TAMPERE UNIVERSITY OF TECHNOLOGY
Degree Programme in Industrial Engineering and Management

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LEAN IMPLEMENTATION IN LOGISTICS

Master of Science Thesis

Prof. Juha-Matti Lehtonen has been appointed as the examiner at the Council Meeting of the Faculty of Business and Technology Management on August 19, 2009.

ABSTRACT

TAMPERE UNIVERSITY OF TECHNOLOGY
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The study focuses on logistic operations of the case company, Biohit Group. It is a part of a wider lean development project, and therefore logistics of Biohit Group is evaluated from perspective of lean philosophy. An issue of how inventory management and control has to be organized to facilitate logistic processes and to support better customer service is addressed. A closely related subject is how daily logistic processes can be improved. These two issues are included into the following research problem: how should non value adding activities occurring in ordering, order processing, dispatching and reception of goods be eliminated or improved in order to make logistic value streams of Biohit more efficient? The objective of the thesis is to give concrete guidelines how to change current logistic management and procedures in Biohit Group in order to support weekly ordering cycles and better delivery reliability in the future.

Theoretical section is divided into two main chapters that are logistics and lean thinking. Related literature and previous studies are covered. Empirical section goes first deep into the parent company's end of the logistic chain and then to the subsidiaries' logistics. Material was gathered using on-the-spot interviews and a questionnaire consisting of both quantitative and qualitative data. A lean tool called value stream map is used to illustrate logistic processes.

A key finding is that the subsidiaries' orders from the parent company do not match with the needs of subsidiaries' customers. The subsidiaries anticipate delivery problems of the parent company and therefore hold excess inventory, which results in low inventory turnover rates. The subsidiaries' tendency of ordering in big batches decreases the delivery reliability of the parent company. Corrective actions are required simultaneously in the parent company and in the subsidiaries. Shorter and more accurate delivery times within Biohit Group are needed. Better information sharing is a prerequisite for developing more efficient ordering and inventory management practices. Variation in sizes and timing of the subsidiaries' orders to the parent company has to be reduced. This can be done by ordering in standard-length cycles using kanban to replenish stock. Inventory turnover is suggested to be suitable indicator for logistics to monitor inventory performance.

TIIVISTELMÄ

TAMPEREEN TEKNILLINEN YLIOPISTO
Tuotantotalouden koulutusohjelma

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Työssä paneudutaan kohdeyritys Biohitin logistiikkatoimintoihin. Työ on osa laajempaa lean-tutkimushanketta, minkä vuoksi Biohitin logistiikkaa lähestytään lean-filosofian näkökulmasta. Tutkimuskohteena on, kuinka varastonhallinnan suunnittelulla ja järjestämisellä voidaan tehostaa logistiikkaprosesseja ja parantaa asiakaspalvelua. Tähän liittyen arvioidaan, miten päivittäisiä logistiikkaprosesseja voidaan tehostaa. Nämä kaksi mielenkiinnonkohdetta sisältyvät tutkimusongelmaan: miten tilaustenteon, tilaustenkäsittelyn, tavaroiden lähettämisen ja vastaanoton arvoa tuottamattomat toiminnot olisi poistettava tai korjattava, jotta Biohitin logistiset arvovirrat toimisivat tehokkaammin? Työn tavoite on antaa konkreettinen toimenpidesuositus Biohitin nykyisen logistiikanhallinnan muuttamiseksi, millä tuetaan viikkotilaussyklejä ja entistä parempaa toimitusvarmuutta.

Teoriaosio on jaettu kahteen pääteemaan, jotka ovat logistiikka ja lean-filosofia. Kunkin yhteydessä esitellään aiheeseen liittyvää kirjallisuutta ja aikaisempia tutkimuksia. Empiirisessä osiossa paneudutaan ensin emoyhtiön päähän logistiikkaketjussa ja sitten tytäryhtiöiden logistiikkaan. Aineisto on kerätty haastatteluilla ja lomakekyselyllä, joka koostuu sekä numeerisesta että laadullisesta osiosta. Logistiikkaprosesseja mallinnetaan käyttämällä lean-työkalua nimeltä arvovirtakuvaus.

Työn keskeinen havainto on, että tytäryhtiöiden tilaukset emoyhtiölle eivät vastaa tytäryhtiöiden asiakkaiden kysyntää. Tytäryhtiöt varastoivat ylimääräisiä nimikkeitä ennakoidessaan emoyhtiön toimitusongelmia. Tämä johtaa huonoon varastonkiertoon. Tytäryhtiöiden taipumus tilata suuria eriä heikentää emoyhtiön toimitusvarmuutta. Korjaavia toimenpiteitä tarvitaan yhtä aikaa sekä emoyhtiössä että tytäryhtiöissä. Konsernin sisäisten toimitusaikojen tulee olla nykyistä lyhyemmät ja täsmällisemmät. Jotta tilaustoiminnan ja varastonhallinnan käytännön saadaan tehokkaammiksi, on tiedonjakamista tehostettava. Hajontaa tytäryhtiöiden tilausten koossa ja ajoituksessa emoyhtiölle on vähennettävä. Tämä voidaan toteuttaa standardisoimalla tilaussyklin pituus ja siirtymällä kanban-varastonohjaukseen. Logistiikan suorituskykymittariksi esitetään varastonkiertoa, jolla voidaan seurata varastonhallinnan toimivuutta.

PREFACE

Little did I know what was ahead of me when I started the Master's Thesis project in May 2009. Since then, I have visited several new places, met a number of professional people and above all, learnt more than I could have imagined. In addition, the Master's Thesis project has served as basis for new challenging tasks. I owe great thanks to my two supervisors Production Director Kalle Härkönen and Professor Juha-Matti Lehtonen. They have provided valuable feedback and shared their knowledge at different phases of the project.

Helsinki, 7.3.2010

Maria Haukipuro

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TERMS, ABBREVIATIONS AND NOTATION

Axapta	ERP system used in Biohit Oyj and Biohit SAS.
Bullwhip effect	A phenomenon in which immediate customers' orders fluctuate more than orders of second-tier customers.
Delivery reliability	Ratio of the number of deliveries made without error regarding time, place, price, quantity, or quality to the total number of deliveries in a period (Business Dictionary 2009). In the case settings implies that right items leave from the dispatching department on the exact date that is confirmed to a customer.
ERP system	Enterprise Resource Planning System.
Frame order	System of ordering used in Biohit subsidiaries in which rolling order covering following three-months-period is updated once per month.
Houlihan effect	One cause of the bullwhip effect also known as flywheel effect implying that anticipation of shortages in stock leads to over-ordering and excess stocking.
Kardex	Automated storage used storing pipettes in Biohit.
OEM	Original equipment manufacturer. The name refers to a company that designs, manufactures or packages the final product under its own name. The product may include third-party components, such as instruments, software or applications. (Biohit Annual Report 2008, p. 24.) OEM items manufactured by Biohit are identical to Biohit products but are sold under other brands' name.
PL	Private label products that are designed and manufactured for another company which markets the products under its own brand name (Biohit Annual Report 2008, p. 25). PL items manufactured by Biohit are sold under other brands' name and include additional features not built-in in Biohit products.

VMI	Vendor managed inventory. Suppliers carry responsibility for owning, managing, and replenishing inventory of their customers. Suppliers monitor retail supplies and replenish inventories when supplies are low. (Stevenson 2009, p. 530.)
VSM	Value stream map is a diagram of every step involved in the material and information flows needed to bring a product from order to delivery.

1. INTRODUCTION

1.1. Background

This study is part of a wider *lean* development project being realized in the case company Biohit Group that consists of Biohit Oyj and its subsidiaries. Lean thinking has been studied and lean tools implemented in production settings of Biohit since 2008. Improvements have been achieved but full benefit of the good results cannot be gained as long as other corporate functions are not integrated into lean production system and hence, cannot completely support lean practices. Especially logistics is critical since it can either complicate or support production, depending on how it is organized and managed. Therefore, this study focuses improving corporate logistics exploiting lean approach.

