In order to assess the economical feasibility of the proposed system for merge-in-transit, the associated cost elements need to be identified, and the alternative approaches compared to each other.

The first subsection presents the cost elements in implementation and operation of the information system alternatives. The subsections after that discuss the evaluation of potential cost and service benefits of the proposed system.

3.4.1 Cost elements of the information system alternatives

System investment costs. Two elements are needed to enable communication between business applications. One is a component making the data in the business application available for the middleware, and the other is the communication link provided by the middleware (see section 2.2.2).

The component for making the data available can be implemented as a translator or by accessing the database. Here, this software component is referred to as a translator. The total cost for enabling data translation is formed as a sum of the software price and the costs for work required with the application integration.

$$C_{translator} = C_{software} + C_{integrationwork}$$

Depending on the communication method and the communication standard used, a separate translator may be needed for every partner that needs be communicated with.

The connection between the applications can be formed on private lines connecting only the applications, supplied by a specific service provider, or carried out over the Internet. Private lines are the most secure alternative. They are also the most expensive and least scalable alternative, as every new partner requires a new point-to-point connection to be created. The other options are more suitable for multi-user environments, as generally only one connection for each user is needed to enable communications with other users in that network. In those options there is a cost associated only with each additional connection to the network.

The total investment costs for implementing a communication system can be expressed as:

$$C_{implementation,user} = N_{translator} \times C_{translator} + N_{connection} \times C_{connection}$$

Where

$N_{translator}$ = the number of translators required for an application to communicate with other partners

$N_{connection}$ = the number of connections required for an application to communicate with other partners

Operational costs. The operational costs of a communication system result from costs per transaction or a periodical fee charged by a service provider. Depending on the service model of the service provider, also a combination of these is possible.

Transaction costs include the work in processing one transaction at both sender and receiver ends and the transaction fees charged by the network operator connecting the two ends:

$$C_{transaction} = C_{work,transaction} + C_{fee,transaction}$$

If a periodical fee is charged, the costs are better calculated at a period basis by summing up the transaction costs for the period and adding the periodical fee. This yields a generic model for operational costs:

$$C_{operations,period} = N_{transaction,period} \times C_{transaction} + C_{fee,period}$$

Where

$N_{transaction,period}$ = number of transactions on the period under review

Suggestive costs for EDI implementations and the proposed system. The costs for EDI communications depend on the way it is implemented. Initially, before the rise of the Internet, a private network operator provided the connection through their Value Added Network (VAN), designed for transmitting EDI messages only. The VAN connections are still in use, especially by large companies with heavy message traffic. Other EDI implementations discussed are EDI over Internet and Web-EDI. Finally, the proposed product centric system is reviewed in terms of the costs related to its use.

EDI over VAN: For a non-EDI-integrated supplier the cost of implementing EDI over VAN means costs from a few thousand up to tens of thousands of euros for integrating the translator software with her business application (Lankinen, 2001; Seikkula, 2002; Wilde, 1997), and around 750 euros for each message connection to the Value Added Network (Seikkula, 2002). A disadvantage of using a VAN connection is that it typically only connects users of the same service provider (Wilde, 1997). Should the supplier want to contact other customers in different networks, she would have to pay for another VAN connection. Additionally, a number of translators may be needed for one message-type, if different partners require the use of different message structures.

With the business application integrated with the EDI translator, there is very little or no work related to sending a message. The application can be configured so that when data for events such as order confirmation or shipping a parcel are entered, an EDI message is automatically created and sent to the party mentioned in the data. Nevertheless, the VAN providers charge a transaction fee, based on character count (Seikkula, 2002; Angeles, 2000). The costs per transaction in VAN are generally estimated to be around 0,10 – 0,30 euros, depending on volume.

Internet-EDI: A more recent alternative, often referred to as Internet-EDI, is transferring EDI messages over the Internet using protocols like FTP or attaching them with e-mails. This approach still requires the costly EDI translation software to be integrated to the business application, but the costs of joining a Value Added Network are excluded (Angeles, 2000). The transaction costs are also lower for Internet-EDI, as the messages are sent over the Internet among other Internet traffic. The drawback of Internet-EDI is that the sender of the message cannot be sure that the message has reached its destination. It has been stated, that Internet-EDI is appropriate for transactions that are not mission critical, confidential, do not require a quick response back, and where EDI systems can be isolated from other company applications (Angeles, 2000).

Web-EDI: For companies not wanting to invest in EDI integration, EDI service providers have designed Web based solutions. The service provider can maintain a "message box" where incoming EDI messages are translated into HTML-documents that can be viewed in any Web browser. Similarly, the user can send EDI messages by filling out Web forms that are then translated into EDI format and sent to the EDI integrated recipient over the Value Added Network of the service provider. This is a low implementation cost solution for a smaller company that is requested by a partner to submit information in EDI format, available for an initiation fee of $25 - $495 (Wilde, 1997; Tadjer, 1997).