Wilding (1998, p. 599) notes that uncertainties in supply and demand have a major impact on manufacturing function. Biohit Oyj, the parent company of Biohit Group, has long experienced fluctuating demand which causes are somewhat unknown. The Biohit subsidiaries create majority of direct demand to the parent company. For example during the last two quarters of 2008 and the first two quarters of 2009 their purchases accounted for 56 % of the sales of liquid handling business in Biohit Oyj (Axapta 30.7.2009). The rest of the direct demand comes from external sources, in other words from distributors and end customers. Despite of obvious importance of the subsidiaries, their ordering patterns and inventory policies are not previously studied in Biohit Oyj. The subsidiaries operate somewhat independently. According to Wilding (1998, p. 606) supply networks have to be managed as a system instead of a collection of individual companies. In the case settings the aforesaid notion can be interpreted so that the subsidiaries' inbound logistics, outbound logistics and inventory control should be standardized and build to support corporate-wide goals.

Value stream approach to logistics is exploited throughout the study. A value stream consists of two kinds of activities needed to produce a physical product or service: activities adding value and those not adding value of a product or service (Mapping to See 2007, p. 157). Whether an activity is value adding or non value adding is defined from customers' perspective (Liker 2004, p. 27). For example, a process of order processing and dispatching can include activity of searching for missing information that is non value adding whereas activity of picking items prior to dispatching is value adding. Initially in this study the corporate logistics were to be approached using a lean tool called *value stream mapping*. The following definition of the tool is given in Value Stream Mapping Workshop (2008, p. 66):

It is a simple diagram of every step involved in the material and information flows needed to bring a product from order to delivery.

Application and benefits of value stream mapping is guided in several sources (for example Rother & Shook 2003; Keyte & Locher 2004; Womack 2006; Nash & Poling 2008). However, the problem field of this study was discovered to be so complex and wide that value stream mapping alone would not provide sufficient understanding. It is then exploited alongside with other approaches and tools.

According to Rother & Shook (2003) value stream mapping creates basis for development planning and serves as a communication tool between different functions in a company. Aforementioned role of value stream mapping is suitable in this study: value stream mapping is exploited to visualize and understand current logistic value streams. Deeper understanding of problems and possible solutions are acquired by analyzing numerical data and interviewing personnel involved in corporate logistics. The most suitable means to process data and deal with appearing issues are collected and adapted from lean literature and research (for example Jones et at. 1997; Smalley 2004), logistic literature and research (for example Lee et al. 1997; Ballou 2004), and current practices of Biohit.

An apparent consequence of poor logistic management is accumulating and slow-turning inventories of the subsidiaries. In lean literature inventories represent one type of non value adding *waste* (for example Liker 2004, pp. 28-29). Waste is an activity which does not create value for a customer still consuming resources (Value Stream Mapping Workshop 2008, p. 66). Hence, extra attention is given to inventory control and management. Inventory accumulation has long been studied both separately from and alongside with lean thinking. Studies of Forrester (1958) have created basis for research of *the bullwhip effect* later studied by several academics (for example Burbidge 1991, see Disney & Towill 2003; Houlihan 1987, see Disney & Towill 2003; Lee et al. 1997). Findings of Burbidge regarding influence of batching policies on inventory levels apply in the case settings. Also influence of delivery reliability and shortage anticipation on inventory accumulation, specialization of Houlihan, is experienced in Biohit Group. Hence, proposals for action to improve inventory performance are found in existing publications.

1.2. Study outline

This study addresses the logistic issues of Biohit Group. Main focus is on logistics between Biohit Oyj and its subsidiaries, and outbound logistics of the subsidiaries.

Processes of outbound logistics are processing of incoming orders and their dispatching. Respectively, processes of inbound logistics are ordering and reception of goods. Inventory management is considered as a part of these processes.

The focus is on liquid handling business of Biohit Group. The study focuses on make-to-stock items, which implies that only products sold under Biohit brand name are covered. Private label products, from now on abbreviated as PL, and original equipment manufacturer products, from now on abbreviated as OEM, are items sold under other brands' name. Contrary to Biohit brand name products, PL and OEM are make-to-order items.

1.3. Research problem

This study addresses an issue of how daily logistic processes can be improved. Another subject to be studied is how inventory management and control has to be organized to facilitate logistic processes and support customer service. The both issues are included in the research problem formulated as follows:

How should non value adding activities occurring in ordering, order processing, dispatching and reception of goods be eliminated or improved in order to make logistic value streams of Biohit more efficient?

The research problem implicitly includes a question of which are the non value adding activities of ordering, order processing, dispatching and reception of goods. The research problem is approached with help of sub-problems. The most significant non value adding activity is excess inventories. Hence, inventory control is given extra attention, and the latter of below-stated sub-problems addresses issue of inventory control.

1. How materials and information flow between Biohit Oyj and the subsidiaries?

2. How inventories should be controlled to support recent improvements in production?

1.4. Objectives

More effective logistics is needed to support improvements achieved recently in production of Biohit Group due to the lean development project. Hence, an objective of Biohit Oyj is that processing and dispatching of the subsidiaries' orders can be carried out in level weekly cycles in the near future. This can be achieved by increasing subsidiaries' inventory turnover, eliminating process variation and standardizing logistic procedures. Intention is to build more predictability in operations of the logistics department, the dispatching department and production of Biohit Oyj. A long term objective of Biohit Oyj is to increase delivery reliability up to 100% with help of better coordinated logistics. Delivery reliability in the case company means that right items leave from the dispatching department on the exact date that is confirmed to a customer.

The below-stated objective of this study is derived from the objectives of Biohit Oyj.

The objective is to give concrete guidelines how to change current logistic management and procedures in Biohit Group in order to support weekly ordering cycles and better delivery reliability in the future.

This can be achieved by identifying critical development targets in Biohit Group's existing logistic management and procedures. The objective is multifaceted since it includes both ends of the logistic chain, the parent company and the subsidiaries, and requires two types of guidelines, how to alter current practices and how to create new ones. This is illustrated in figure 1.1.

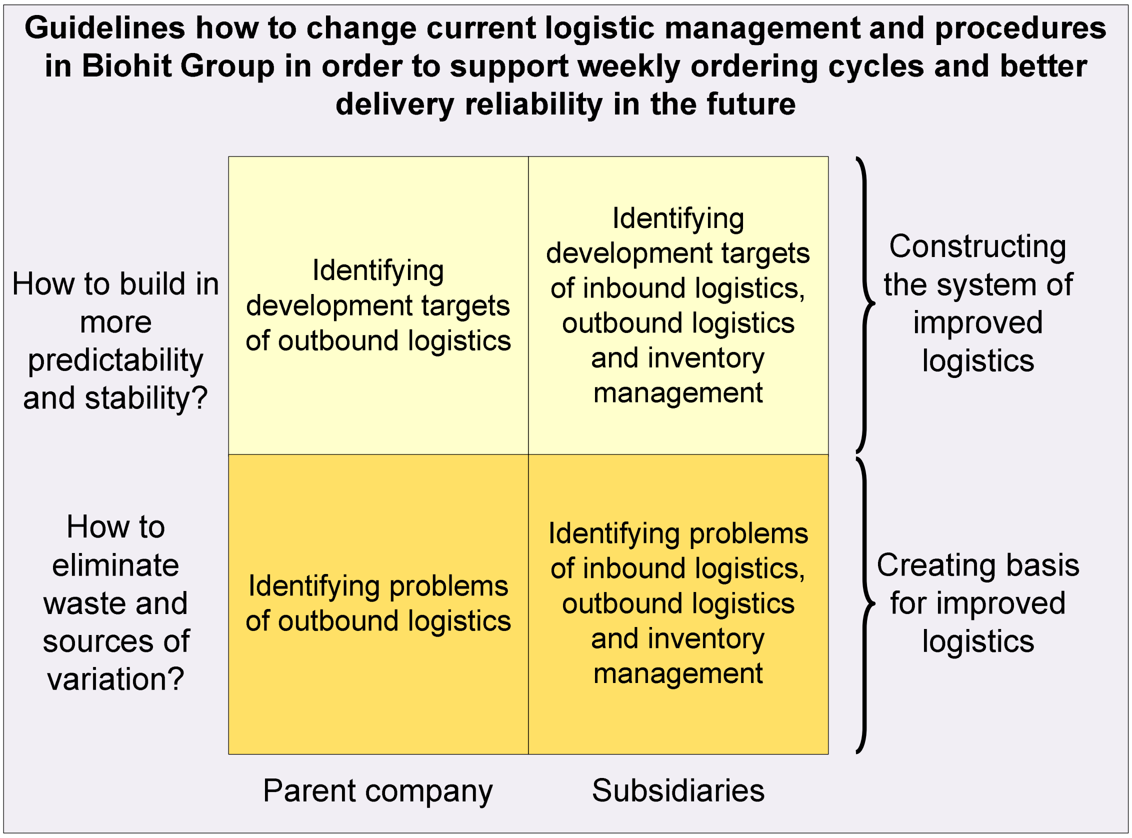

Figure 1.1. *Structure of the objective.*

Accomplishing the target requires creating basis for improved logistics in Biohit Oyj and in the subsidiaries. This can be done by identifying problems and solving how to eliminate existing waste and sources of variation in the both ends of the logistic chain, as illustrated in the lower part of figure 1.1. Constructing a new system of improved logistics requires solving a problem of how to build in more predictability and stability into logistics. This is illustrated in the upper part of the figure 1.1.