The Web based EDI connections offered by an EDI service provider are designed for low volumes of transactions. For example, GE Information Services have provided the service with a monthly fee of $30, including 15 messages sent for free, and additional messages at $1.50 each (Tadjer, 1997). Another option for an even more infrequent user is a transaction fee of $6 with no other charges (Wilde, 1997). However, since there is no integration to the business application of the user, there are additional costs due to manual work in entering data on a Web form. These costs are not easy to evaluate, and depend on the amount of information that needs to be input. An example from Nestle gives an estimate of roughly two dollars: After removing the need to manually enter customer orders, they were able to reduce the costs of handling one order from $2.35 to $0.21 (Echikson, 2000). Cost reductions from $50 to less than $5 per customer order have also been reported when shifting from paper to EDI (Droge and Germain, 2000).

It is also possible for EDI enabled companies to provide similar Web services for their partners on their own Extranet. Costing around $20 000 to $25 000 to put up such a server, this enables larger companies to use EDI transactions with their smaller partners, without demanding the partners to make any investments (Tadjer, 1997). From the Web user viewpoint, the implementation cost is zero, if they already have an Internet connection in place. The integration with this approach is also one-sided, since the data must be manually input on the Web form, resulting in the same problems as above.

The proposed system: The proposed product centric system is implemented by installing a software agent for each company. In a limited pilot installation conducted with the case company and its logistics service provider, the installation time of the software component was measured to be eight minutes.

During the installation the software automatically integrates to the business application database. This automation is feasible, because the database connectivity can be achieved with standardised software solutions (Linthicum, 2001). The connection to other users takes place over the Internet, which means there are no additional connection set-up costs for the system. Thus, the implementation costs associated with the proposed system are those of the installation work. Furthermore, only one installation of the software agent is needed for each business application, independent of the number of other users in the system. Each supplier installs a server agent providing information on the deliveries, and each consolidation centre installs a client agent capable of retrieving the delivery information. New users can be included flexibly, without modifications to the agents already in use, making the installation a one-time investment.

Since the proposed system is integrated to the application database, there is no additional work related to a transaction. More specifically, data is never actively sent anywhere, so no manual work needs to be done. Once the delivery details are input to the consignor's database, they are available to all authorised users of the system. And as they are transmitted over the Internet, no noteworthy fees are applied to the transactions. As with all traffic on the Internet, the reliability of the connection is always an issue, but since it operates on a request – response basis, there is no uncertainty related to message arrival.

A summary of the above discussion is presented in Table 2 below. The figures shown should not be considered absolutely precise, but as illustrations of the magnitude of differences between the systems.

Table 2. Suggestive implementation and operating costs of various communication systems

	EDI over VAN	Internet-EDI	Web-EDI	Proposed system
Investment costs				
Software integration	€ 1.000 – x0.000	€ 1.000 – x0.000	0	See below
Connection set-up	€ 750	0	€ 25 – 500	0
Operational costs				
Transaction work	0	0	€ 2	0
Transaction fees	€ 0,10 – 0,30	0	€ 2 - 6	0
Periodical fees	0	0	€ 30	0

Since the proposed system is still under development, and thus neither in operative use nor commercially available, there are no indicative figures available for the direct comparison of software integration costs. These costs are likely to be much lower than those of EDI-integration, since the software components are very light weight and easily installed, as proven in the pilot-installations. Also the purchase prices of the software components, if once commercially available, remain undetermined for the moment.

3.4.2 Assessing information system costs in merge-in-transit

When evaluating the difference in creating merge-in-transit distribution model based either on EDI or the proposed system, both implementation and operational costs need to be calculated. As discussed earlier, the logistics service provider is in a central position in executing the customer delivery. Therefore, every participant needs to have a communication link at least with the LSP. When assessing EDI costs, at least the Logistics Service Provider needs to have an EDI server. The other partners may then communicate with the LSP using a Web-EDI service or having an EDI-integration in their own business application. Each required communication channel includes an installation cost. With the proposed system, every participant needs only one agent to provide or have access to the delivery data and an Internet connection.

The costs of setting up the required network of communications depend on the number of suppliers to be included. Correspondingly, the operational costs depend on the number of transactions carried out, i.e. shipments sent to the consolidation centre.

With the case company merge-in-transit implementation, the distributor manages the information flows. The suppliers transmit delivery information to the distributor either with EDI or with a Web-application in the distributor’s Extranet. The distributor then sends the delivery information to the logistics service provider with EDI.

For the case company, the implementation of the merge-in-transit distribution has meant implementing new EDI-messages with the participating suppliers. As an example, the configuration and verification of the message structure with one partner took nearly three months to be completed and accepted for operational use. This very much hinders the expansion of the merge-in-transit distribution to include additional suppliers.

The estimated yearly volume for delivery information is around a thousand transactions for each of the initial partners in the merge-in-transit process. This volume results in moderate costs per supplier when using EDI-messages, but the costs are more notable when the supplier enters the information manually in the Web-application. In addition, the distributor forwards all the messages with EDI to the logistics service provider thus further increasing the amount of transactions and costs in the delivery chain.

The product centric approach presented here has also other advantages over the traditional message based approach in merge-in-transit. Those are discussed in the following section.

3.4.3 Assessing potential service benefits of the product centric system in merge-in-transit

Besides the cost differences resulting from the two different approaches, there are also service benefits resulting from a product centric control system. These issues should be addressed as well, when evaluating the attractiveness of the new concept. In this section qualitative evaluation methods are presented to assess the potential service benefits of product centric control systems for the multi-company environment of merge-in-transit.

Tracking and tracing included in the proposed system. As stated in section 2.1.2 merge-in-transit operations require reliable shipment tracking. With the product centric approach no separate implementation efforts are needed for the tracking of shipments, as every time a parcel is identified its agent can update the current location in the database. This is a major benefit compared to message-based systems, where an additional application is needed to keep partners informed of the location of each of the shipments.

Virtual single database. Since the delivery data of a shipment is always accessed via the shipment's agent, there exists only one copy of the delivery information. This helps reduce obsolete and erroneous information in the delivery chain, as well as non-value-added work associated with re-entering or otherwise duplicating data. The benefits of this can be assessed with evaluating the following issues:

- How often is the same information manually input in an application during a single delivery?
- How frequently are there errors in operations due to false or too old information?
- How frequently are there changes in the delivery details of shipments?

Without automation of the manual work, the costs of yearly entries in the delivery process may sum up to significant figures. It has also been estimated that the error frequency in manual typing is roughly one in three hundred entries (Whitney, 1999;

Anon., 2000). The cost of correcting each of these errors depends on the severity of problems caused.

Creating a control application for a shipment. It is possible to have control applications for individual shipments or consolidated deliveries, as the shipment's agent is always accessed when the identity of the shipment is registered. For example, the control application may track the shipment in the delivery chain and notify predetermined parties of disruptions. This enables exception-based tracking in the entire delivery chain, and promotes the controllability of the merge-in-transit process.

A control application for the customer order could provide delivery status information on the component shipments it consists of, thus making it easy for the logistics service provider to track all the shipments needed to complete the consolidation.

Further, the shipment's control application can provide very precise handling instructions for transportation workers, such as where each parcel can be lifted or what weather conditions the parcels can tolerate.

To assess these potential benefits, the following should be considered:

- Do current shipment tracking alternatives require active efforts from employees?
- Do individual shipments require customised handling?
- Are there problems with getting fragile products undamaged to the customer?

Extending the merge-in-transit concept. Another feature of the product centric merge-in-transit system is that it makes the change of location for the consolidation operations easy, as all delivery related information is available with the deliveries themselves. This enables "merge-at-destination" operations, where the final consolidation takes place just prior to handing the delivery over to the customer.

The usefulness of this property can be evaluated with the following:

- Are several modes of transportation needed for a customer delivery?
- Are several logistics service providers involved in the same delivery?
- Do separately delivered components form an entity for the customer?

For example, the logistics service provider (or several service providers) could use different transportation modes for delivering components to a construction site. When all components of an on-site sub-assembly have arrived, all the components are handed over to the site recipient as a single delivery, and ready to be assembled. This would reduce the work needed at the construction site to make sure all individual parts of an assembly unit have arrived.

3.4.4 Checklist for the product centric control evaluation

The final evaluation step in assessing the suitability of product centric control for the merge-in-transit distribution is essentially one question. After weighing the cost and service benefits of the proposed system, it either provides an interesting solution to the challenges in multi-company logistics integration or is perceived as too challenging itself.

CHECKPOINT

Does the product centric control approach seem attractive?

- If yes, organise the merge-in-transit distribution chain around the deliveries rather than extend the traditional messaging approach to include merge-in-transit operations.
- If not, implement the controlling of merge-in-transit distribution chain with the most suitable traditional method

3.5 Summary of the case company situation

The distributor company started to consider merge-in-transit distribution as an alternative to their operations as their customers requested single deliveries for single orders. Due to the wide assortment of products on offer it was impossible to store all stock keeping units in the distributor warehouse, and some products were delivered directly by the suppliers to the customers resulting in multiple deliveries for one order. In addition to the customer service aspect, the possibility to operate without storing products centrally in an own warehouse was deemed an interesting opportunity presented by merge-in-transit operations.

Recognising the problems with a wide rollout of a new process, the merge-in-transit implementation was started with a few companies. After evaluating the possible first partners, the implementation was initiated with a few suppliers seeing benefits in delivering their volume products to a single distribution centre instead of direct lower-volume deliveries to geographically dispersed customers. A scenario of merge-in-transit operations was built with these suppliers.