1.5. Structure of the study

Focus of the research is in logistics. Perspective is that of lean philosophy. This perspective is dictated by the wider lean development project carried out in Biohit Group. Hence, logistics form a study frame where applicability of lean thinking is evaluated. First, lean thinking is connected to logistics in the theoretical section of the study. Then, applicability of lean thinking in the case company's logistic operations is evaluated. Research setting is illustrated in figure 1.2.

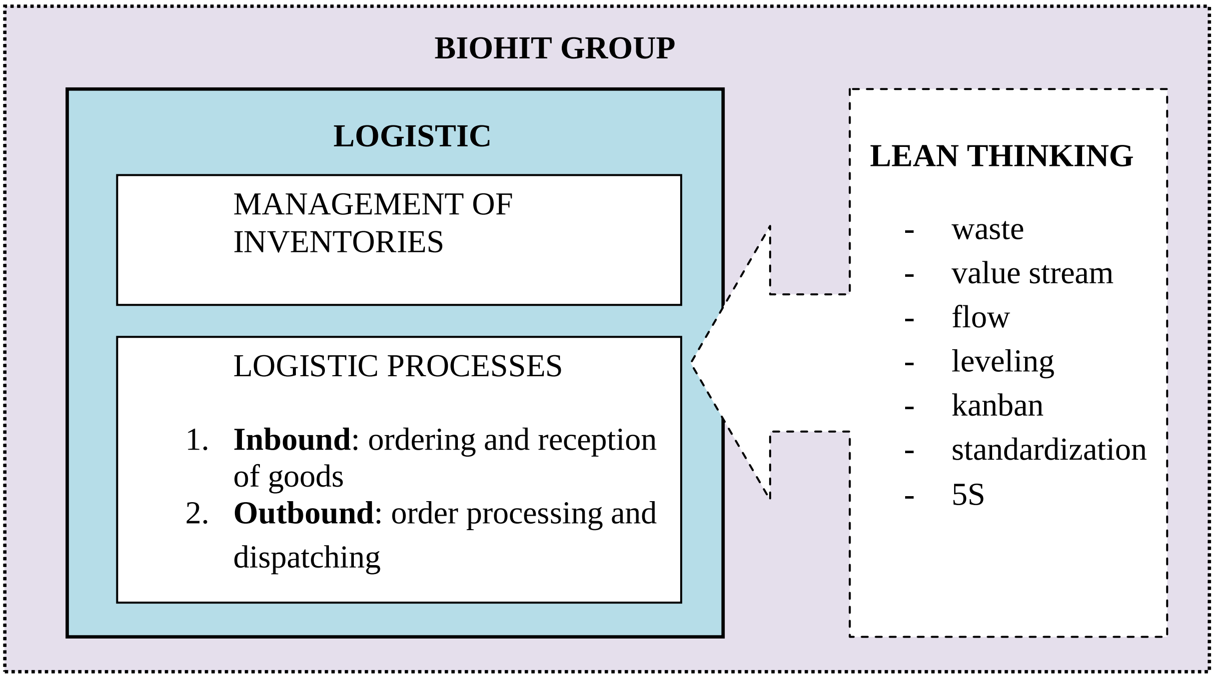

Figure 1.2. *Research setting.*

The first part of the theoretical section, chapter 2, studies logistics and its typical features. As illustrated in figure 1.2, the two separate subjects within logistics are management of inventories and logistic processes. These are not studied independently but discussed in parallel. Logistic processes include inbound and outbound logistics. Lean philosophy and selected lean tools are discussed in the latter part of the theoretical section in chapter 3.

Theoretical study is followed by chapter 4 introducing empirical research method and material. Accuracy of data is evaluated in this context. Results are presented in chapter 5. The parent company's end of the logistic chain is discussed first. Accomplishment of the objective presented in figure 1.1 is initiated covering the lower left-hand corner and some of the upper left-hand corner. This is followed by comparison of the subsidiaries' performance and discussion of each subsidiary individually, which means covering the lower right-hand corner and some of the upper right-hand corner of figure 1.1. Understanding of the upper part of the figure 1.1 builds up throughout the study. Conclusions and proposals for action are presented in chapter 6.

2. LOGISTICS

2.1. Essential terms and their relations

Logistics, as defined in Supply Chain Management Terms and Glossary (2009), is a process consisting of three kinds of activities that are planning, implementing, and controlling transportation and storage of goods from the point of origin to the point of consumption. Logistics takes into consideration services and related information besides considering physical goods. The same source defines *business logistics* as a systematic and coordinated set of activities required to provide the physical movement and storage of goods from supply services through company facilities to the market. (Supply Chain Management Terms and Glossary 2009.) These definitions clearly highlight the two important aspects of logistics: storing and moving items. The aforementioned three kinds of logistic activities implicitly include tasks such as ordering or preparing outgoing shipments that are of interest in this study. Shortcoming of the definitions above is that they assume one-way transport of goods. In addition, the role of services and information is rather minor and movements of currency are not mentioned. Regardless of these shortcomings, the ideas presented in the aforementioned definitions are useful in these study settings.

Definition of Council of Supply Chain Management Professionals (2009) for logistics management highlights that logistics is a subset of supply chain management. Hence, logistics issues, such as inventories, are commonly discussed in more extensive context of supply chain management (for example Lee & Billington 1992; Cooper & Ellram 1993). Because of that, studying literature covering purely just logistics can limit holistic understanding. Not in this study either is the concept of logistics isolated from the concepts of supply chain and supply chain management. Supply chain is, according to Mentzer et al. (2001, p. 4), a set of three or more entities involved in the upstream and downstream flows of products, services, finances or information from a source to a customer. This definition alone is exact enough for purposes of this study. It includes two concepts, *downstream* and *upstream* of a supply chain, which are referred later in this thesis. Downstream implies entities after the one under consideration such as distributors and end customers whereas upstream implies preceding entities such as supplying organizations.

A definition of logistics suitable for this study is formulated based on the discussion above:

Logistics is a subset of supply chain management consisting of coordinated set of activities of planning, implementing, and controlling transportation and storage of goods and related information to meet customer requirements.

Logistics management is an integrating function coordinating logistic activities and integrating them with other functions. It is involved in strategic, operational and tactical levels of planning and execution. (Council of Supply Chain Management Professionals 2009.) Stevenson (2009, p. 512) gives a concrete listing of the activities of logistics management that are administrating inbound and outbound transportation, material handling, warehousing, inventory, order fulfillment and distribution, third-party logistics, and reverse logistics.

2.2. Inventory management

As noted earlier, logistics management includes several inventory-related activities. An essential starting point of the thesis is need for more coordinated inventory management in Biohit subsidiaries. Hence, inventory-related issues are given extra attention.

2.2.1. Typical problems

Important issues of inventory management are what to hold in stock and how much, where to locate inventories and how to control them. Lee & Billington (1992) have identified 14 common pitfalls of inventory management. These are summarized in table 2.1.

Table 2.1. *Pitfalls of inventory management (Lee & Billington 1992).*

	Pitfall	**Comment**
1	No supply chain metrics	Each organization has own objectives that do not support the supply chain's overall performance. In result there are no performance measures for the complete supply chain.
2	Inadequate definition of customer service	Service is poorly measured. Service level might be measured in terms of line item fill rate but fill rate of complete orders or average backorder levels are not tracked.
3	Inaccurate delivery status data	Customers are not provided with timely and accurate updates on the status of late orders.