The cost evaluation of the scenario revealed, that in most cases the costs of delivering the customer orders would be lower than with the direct delivery model in use. In some cases the costs were slightly higher, but the achievable service benefits as well as the opportunity of removing a warehouse in the distribution chain were a strong incentive to continue with the implementation project.

The delivery information transfer necessary for the merge-in-transit process was implemented using EDI-messages and a Web-based application between the suppliers and the distributor. The distributor operates as an information hub sending all the delivery information related to the consolidation operations with an EDI over VAN connection to the logistics service provider.

In a limited pilot installation of the proposed system at the logistics service provider, both the representative of the distributor and the representatives of the logistics service provider were very interested in the possibilities offered by the system. The most promising achievable benefits seen by the representatives were:

- Removal of costs with EDI transactions
- Facilitation of electronic communications, especially the opportunity for automated communications with smaller partner companies not capable of implementing an EDI-connection
- Availability of up-to-date information everywhere in the chain
- One possibility for standardisation of delivery information transactions

Negotiations of an operational pilot installation of the proposed system for the merge-in-transit process were initiated with both companies.

4 CONCLUSIONS AND FURTHER RESEARCH

In this thesis an evaluation model is constructed to assess the applicability of merge-in-transit operations for distributors. In order to address the first research problem – *how to assess the costs and benefits of merge-in-transit distribution for a business situation* – a merge-in-transit scenario is constructed as an alternative for current operations in a specific delivery chain.

With the model the logistics costs can then be analysed and available service benefits evaluated for the business situation to give decision-making support for a prospective implementation of merge-in-transit distribution.

The second research problem – *how to assess the costs and benefits of implementing the product centric model in multi-company distribution situations* – is addressed with similar methods. A scenario utilising the product centric approach is constructed for the delivery chain. The resulting costs and potential service benefits are then assessed for the scenario.

The operational costs of distribution channels as well as the implementation and operation costs of necessary communications for the control of materials flows are estimated quantitatively. The cost structure changes in the distribution network when moving to merge-in-transit distribution, but no suggestions are made here on how to allocate the costs and benefits among the participants in the network. This remains a decision related to the business strategies of the companies involved, although it must be noted that the commitment to the development project of each participant is proportional to the attainable benefits for the company.

The service benefits available with merge-in-transit distribution and product centric control are evaluated qualitatively. The detailed analyses of the actual impacts of each of the service benefits are suggested as topics for additional studies.

The usability of the model was evaluated with a case company business situation, and the initial results suggest, that the model can provide guidelines for implementing a merge-in-transit distribution channel. An issue for further research is to analyse the accuracy of the costing model by comparing the actual logistics costs after the full implementation in the case company with those approximated with the model.

Furthermore, the model should be applied to other business cases to evaluate its usability in a variety of business situations. Another suggestion for further research is extending the costing model to cover the entire delivery process by including costs related to the order flow.

The constructed model also provides estimations on the feasibility of the product centric control approach for the merge-in-transit distribution channel. The product centric control model proved attractive for the following main reasons:

- Low installation overhead: No expensive investments required for partners in the merge-in-transit process.
- Scalability: Connecting another participant to the merge-in-transit process does not produce any changes in operations or supplementary costs for the other parties.
- Performance: The material flow control information accessed through the proposed system is accurate, rapidly available and, in particular, the same for all participants. These are primary requirements for information in complex logistics systems.

As product centric control is a new approach in managing distribution networks, an issue for further research is implementing an operational pilot system for a merge-in-transit channel and measuring the actual performance in automation of merge-in-transit operations.

A problem for all electronic communication means is present in a situation, where the network connection is unexpectedly unavailable. To handle such exceptions, the most essential control information should be provided with the shipment in some form. A promising technology for this is Radio Frequency Identification, where data can be provided in electronic form on a rewritable memory chip attached to the shipments. This kind of electronic availability of information supports the concept of product centric control, and with the proposed system the control data on the chip could be updated whenever the connection to the shipment’s agent is available.

Current road map in the Dialog project for the potential application areas in supply chains is illustrated in Figure 14 along with the cost and service benefits sought for with the applications. The areas are presented as successive steps, each requiring new capabilities of the product centric model, as listed on the far right.

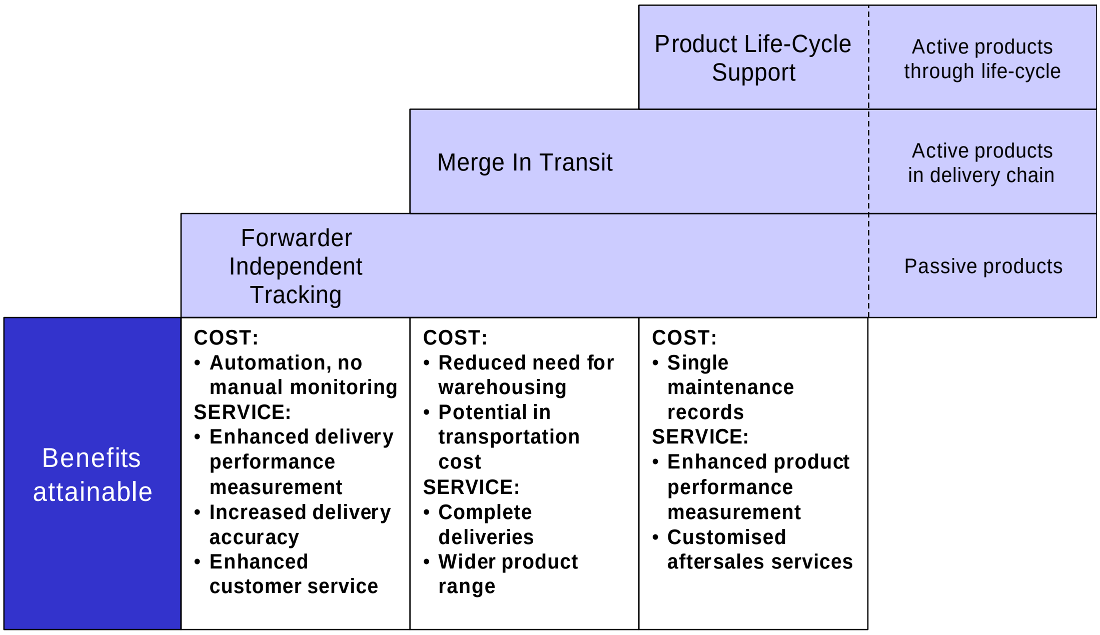


Figure 14 Application areas for product centric control

The present piloting implementations of the Dialog project concentrate on tracking shipments in project delivery networks, which means that the parcels are registered passively with no control information accessed with them. The next step is implementing a pilot system, where the shipments are active by providing access to material flow control information. This is needed for example in the automation of the consolidating operations in merge-in-transit distribution. The final step will be making individual products active through their life cycles, which will enable a host of after-sales value added services. Further research is required also to evaluate additional application areas for the product centric control.

REFERENCES

Books, articles and research papers

Aichlmayr, Mary, 2001, "Never Touching the Floor", *Transportation & Distribution*, Vol. 42, No. 9, pp. 47-52.

Aminoff, Anna; Kettunen, Outi; and Pajunen-Muhonen, Hanna, 2000, "Research on Factors Effecting Warehousing Efficiency", *Logistics Research Network 5th Annual Conference Proceedings*, September 7-8, 2000, Cardiff University, UK.

Angeles, Rebecca, 2000, "Revisiting the role of Internet-EDI in the current electronic commerce scene", *Logistics Information Management*, Vol. 13, No. 1, pp. 45-57.

Angeles, Rebecca; Nath, Ravi, 2001, "Partner congruence in electronic data interchange (EDI)-enabled relationships", *Journal of Business Logistics*, Vol. 22, No. 2, pp. 109-128.

Anon., 2000, "AIDC – What is the impact of the technologies on IT and business?", *AIM Yearbook & Buyer's Guide 2000-2001*, p. E8.

Baker, Michael J., 1990, "Dictionary of Marketing and Advertising", 2nd ed, Nichols Publishing, New York, 1990, p. 47

Bowersox, Donald J., Closs, David J., 1996, *Logistical Management: The Integrated Supply Chain Process*, International Edition, McGraw-Hill Companies Co., Singapore, 1996

Bradley, Peter; Thomas, Jim; Gooley, Toby; Cooke, James Aaron, 1998, "Merge-in-transit yields benefits", *Logistics Management and Distribution Report*, Vol. 37, No. 10, p. 30.

Brooksher, Dane, 1999, "E-commerce and logistics", *Traffic World*, Vol. 260, No. 7, p. 31.

Carbone, James, 2001, "Buyers expect VA, timely delivery from distributors", *Purchasing*, Vol.130, No. 12, pp. 40-44.

Christopher, Martin, 1992, *Logistics and Supply Chain Management*, Pitman Publishing, London, 1992

Dawe, Richard L., 1997, "Move it fast…eliminate steps", *Transportation & Distribution*, Vol. 38, No. 9, pp. 67-74.

Droge, Cornelia; Germain, Richard, 2000, "The relationship of electronic data interchange with inventory and financial performance", *Journal of Business Logistics*, Vol. 21, No. 2, pp. 209-230.

Echikson, William, 2000, “Nestle: An Elephant Dances”, *Business Week*, No. 3711, p.16.

Främling, Kary; and Holmström, Jan, 2000, “A distributed software for collaborative sales forecasting”, *Proceedings of the Management and Control of Production and Logistics MCPL’2000 conference*, 5-8 July 2000, Grenoble, France

Johnston, R. B., and Yap, A. K. C., 1998, “Two-Dimensional Bar Code as a Medium for Electronic Data Interchange”, *International Journal of Electronic Commerce*, Vol. 3, No. 1, pp. 86-101.