	Pitfall	Comment
4	Inefficient information systems	There are several databases that are not linked. This can lead to gross forecast errors and inventory accumulation.
5	Ignoring the impact of uncertainties	Different sources of uncertainties, such as lead time, delivery performance, demand or quality, are not understood or tracked. This can result in overstocking some items and under-stocking others.
6	Simplistic inventory stocking policies	Inventory stocking policies are too generic and static.
7	Discrimination against internal customers	Internal customers experience poor customer service, which has a negative impact on the overall supply chain.
8	Poor coordination	There is lack of coordination of supplying divisions, which results in delays and poor customer service.
9	Incomplete shipment method analysis	Maintaining transport costs low can lead to increase in total costs. Using sea freight instead of air freight or ordering bigger batches infrequently instead of frequent small batches can increase pipeline inventory and level of safety stock.
10	Incorrect assessment of inventory costs	Some inventory costs such as opportunity cost, and cost of reworking existing inventory are often ignored.
11	Organizational barriers	Differences in objectives, disagreements on inventory ownership, and unwillingness to commit resources to help others inhibit coordinated inventory control.
12	Product-process design without supply chain consideration	Inventory implications and required changes in supply chain are not considered during the product-process design.
13	Separation of supply chain design from operational decisions	When changing a supply chain structure the main consideration is usually fixed costs and the logistic cost implication. Operational efficiency factors such as inventory investment are ignored.
14	Incomplete supply chain	Immediate customers are considered being the end of a supply chain.

Stevenson (2009, pp. 540-541) highlights the trade-offs implicitly included in the ideas of Lee & Billington (1992). He concludes them into the following five trade-offs: *lot size - inventory*, *inventory - transportation cost*, *lead time - transportation cost*, *product variety - inventory* and *cost - customer service*. Disney & Towill (2003) do not use wording trade-off but discuss about the production/inventory control problem, which in their opinion is a fundamental characteristic of a tradition supply chain. That is, each organization needs to solve the problem of how much to produce or purchase in order to satisfy immediate customers' demand (Disney & Towill 2003).

2.2.2. Bullwhip effect

Small changes made to optimize one part of a supply chain can cause major changes elsewhere in the supply chain (Wilding 1998, pp. 599-604). A phenomenon, in which variation in demand intensifies when moving upstream of a supply chain, was first introduced by Forrester (1958). He simulated how minor changes in retail sales can lead to large swings in production: random events in the customers' end of a logistics chain convert into upswings and downswings in orders and production. Forrester (1958) also demonstrated how orders are left unfilled even though production capacity exceeds final customers' demand. Forrester's simulations have served as a basis for study of the phenomenon known as the bullwhip effect (McCullen & Towill 2002). Later a considerable amount of evidence is provided to show that the bullwhip effect exists also in real-world settings as distinct from simulation model results (Disney & Towill 2003).

Lee et al. (1997, p. 93) suggest that the common symptoms of the bullwhip effect are *excess inventories, poor forecasts, insufficient or excess capacity, unsatisfactory service due to unavailable products* and *uncertain production planning*. McCullen & Towill (2002, p. 169) list mainly similar symptoms but have in addition identified *unnecessary fluctuations in the level of production and shipments* as one of the consequences of the bullwhip effect. The bullwhip effect appears in many ways and in different fields of a logistic chain. The four major causes of the phenomenon adapted from Lee et al. (1997) and further studied by Disney & Towill (2003) are listed below, and later discussed in more detail.

1. Each tier of a supply chain bases its demand forecasts on previous tiers' orders.

2. Orders are placed in batches.

3. Prices fluctuate due to promotions, which leads to demand that does not reflect real consumption rate.

4. Customers anticipate shortages and therefore exaggerate their real needs.

Disney & Towill (2003) call the first cause *the Forrester effect*. The bullwhip effects are created when supply chain members process the demand input from their immediate downstream members and do not consider the supply chain as a whole (Lee et al. 1997, p. 95). This means real end customers' consumption data is distorted when moving upstream of a supply chain, and upstream organizations do not have first-hand information about end customers' demand. Lee et al. (1997, p. 98) advise sharing demand data at a downstream site with upstream organizations to reduce distortion of information. However, Chen et al. (2000) note the bullwhip effect cannot be fully eliminated as long as downstream data is based on forecasts instead of real demand. This idea is supported by Womack (2006) noting that market forecasts of demand are incorrect. Traditional forecasting techniques need past sales figures as feedback whereas many lean approaches do not rely on complex information feedback systems. Therefore, chaos can be controlled by communicating demand information upstream using lean approaches. (Wilding 1998, pp. 610-611.) Similar idea was presented already in 1987 by Suzaki who proposed using level schedules to respond to true demand instead of forecasts. This is an essential idea in lean thinking (see McCullen & Towill 2002, p. 171), and is discussed in more detail in chapter 3.3 Leveling.

The second cause of the bullwhip effect, ordering in batches, is studied in more detail by Burbidge (for example 1991), and therefore is sometimes referred as *the Burbidge effect* (see Disney & Towill 2003). It intensifies the bullwhip effect as there are many customers. Timing of orders tends to be random, and at the worst case different customers' orders overlap. Customers' order cycles should be spread out evenly to avoid demand peaking. Batch sizes can be reduced by lowering the benefits of big batches. This can be done by minimizing transaction costs and costs of transport. (Lee et al. 1997, pp. 96-100.) In addition, ordering has to be made as easy as possible to encourage ordering in frequent and small batches. Placing orders and processing incoming dispatches must be simple and standardized.

Fluctuating prices encourage buying in batches. Lee et al. (1997, p. 97) state that low prices promote forward buying, and demand can drop when discounted product's price returns to its normal level. According to studies of Disney et al. (2003) fifty percent increase in capacity is required to maintain desired service level in a traditional supply chain due to price variations. Therefore, frequency and level of price discounting should be kept minimal (Lee et al. 1997, p. 101). Besides organizations at downstream sharing information about demand, they should communicate about promotion campaigns upstream. Hence, upstream companies can prepare their operations and also influence pricing campaigns.

The fourth cause of the bullwhip effect, exaggerating real needs, happens when customers are uncertain about supply (Lee et al. 1997, p. 101). Disney & Towill (2003) note the practice is also known as *the Houlihan effect* discussed further in chapter

2.2.2.1. Considering Wilding's (1998) aspect of parallel interactions in a supply chain echelon, the Houlihan effect can greatly intensify the bullwhip effect. Wilding's (1998) finding is that parallel interactions generate uncertainty in a supply network and can intensify demand amplification. This means that actions of one organization affect operations of other organizations at the same tier in a supply network (Wilding 1998, p. 604). If one organization of a supply chain echelon exaggerates its needs, production capacity can be tied up causing prolonged delivery times to other organizations in the same echelon. This in turn encourages the others to exaggerate their needs. Lee et al. (1997, p. 101) claims that the sharing of capacity and inventory information reduces the need for anticipating. Based on the discussion so far, it is important that information flow is two-way. Coordinating information and planning in co-operation along a supply chain are means to control the bullwhip effect (Lee et al. 1997, pp. 94-95).

The bullwhip effect is a complicated phenomenon since it appears in many ways and is caused by several factors. Hence, a definition is needed to specify what is meant by the bullwhip effect in this study. Business Dictionary (2009) defines the bullwhip effect as *tendency of consumers of a material or product in short supply to buy more than they need in the immediate future.* Considering the theory covered above, this definition is very limited. However, a definition highlighting a complete supply chain would be too wide for purpose of this study since it is useful to consider the phenomenon from the point of view of Biohit Oyj. A suitable definition should highlight the outcome of the phenomenon more than the causes because the outcomes are more recognizable. The following definition is used in this study:

The bullwhip effect is a phenomenon in which immediate customers' orders fluctuate more than orders of second-tier customers.

The definition does not provide an explanation why customers' demand fluctuates. Upswings and downswings in demand can occur for example due to anticipating of shortages, seasonal variation or mistakes in ordering.

2.2.2.1 Houlihan effect

Forrester (1958, p. 46) described a situation where distributors' demand exceeds factory capacity, which leads to longer delivery times. He showed that this motivates distributors to order in advance of needs and still more orders are placed. In such situation production operates at full capacity unable to fulfill distributors' needs on time while retail sales are far below production's maximum capacity (Forrester 1958, p. 46). Houlihan (1987, see Disney & Towill 2003) has further studied the impact of delivery reliability on ordering patterns. Houlihan effect, also known as the flywheel effect, is presented in figure 2.1.