Korpela, Jukka, 1994, *An Analytic Approach to Distribution Logistics Strategic Management*, Thesis (PhD), Research Papers 42, Lappeenranta University of Technology.

Kärkkäinen, Mikko; and Holmström, Jan, 2001, “Wireless item identification: a solution for e-commerce fulfilment problems”, forthcoming in International Journal of Electronic Business.

Kärkkäinen, Mikko; Holmström, Jan; Främling, Kary; and Artto, Karlos, 2001, “Intelligent Products – a Step Towards a more Effective Project Delivery Chain”, *Forthcoming in Computers in Industry*

Kärkkäinen, Mikko; Punakivi, Mikko; and Ala-Risku, Timo, 2002, “Merge in Transit – a Key for Effective Order Fulfilment in B2B E-commerce”, *Twelfth International Working Seminar on Production Economics*, February 18-22, 2002, Igls / Innsbruck, Austria

Lambert, Douglas M.; Stock, James R.; Ellram, Lisa M., (1998), *Fundamentals of Logistics Management*, The McGraw-Hill Companies, Inc., 2000

Linthicum, David S., (2001), *B2B application integration: e-business-enable your enterprise*, Addison-Wesley, Boston, 2001

Manunen, Outi, (2000), “An Activity Based Costing Model for Logistics Operations of Manufacturers and Wholesalers”, *International Journal of Logistics Research and Applications*, Vol. 3, No. 1, pp. 53-65.

McLeod, Marcia, (1999), “Cutting both ways”, *Supply Management*, Vol. 4, No. 7, pp. 24-25.

Muller, E. J., (1992), ”Exploring the Outsourcing Frontier”, *Chilton’s Distribution*, Vol. 91, No. 6, pp. 44-50.

Norelius, Hans, (2002), *Merge in Transit – A non-stock distribution structure*, Linköpings Studies in Science and Technology, Thesis No. 935.

Pagh, Janus D.; Cooper, Martha C., (1998), “Supply Chain Postponement and Speculation Strategies: How to Choose the Right Strategy”, *Journal of Business Logistics*, Vol. 19, No. 2, pp. 13-33.

Pedler, Mike, (1994), "Information Technology in the Supply Chain", *Purchasing & Supply Management*, Sep 1994, pp. 15-16.

Richardson, Helen, (1994), "Planning for the year 2000", *Transportation & Distribution*, Vol. 35, No. 11, pp. 73-76.

Richardson, Helen, (1999), "Cross Docking: Information Flow Saves Space", *Transportation & Distribution*, Vol. 40, No. 11, pp. 51-54.

Schaffer, Burt, (1997), "Implementing a Successful Crossdocking Operation", *IIE Solutions*, Vol. 29, No. 10, pp. 34-36.

Seideman, Tony, (2000), "Weapons for a new world", *Logistics Management and Distribution Report*, Vol. 39, No. 4, pp. E33-E36.

Simchi-Levi, David, Kaminsky, Philip, Simchi-Levi, Edith, (2000), *Designing and managing the supply chain – concepts, strategies, and case studies*, The McGraw-Hill Companies, Inc., 2000

Stalk, George; Evans, Philip; Shulman, Lawrence E., (1992), "Competing on Capabilities: The New Rules of Corporate Strategy", *Harvard Business Review*, Vol. 70, No. 2, pp. 57-69

Tadjer, Rivko, (1997), "Shopping around for the best Internet EDI deal", *Network Computing*, Vol. 8, No. 14, pp. 26-27.

Whitney, Sally, (1999), "Bar codes save time, stop errors in sales", *Best's Review*, Vol.100, No. 3, p. 100.

Wilde, Candee, (1997), "New Life for EDI?", *InformationWeek*, Issue 622, March 17, 1997, pp.65-67.

Witt, Clyde E., (1998), "Crossdocking: Concepts demand choice", *Material Handling Engineering*, Vol. 53, No. 7, pp. 44-49.

Internet sources

Anon., 2002, "A summary of: Merge in Transit – From Theory to Practice", GeoLogistics (Online), [retrieved 25.2.2002], Available from: http://www.geo-logistics.com/pdfs/internet_mit.pdf

Brock, David, 2001, "The Compact Electronic Product Code", MIT Auto-ID Center White Paper (Online), [retrieved 25.2.2002], Available from: http://www.autoidcenter.org/pdfs/MIT-AUTOID-WH-008.pdf.

EAN International, 2002, "Identification – Logistic Units: SSCC", EAN International (Online), [retrieved 2.1.2002], Available from: http://www.ean-int.org/sscc.html.

ETH Zurich, 2002, "Research in the Distributed Systems Group", ETH Zurich (Online), [retrieved 25.2.2002], Available from: http://www.inf.ethz.ch/vs/res/index.html.