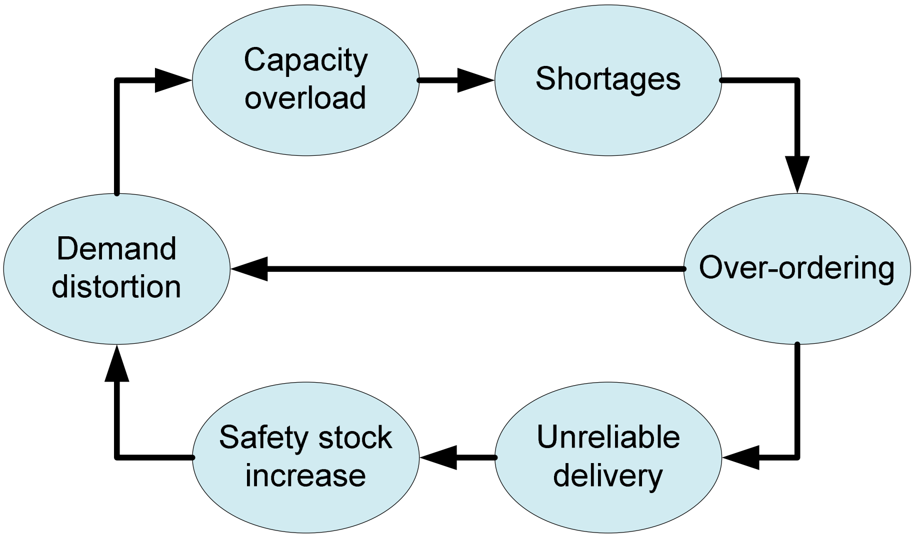

Figure 2.1. *Houlihan effect (Houlihan 1987, see Disney & Towill 2003).*

Figure 2.1 illustrates how customers overload their schedules or orders as shortages occur. This leads to demand distortion: order quantities do not match real with demand. Additional loading of production results in more unreliable deliveries. Customers then increase their safety stock target. (Houlihan 1987, see Disney & Towill 2003.) This step of the flywheel effect is supplemented with finding of Lee et al. (1997) which suggests that long resupply lead times compel holding of safety stock. Increase of safety stock further distorts demand and accelerates the bullwhip effect (Houlihan 1987, see Disney & Towill 2003).

Disney & Towill (2003) have simulated how causes of the bullwhip effect are affected by vendor managed inventory (VMI), which according to Stevenson (2009, p. 530) means that suppliers carry responsibility for owning, managing, and replenishing inventory of their customers. The results of Disney & Towill (2003) suggest that the Houlihan effect can be completely eliminated when successfully adapting VMI in a supply chain. In consequence the bullwhip effect can be reduced.

2.2.2.2 Measuring the bullwhip effect

Statistical methods to measure the bullwhip effect are utilized in research (for example Chen et al. 2000; Disney & Towill 2003). The equations of these methods are based on hypothesis and constraints, which limits their applicability in different settings. The purpose here is not to quantify the bullwhip effect precisely, and therefore statistical methods based on complex equations would be too laborious for this study and hence not the most suitable means in the case settings.

A simpler tool to analyze the bullwhip effect is *demand amplification mapping* (Jones et at. 1997, pp. 166-167). Of the seven techniques discussed by Jones et at. (1997) demand amplification mapping is the most suitable in the case settings. It is a graph used to compare changes in different organizations' demand in a supply chain. The graph illustrates how variability of sales in downstream of a supply chain is lower than variability in orders placed upstream. Jones et at. (1997) proposes demand amplification mapping as an appropriate tool for analyzing logistics from the lean perspective. Hence, the bullwhip effect, first studied by Forrester in 1958, and the lean thinking, having evolved in Japan since 1950s (Liker 2004, p. 20), are at some degree interconnected: one objective of lean metrics and measures, discussed in greater detail in chapter 3. Lean thinking, is to understand and reduce the bullwhip effect.

Another lean tool suitable for studying the bullwhip effect is *decision point analysis*. It is means of identifying the point in the supply chain where making products due to actual demand is stopped and making against forecasts is started. (Jones et at. 1997, pp. 167-168.) As noted earlier in chapter 2.2.2 the bullwhip effect intensifies as data of demand is based on forecasts, which is why decision point analysis is interesting when studying the bullwhip effect.

2.2.3. Inventory turnover

Inventory turnover is a key figure measuring how many times a year inventory is sold. It is a widely used measure for effectiveness of inventory management. (Stevenson 2009, p. 553.) Inventory turnover can also be interpreted as measure for purchasing efficiency (Jahnukainen & Lahti 1999). It is an ambiguous parameter because it can be calculated several ways. According to several sources (for example Gaur et al. 2005, p. 181; Stevenson 2009, p. 553) inventory turnover is calculated dividing average cost of goods sold by average inventory investment. Ballou (2004, p. 376) provides the following formula (1) very similar to the method of Gaur et al. and Stevenson.

$$Turnover\ ratio = \frac{Annual\ sales\ at\ inventory\ \cos t}{Average\ inventory\ investment} \tag{1}$$

The denominator of Ballou's formula is an average inventory investment. Another option is to use prevailing inventory value in the end of a period under review as Huson & Nanda (1995). The numerator in Ballou's formula is sales at inventory cost .The problem is how to define sales at inventory cost or, as defined by Stevenson (2009, p. 553), average cost of goods. Sales at inventory cost can include not only a purchase price but also inventory management costs that can be hard to allocate as already noted in chapter 2.2.1 Typical problems (see pitfall 10). This issue can be solved using other units, such as number of pieces, instead of monetary values. In consequence Ballou's formula alternates to the following form (2).

$$Turnover\ ratio = \frac{Annual\ sales\ in\ number\ of\ pieces}{Average\ inventory\ in\ number\ of\ pieces} \tag{2}$$

When in addition exploiting end-of-a-period values instead of average inventory, the formula can be expressed as below (3).

$$Turnover\ ratio = \frac{Annual\ sales\ in\ number\ of\ pieces}{Inventory\ in\ number\ of\ pieces\ in\ the\ end\ of\ a\ period} \quad (3)$$

In formula (3) the denominator can be inventory at any point of time since period can refer to one week as well as to a full year. The most convenient way of calculating inventory turnover depends on the situation and available data. It is essential to systematically apply the same method because different formulas can yield slightly different outcomes. When comparison is done between companies that deal with different currencies, such as the subsidiaries of Biohit Group, it is well justified to use number of pieces instead of monetary values.

The formula (3) can be exploited in two ways: If calculating one year's performance afterwards, annual sales can be constant. When periodically updateable figure is required, annual sales can cover previous twelve months so that the time horizon is rolling. The first procedure is useful when analyzing Biohit subsidiaries' past performance and only data covering a limited time frame is available. The latter procedure, rolling turnover rate, can be exploited if establishing updateable monitoring system.

Period of storage is another measure for effectiveness of inventory management. It is the reciprocal number of inventory turnover ratio, and can be expressed as in the following formula (4).

$$Period\ of\ storage = \frac{1}{Turnover\ ratio} \quad (4)$$

Period of storage equals the time items spend in stock. It is perhaps a more concrete measure than turnover ratio. However, inventory turnover is currently used in Biohit group to some extent, and for that reason it is the favored measure for effectiveness of inventory management used in this study.

3. LEAN THINKING

3.1. Introduction to lean thinking

According to Taiichi Ohno (Monden 1983, p. i) the basis of the Toyota production system was to increase productivity and reduce costs by eliminating all kinds of unnecessary functions. From this starting point evolved mindset called lean thinking. The ultimate vision of a lean organization is to provide the best quality, the lowest costs, the shortest lead time and the best safety while maintaining the highest morale (Liker 2004, p. 33). Ideally this would imply that no traditional trade-offs were needed. Liker (2004, p. 13) suggests lean has four dimensions that he has captured in the “4 P” model. A true lean company has internalized all the four dimensions that are philosophy, problem solving, partnerships and processes (Liker 2004).

Plenty of lean development methods and practical lean tools are presented in literature (for example Monden 1983 discussing several key tools; Smalley 2004 discussing pull system; Glenday 2007 discussing leveling). These form the process level of Liker’s (2004, p. 13) “4 P” model. Jones et al. (1997, p. 156) discuss the key elements of Toyota tool box. The most interesting ones, especially appropriate when considering logistics operations, are listed and explained in table 3.1. Descriptions of Jones et al. are supplemented with discussion from other sources.