Interviews

Lankinen, Jari, (2001), Personal contact with a salesman of a Finnish EDI service provider Oy Datatie Ab, December 5, 2001.

Seikkula, Sami (2002), Personal contact with a salesman of a Finnish EDI service provider Elma Oyj, February 28, 2002.

Tirkkonen, Ilkka, (2002), Personal contact with the managing director of the Finnish logistics service provider Kiitolinja Oy, May 7, 2002.

A Appendix 1

The calculation model for delivery costs consists of five main elements, as illustrated in Figure 12. The calculation of each of these elements is explained below.

A.1 Order picking costs

Applied from (Aminoff et al., 2000) the costs of outbound operations in warehouses can be estimated for one shipment with two cost components: A component for delivery-specific costs and a cost associated with each order line of the shipment.

$$C_{out} = C_{shipment,out} + N_{orderline} \times C_{orderline,out} \quad (1)$$

Where

C_{out} = total outbound logistics costs per shipment

$C_{shipment,out}$ = outbound logistics costs per shipment independent of order size

$C_{orderline,out}$ = outbound logistics cost of handling one order line of the shipment

$N_{orderline}$ = number of order lines in a shipment.

Here, $C_{shipment,out}$ and $C_{orderline,out}$ are independent of the compared distribution models, and can be approximated with industry averages, if company-specific figures cannot be obtained. In Finnish warehouses $C_{shipment,out}$ and $C_{orderline,out}$ have average values of €9.60 and €3.00 respectively (Aminoff et al., 2000). These figures include picking, packaging and shipping.

The total outbound logistics cost for the delivery of one customer order are calculated as the sum of all the shipping costs resulting from fulfilling the order. If products from several suppliers are included in the customer order, the costs of the individual shipments are summed up to form the total outbound logistics costs:

$$C_{out,order} = N_s \times C_{shipment,out} + N_o \times C_{orderline,out} \quad (2)$$

Where

N_s = number of suppliers for the customer order

N_o = number of order lines in the order

When calculating the batch picking costs related to replenishing the warehouse, it needs to be noted that only a portion of the suppliers' picking costs must be allocated to an individual customer delivery. The amount to allocate can be calculated by multiplying the batch picking costs with the ratio of products in the customer order to products in one replenishment order.

$$A_{customerorder} = \frac{N_{customerorder}}{N_{replenishmentorder}} \quad (3)$$

Where

$A_{customerorder}$ = Customer order allocation factor for replenishment activities

$N_{customerorder}$ = Number of products in the customer order

$N_{replenishmentorder}$ = Number of products in the replenishment order

The outbound logistics costs are calculated for a replenishment order in the same way as for any order, and allocated for one customer order with the allocation factor of (3):

$$C_{out,order} = A_{customerorder} \times C_{out,batch} \quad (4)$$

A.2 Transportation costs (Collection & Customer delivery)

The transportation costs can be calculated using the logistics service provider's pricing table for transportation. The price is generally a function of the shipment's weight and the distance to be transported:

$$C_{trans} = f_{trans}(w,d) \quad (5)$$

Where

C_{trans} = transportation cost of a delivery

$f_{trans}()$ = pricing function of the logistic service provider for transportation

w = weight of the shipment

d = transportation distance

The total transportation costs of one customer order are calculated as the sum of costs of all individual deliveries needed to fulfil that order:

$$C_{trans,order} = \sum_{i=1}^{N_{trans}} f_{trans}(w_i, d_i) \tag{6}$$

Where 'i' indexes the individual deliveries.

The use of a service provider's pricing table in assessing operational costs can be criticised, but assuming that the transportation company can price its services according to incurred costs, the figures provide accurate enough information on true costs to evaluate the difference between direct delivery, delivery from warehouse and merge-in-transit. The main use of the pricing table here is to compare costs of different distribution channels, and the figures used are from the customer's viewpoint the real amounts they have to pay for transportation with the alternative channels.

Again, when calculating the batch transportation costs related to replenishing the warehouse, the costs per customer order are estimated with the allocation factor of (3).

A.3 Consolidation costs

The consolidation costs are calculated using a pricing table for consolidation operations of the logistics service provider. The pricing table of the logistics service provider can be based on several separate factors, while in the case studied in this thesis the logistics service provider prices its consolidation operations based on the weight of each shipment to be merged.

$$C_{cons} = f_{cons}(w) \tag{7}$$

Where

C_{cons} = consolidation costs for a shipment
f_{cons} = pricing function of the logistics service provider for consolidation
w = weight of the shipment

The total consolidation costs for one order are the sum of costs associated with each consolidated lot, depending on their individual weights:

$$C_{cons,order} = \sum_{i=1}^{N} f_{cons}(w_i) \tag{8}$$

Where 'i' indexes the individual shipments to be consolidated for the order.

Again, using a pricing table of a logistics service provider for operational cost assessment can be criticised, but it is assumed here that the pricing done by the service provider caters for all the incurred costs accurately enough.

A.4 Receiving costs

Applied from (Manunen, 2000), the inbound logistics costs of a delivery can be estimated with two cost components: A delivery-specific component that is independent of the amount of order lines and a cost associated to each order line of the delivery.

$$C_{in} = C_{shipment,in} + N_{orderline} \times C_{orderline,in} \tag{9}$$

Where

C_{in} = total inbound logistics costs per shipment

$C_{shipment,in}$ = inbound logistics costs per order independent of shipment size

$C_{orderline,in}$ = inbound logistics cost of handling one order line in the shipment

$N_{orderline}$ = number of order lines in a shipment.

Here, $C_{shipment,in}$ and $C_{orderline,in}$ are independent of the compared distribution models, and can be approximated with industry averages, if company-specific figures cannot be obtained. For Finnish wholesalers and manufacturers $C_{shipment,in}$ and $C_{orderline,in}$ have average values of €15 and €5, respectively (Manunen, 2000). The figures include receiving, inspection and shelving. The amounts are originally in USD, but during year 2000 the USD to EUR exchange rate was close to 1.

If there are several deliveries for one order (as is with the direct delivery model), the total inbound logistics costs for one customer delivery are the sum of all the costs associated with the deliveries:

$$C_{in,order} = N_d \times C_{shipment,in} + N_o \times C_{orderline,in} \tag{10}$$

Where

N_d = number of deliveries for one customer order

N_o = number of order lines in one customer order

A.5 Warehousing costs

Warehousing costs consist three main elements: handling costs, fixed costs, and inventory holding costs (Simchi-Levi et al., 2000, pp. 26-27). The handling costs can be calculated with the outbound and inbound logistics cost models, presented in (2) and (10).

The fixed storage costs resulting from equipment and space can be allocated to the orders on per pallet or per shelf-meter basis, or more generally as percentage of sales or percentage of average inventory (Manunen, 2000). The percentages are easier to obtain for the evaluation, although calculations result in more product-specific figures by using costs per pallet or shelf-meter, if such numbers are available.

Inventory holding costs include the main elements of capital cost, insurance and obsolescence (Bowersox and Closs, 1996, pp. 254-256). Of these, capital cost is often the most influential component, and at the same time the hardest to determine. Obsolescence is calculated based on experience of how products must have been marked-down or destroyed. Obsolescence is often remarkable for high tech products, where technological development rapidly decreases the value of older products (Anon., 2002). The elements can be expressed as percentage of sales or percentage of average inventory. The individual percentages are then summed up to assess the total inventory holding costs.

The relationship between percentage of sales and percentage of average inventory can be explained with inventory turnover ratio, defined as (Simchi-Levi et al., 2000, p. 27):

Inventory turnover ratio = Annual sales / Average inventory level

Since the same annual cost C can be calculated with percentage of sales (C = percentage of sales * annual sales) or with percentage of average inventory (C = percentage of average inventory * average inventory), these can be used to substitute for the annual sales and average inventory level in the above formula. It can be shown that this results in the following equation:

Percentage of sales = Percentage of average inventory / Inventory turnover

In the below formula, both the storage costs and inventory holding costs are expressed as percentages of sales for a stock-keeping unit (which can be derived from the percentage of average inventory –figure, if that and the inventory turnover for the stock-keeping unit are available). Using stock-keeping unit (SKU) specific percentages enables the differentiation of costs between separate product types.

To estimate the warehousing costs of a customer order, all the cost elements of the warehousing activity are added up. The inbound logistics costs, storage costs, and inventory holding costs are calculated individually for each stock-keeping unit of the order. These are summed up and the outbound logistics costs for the order are added.

In the below formula the inbound logistics costs ($C_{in,i}$) for each order line are calculated as in A.4 by using the warehouse replenishment orders and the allocation factor presented in A.1. The outbound logistics costs ($C_{out,order}$) are calculated as in A.4 for the customer delivery.

$$C_{warehouse,order} = \sum_{i=1}^{N_o} \left(C_{in,i} + \left(P_{storage,SKU} + P_{inventory,SKU} \right) \times V_i \right) + C_{out,order} \tag{11}$$

Where

$C_{warehouse,order}$ = warehousing costs for a delivered order

i = index for order lines up to N_o

$C_{in,i}$ = inbound logistics costs of the order line as a part of a replenishment delivery

$P_{storage,SKU}$ = storage costs as percentage of sales for the SKU of the order line

$P_{inventory,SKU}$ = inventory holding costs as percentage of sales for the SKU of the order line

V_i = sales value of the order line

$C_{out,order}$ = outbound logistics costs for the order

This model for warehousing costs can be considered rather rough, but it gives a reasonable estimate for the purposes of these distribution model comparisons.

According to Manunen (2000), for the Finnish wholesalers the above storage and inventory costs can be estimated at 0,7 and 1,1 percent of sales, respectively.