Table 3.1. *Selected key elements of Toyota tool box (adapted from Jones et al. 1997, p. 156).*

Element	**Description**
Creating flow	Purpose is to organize work so that a product moves without interruptions. Ideally, items are moved one piece at a time directly from one process step to the next one, which enables minimum use of resources and shortest possible lead time (Rother & Harris 2008, p. 101).
Leveling flow of orders	Purpose is to eliminate all causes of demand amplification. A leveled system adapts to variable demand, and batching is avoided (Mapping to See 2007, p 156). The ultimate objective of leveling is perfect flow (Glenday 2007, p. 15).

Element	Description
Using pull system	A downstream operation paces the work by providing information to its preceding operation about what is needed and how much (Mapping to See 2007, p. 156). Purpose is to deliver the same amount what is pulled by downstream, no more than that.
Standardizing	Purpose is to identify and widely adapt the best work practices. Standardization is the foundation for continuous improvement (Liker 2004, p. 148).
Minimizing safety stock	Purpose is to facilitate smooth flow by holding only inventories directly supporting customer who cannot, by the nature of demand, be linked directly to the flow (Perry 1988).
Visual control	Visual control is any communication device that signals at a glance how work should be done and whether it is deviating from the standard (Liker 2004, p, 150). Visual aids are used to indicate who brings, what, to where and exactly when (Wu 2003, p. 1361).
Removing waste	Removing waste implies streamlining and simplifying material and information flows. This means eliminating anything not adding value to customers. (Naylor et al. 1999, p. 110.)

The elements presented in table 3.1 are interconnected and descriptions overlap to some extent. Each element can be implemented in many ways in practice as discussed later in this theoretical section. Even though lean thinking and the bullwhip effect (see chapter 2.2.2 Bullwhip effect) are originated from different settings and cannot be tightly associated, it can be assumed that *leveling flow of orders* and *using pull system* could be useful counter-measures to tackle the bullwhip effect.

3.1.1. Seven waste

Work can be divided into value adding and non value adding work. Whether an activity is value adding or not can be assessed by asking if a customer would be less satisfied with a product if this step was left out (Womack 2006, p. 149). Non value adding work can be further divided into incidental work and waste (Mapping to see 2007, p. 27). Waste, in Japanese *muda*, is one of the three M's in focus of lean efforts. The other two are *muri*, overburdening people and equipment, and *mura*, unevenness in workload. (Liker 2004, pp. 114-115.)

Jones et al. (1997, p. 171) highlights that as a starting point to successfully create and implement lean philosophy, Toyota worked on understanding waste and inefficiency in its value streams. Hence, waste is an essential concept and serves as basis for lean thinking. Since waste or muda is result of unevenness or mura, focus has to be simultaneously in these two issues (Liker 2004, pp. 114-115).

The following categorization of waste originated in Toyota (Liker 2004, pp. 28-29):

1. Overproduction
2. Waiting
3. Unnecessary transport or conveyance
4. Over-processing or incorrect processing
5. Excess inventory
6. Unnecessary movement
7. Defects

Liker (2004, p. 29) has supplemented the list with one more type of waste, unused employee creativity. The types of waste traditionally associated with production settings exist also in office environment. For example over-processing occurs when data has to be re-entered or excessive reports are created. (Keyte & Locher 2004, p. 17.)

3.1.2. Lean logistics

Jones et al. (1997) talks about lean logistics, lean warehousing, and lean ordering. According to Bowersox et al. (2002, see Wu 2003) lean logistics refers to excellent ability to design and administer systems to control movement and geographical positioning of raw materials, work in process, and finished inventories at the lowest cost. Bartholomew (2008) presents a business case about applying lean thinking in a warehouse. A lean warehouse differs from a traditional one in that there are no bottlenecks in the basic processes and process flow is transparent. Goals as speeding material flow and reducing inventory are the same as in production environment. In addition, some logistics-specific objectives can be defined. For example reduced number of picking errors, better accuracy of inventory, higher productivity of logistic activities, saving in warehouse space and safer working environment can be gained when successfully applying lean philosophy and tools in a warehouse. (Bartholomew 2008.)

Perry (1988) notes that transport assets substitute for inventory assets in just-in-time systems. Similarly Kamoun & Yano (1996), who also refer to lean as a just-in-time system, note that focus is on material flows instead of material storage. Trade-off is made between transport costs and inventory holding costs (Kamoun & Jano 1996). Wu (2003, p. 1365) who has studied differences between lean suppliers and suppliers that have not applied lean philosophy in their operations points out that vehicle utilization of lean suppliers can be poor. Hence, lean can bring along some disadvantages. However, based on studies of Wu (2003) lean suppliers achieve higher scores on most aspects of logistics performance. Besides lean suppliers have significantly lower inventory levels they spend less in emergency shipments and no more than the other suppliers on routine shipments. (Wu 2003.) The findings of Wu and other academics strongly suggest that lean thinking and tools can be successfully applied to logistics. However, it should be noted that probably companies that have not benefited from lean are left outside of the majority of studies, which might reflect to these very positive conclusions.

Womack & Jones (1996) have studied Toyota's distribution system. The main actions and implications of the study have later been summarized by Jones et al. (1997). Operation in Toyota's warehouse include reduction of bin sizes, placing frequently used parts near the front of a warehouse, using standard picking routes, preventing working ahead and dividing working day into standard work cycles. Such warehouse management has resulted in low inventories while service rate and productivity are up. Respectively, delivery and ordering is realized to support lean system: demand information is inputted steadily and deliveries are frequent, which has eliminated need for emergency orders. (Jones et al. 1997.) This practice is also supported by Liker & Wu (2000, p. 82) stating that logistic practices and management policies of customers can have a great impact on ability of suppliers to respond to demand. Based on studies in the car industry, stable orders and regular demand are important means of supporting a lean logistics system (Liker & Wu 2000, p. 86). Conversely, stable production schedules have a positive impact on maintaining stable schedules for customers (Wu 2003, p. 1367). Hence, each party of a supply chain has to commit to support the system.

3.2. Flow

MOT Oxford Dictionary of English 1.0 (2005) provides following sense for the term flow:

1 *The action or fact of moving along in a steady, continuous stream /* ***2*** *a steady, continuous stream or supply of something*

The term *steady* denotes something invariable and *continuous* something uninterrupted. According to Glenday (2007, p. 11) a perfect flow means producing and supplying the same rate as market demand. In ideal case this would mean there are no inventories, items are produced one at a time and resources are adjusted as demand changes (Liker 2004, p. 90; Glenday 2007, p. 11). In reality inventories are needed because there is variation in customer demand and internal processes (Ballou 2004, p. 329; Rother & Harris 2008, p. 64; Stevenson 2009, pp. 551-552).

Rother & Harris (2008, p. 9) identify three types of flow in production environment: *material flow, information flow* and *flow of operators*. All three types of flow should be smooth and continuous in a lean system. Focus here is on information and material flows. Rother & Harris (2008, p. 9) have listed some indicators, in form of assisting questions, that can be used when analyzing if there are true flows in the system. These are presented in table 3.2.

Table 3.2. *Indicators to analyze flows (Rother & Harris 2008, p. 9).*

Material flow	Does the work piece move from one value adding processing step right to the next value adding step?
Information flow	Does everyone working in a process know the targets?
	How quickly are problems and abnormalities noticed?
	What happens when there are problems and abnormalities?

If the material does not flow there is waste between value-adding process steps and the flow is not continuous. If information does not flow people may not share common targets, reaction times are long and no one has responsibility for problem solving.

3.3. Leveling

In Toyota a Japanese term heijunka is used to describe the process of leveling production. It consists of three characters that together specify what is meant by leveling. *Hei* denotes level or flat and applies to quantity and mix. *Jun* denotes standard implying a fixed sequence and fixed quantity. *Ka* is a grammatical ending that converts standard into standardization. (Glenday 2007, p. 15.) So leveling refers to methods of evening out variation by quantity and mix of items produced. According to Liker & Wu (2000, p. 86) the opposite of leveling is non-level scheduling that results in demand spikes, in other words, intensifies the bullwhip effect discussed in chapter 2.2.2. Leveling makes it possible to keep inventory levels low and lead times short while avoiding batching (Mapping to See 2007, p 156). As stated in table 3.1 (see chapter 3.1 Introduction to lean thinking) the ultimate goal of leveling is to enable perfect flow.

3.3.1. Using supermarkets to level the volume of work

Leveling is done by first identifying a spot along the value stream where orders from a customer are transformed into production instructions. This is called a pacemaker. Then a standard inventory is created at the pacemaker to permit every step before and after to operate in a leveled manner, using first-in-first-out scheduling downstream from the pacemaker and pull signals upstream. In make-to-stock environment a pacemaker is at the end of an assembly operation. (Womack 2006, p. 155.) Rother & Harris (2008, p. 64) discuss about a kind of standard inventory, finished goods supermarket, that is used to level fluctuations in customer demand. Supermarkets are inventories replenished only when old goods are taken away. There is a specific amount of inventory kept in supermarkets based on purchase patterns and expected demand. Customers pull items from a supermarket and so replenishment is done in phase with real demand. (Liker 2004, pp. 105-106). An illustration of this is presented in Figure 3.1.

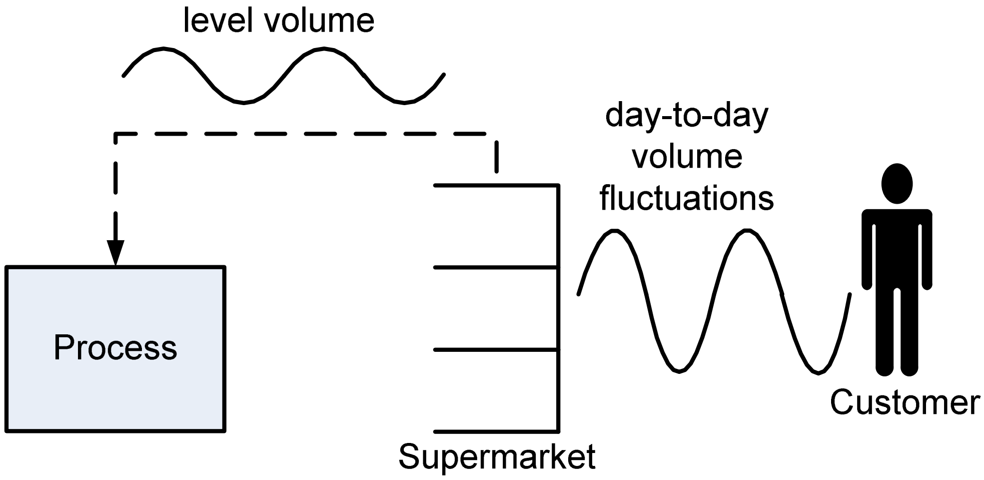

Figure 3.1. *Use of a supermarket to level the volume of work (adapted from Rother & Harris 2008, p. 64).*

Ideally a supermarket allows satisfying customer demand on time while smoothing need for volume variation in upstream processes. In reality new items are introduced and old items pulled off from market, which implies that a supermarket needs to be frequently updated. There is also a risk that customer demand changes or initial stock level of a new item is estimated incorrectly. Hence, stock-out situations or overstocking can occur, which again can result in problems in production. In summary, maintaining a supermarket might be more complicated that suggested in theory.

3.4. Kanban

The Japanese word *kanban* means literally a visible sign or card (Gupta et al. 1999). It is one means of visual control mentioned in table 3.1 (see chapter 3.1 Introduction to lean thinking). According to Ballou (1999, p. 400) kanban is a card-based production control system. More extensive definition is provided by Smalley (2004, p. 107) who states that kanban is a tool for controlling information and regulating materials' movements. It is used to signal upstream when a product is consumed by a downstream process and hence link sequential process steps (Smalley 2004, p. 107). Ramnath et al. (2009, p. 58) provide similar definition stating that a kanban is an authorization to act, and a *kanban* *system* is a pull-system for managing materials' movements. Karmarkar & Kekre (1987, p. 4) specify kanban system slightly differently: it is a control mechanism that consists of production process and inventory location. Derived from the specifications discussed above the following description of kanban applicable in this study is formulated:

Kanban is a means of transmitting information and controlling material movements in a system consisting of processes and inventories.

Kanban can also be seen as an instrument to facilitate flow discussed in chapter 3.2. Details of kanban such as information content and types of kanbans are discussed in several sources (for example Monden 1983; Suzaki 1987; Smalley 2004). The basic idea of kanban system is illustrated in figure 3.2. The arched arrows represent pull signals transmitted by kanban cards and the straight arrows represent material movements. Cards are placed in queues in front of the workstations.

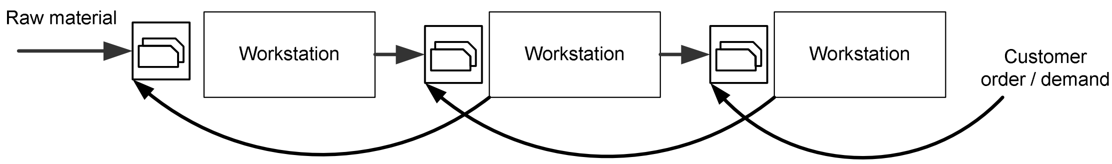

Figure 3.2. *Basic idea of kanban system (adapted from Marek et al. 2001).*

The basic principle is that material is pulled through the system only when authorization to move it is received from downstream. Each set of kanban cards between workstations authorizes material to be pulled into the upstream workstation for processing and delivery to the downstream workstation (Marek et al. 2001, p. 122). Delivery of items follows usually either a *fixed-time and variable-quantity* pattern or a *fixed-quantity and variable-time* pattern (Monden 1983, p. 24; Smalley 2004, p. 113). The prior is appropriate for frequently consumed items whereas the latter suit items that are needed only randomly. Fixing one of the two variables reduces uncertainty in a system.

In kanban system the total quantity of inventory on-hand and on-order is fixed since the number of containers and cards is fixed (Karmarkar & Kekre 1987, p. 4). Maximum stock for any item is product of one kanban's size and number of kanbans. Hence, overproduction, which prevention is one purpose of kanban, can be avoided (Smalley 2004, p. 107). Monden (1983, p. 42) notes that in Toyota kanban is a major factor of successful control of inventory level. According to Smalley (2004, pp. 107-108) other purposes of kanban are to provide specific instructions, serve as visual control tools and establish basis for continuous improvement. Providing specific instructions signify that kanbans carry standardized and unambiguous information that indicate exactly what to produce or transfer and how much. Visualization of the kanban system enables detecting abnormalities immediately. Improvement can be done easily by reducing the number of kanbans which automatically reduces the total amount of inventory in a system. Another benefit of kanban can be reduction of amount of paperwork (Gupta et al 1999, p. 1066).

Ramnath et al. (2009, p. 63) note that a kanban system functions well when only small fluctuations in demand occur. This issue is approached for example by Gupta et al. (1999) and Smalley (2007). Gupta et al. have studied the use of flexible kanban system in production environment. In their simulation number of kanbans is increased when system performance needs to be improved and removed as soon as additional kanbans are no longer needed or their presence results in lowered system performance. The finding is that altering amount of kanbans is an effective means of adapting to variability, such as fluctuation in demand. (Gupta et al. 1999.) Similarly Smalley (2007, p. 112) states that *temporary kanbans*, destroyed after one-time-use, are a means to react to exceptional short-term changes. Without doubt, a need to constantly alter the number of cards complicates running of a kanban system and increases amount of work.

3.5. Value stream map

Womack (2006, p. 145) introduces value stream as follows:

All value produced by an organization is the end result of a complex process, a series of actions that lean thinkers call a value stream. What’s more, the customer, whether external or internal, is interested only in the value flowing to them, not in the weighted average of an organization efforts for all products or in value flowing to other customers.

The quote above highlights the importance of understanding how customer value is created. According to Rother and Shook (2003, p. 3) a value stream consists of all value adding and non value adding actions needed to design and produce a product. Hence, value stream is closely related to the concept of waste (see chapter 3.1.1 Seven waste). The idea of value stream is fairly abstract, and hence a systematic tool is needed to understand it. A suitable tool called value stream mapping was first introduced outside of Toyota in 1998 by Rother & Shook (2003, version 1.3; see Womack 2006). It is a process mapping tool that enables visualizing and understanding value streams (Nash & Poling 2008, p. 1).

Nash & Poling (2008, pp. 1-6) identify three components that need to be portrayed in a complete value steam map. These are process or production flow, communication or information flow and timelines. The first one consists of sequential process steps connected with arrows and locations and sizes of inventories. Communication flow includes formal and informal information sharing throughout a process. Timeline portrays for example lead time and value adding time. (Nash & Poling 2008.) System summary metrics can be calculated to assess the aggregate value stream performance (Keyte & Locher 2004). Mapping techniques, applications and standardized mapping symbols are discussed in more detail in several publications (for example Rother & Shook 2003; Womack & Jones 2003; Mapping to See 2007; Nash & Poling 2008).

Value stream mapping is useful in four ways: it helps visualizing processes, it helps identifying sources of waste, it shows the linkage between information flow and material flow, and it helps forming the basis of an implementation plan (Mazur & Chen 2008). Mapping activity is two-phase: first a current state drawing is created to understand existing operations and it is then used as the basis for a future state drawing (Keyte & Locher 2004, p. 7). The important attributes to be captured are flow versus stagnation, push versus pull and level versus erratic (Womack 2006, pp. 152-153). These attributes capture waste, that is muda, and unevenness, that is mura, of a process (see chapter 3.1.1 Seven waste). Elimination of muda and mura is only possible after their existence is mapped and understood.

3.6. Standardization

According to Ismai (1986) it is impossible to improve any process until it is standardized (see Liker 2004, p. 124). In Toyota, deviation from standard signals need for worker training or need to revise inadequate methods (Adler 1999). Hence, standardization serves as basis for continuous improvement and provides common rules of play based on best practices (Liker 2004). Adler (1999) discusses the issue of bureaucracy following from standardization and routines. He notes that a system can be either coercive or enabling. Coercive system is rigid due to standards whereas enabling system helps people to control their own work. Standardization is needed to capture the best practices in an enabling system. (Adler 1999.)

Standardization can be applied to several aspects of logistic processes and warehouse control. Nicholas (1998) for example suggests using standard-sized containers to reduce inventories and facilitate distribution process (see Wu 2003, p. 1354). Also process steps can be standardized. Wu (2003, p. 1367) notes that fluctuating demand makes standardization difficult in production environment. Since production is tightly connected to other functions, one can suppose that demand variation hinders benefits of standardization in a warehouse as well. This implies that the intensity of the bullwhip effect (see chapter 2.2.2 Bullwhip effect) should be tried to reduce in parallel with standardization.

3.7. 5S

5S is a system to create disciplined, clean and well-organized work environment. Abbreviation, 5S, stands for five action steps that are sort, set in order, shine, standardize and sustain. In practice this implies sorting out needed and unnecessary items, putting needed items in fixed places, cleaning up the work place, standardizing these practices and converting these individual actions into normal way of operating. (Chapman 2005.) Suzaki (1987) states that orderliness serves as basis for standardized production and shipping operations (see Wu 2003). Also Chapman (2005) claims that the lack of a robust 5S system can hinder the benefits of other lean tools. Some day-to-day benefits of 5S are less searching for items, decreased walking and motion, reduced downtime, fewer safety hazards, improved flow, fewer mistakes and better utilization of space (Chapman 2005). Improved flow is especially important when striving for better inventory turnover as in case of Biohit. Hence, 5S is one of the first ideas to be implemented in a warehouse when starting to improve logistic operations.

4. RESEARCH METHOD AND MATERIAL

4.1. Presentation of the case company

Biohit Group consists of the parent company, Biohit Oyj, and seven subsidiaries. It has two areas of business: liquid handling products and diagnostic products. The former one accounts for 96% of the net sales of 2008 (Biohit Annual Report 2008), which is why this study focuses on the liquid handling business. Liquid handling products can be divided into three main product groups that are *electronic pipettes*, *mechanical pipettes* and *disposable pipette tips*. In addition, *liquid handling spare parts* can be viewed as an own product group. This classification will be used throughout the study. The majority of the liquid handling products are make-to-stock items. These are sold under Biohit brand. PL and OEM are items sold under other brands' name. These are make-to-order items.

Table 4.1 illustrates the proportions of PL and OEM items of total product range for each product group sold by Biohit Oyj within a time frame of six months terminating in May 2009. The table clearly points out that products under Biohit brand form the most important part of total product range of Biohit Oyj. Meanwhile, importance of PL and OEM products for individual subsidiaries varies. For example, in case of Biohit Ltd., located in U.K., non-Biohit products are essential because they account for 66.0% of all mechanical pipettes sold during the last two quarters of 2008 and the first two quarters of 2009 (Questionnaire Study 2009). Even then, Biohit products are the main concern of the study because they take the majority of production and warehouse capacity corporate-wide.

Table 4.1. *Classification of product types in each product group (Axapta 25.5.2009).*

	Biohit brand % of total	**PL and OEM % of total**
Mechanical pipettes	XX %	XX %
Electronic pipettes	XX %	XX %
Pipette tips	XX %	XX %

Production is carried out in three locations: plastic components for pipettes are produced in Helsinki, Finland; part of the mechanical pipettes is assembled in Suzhou, China and the rest of the liquid handling products are manufactured in Kajaani, Finland. The structure of Biohit Group is illustrated in figure 4.1. The arrows show how liquid handling end items and components flow between the parent company and the subsidiaries and also to outside sources. The bolded arrows illustrate the material flows in focus of this study.

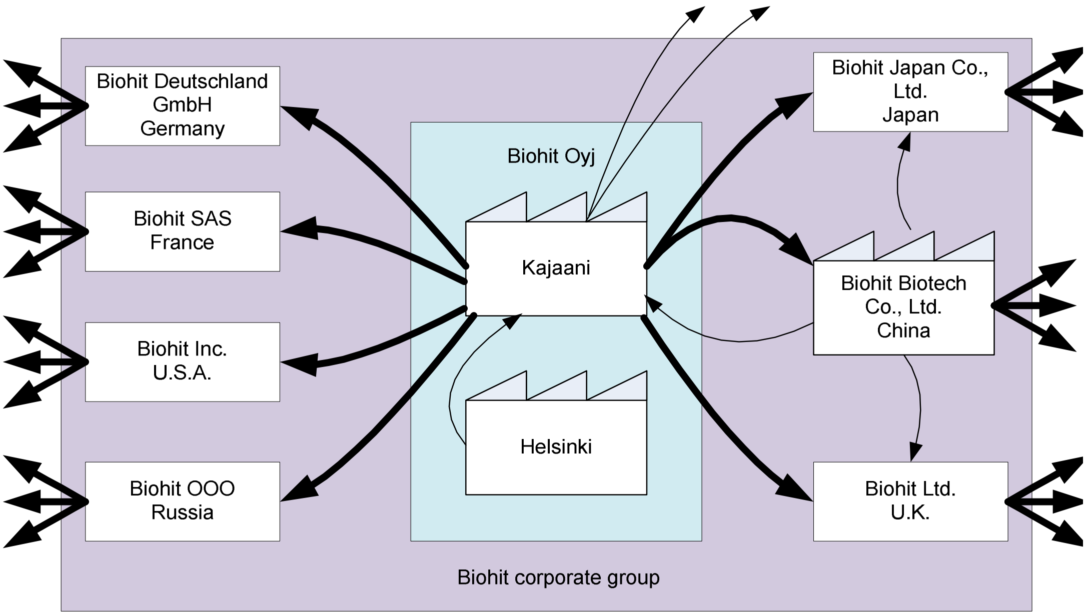

Figure 4.1. *The structure of Biohit Group and material flows.*

The site in Kajaani serves as a logistic hub. The majority of material within the corporate group flows from Kajaani to the subsidiaries. The factory in Kajaani receives plastic components for pipettes from Helsinki. Biohit Biotech China Co., Ltd. ships mechanical pipettes to Biohit Oyj and to Biohit Ltd. During this study Biohit Biotech Co., Ltd. started direct shipments also to Biohit Japan Co., Ltd. Each organization serves as sales- and service company and supplies liquid handling products and maintenance service to end customers and distributors.

Biohit Oyj receives purchase orders from domestic and foreign distributors and final customers, as well as from the subsidiaries. Figure 4.2 illustrates division of liquid handling sales between the subsidiaries and other customers during the last two quarters of 2008 and the first two quarters of 2009. Because intercompany sales account for as much as XX% of total sales, the primary focus of this study is on the subsidiaries' demand and ordering patterns.

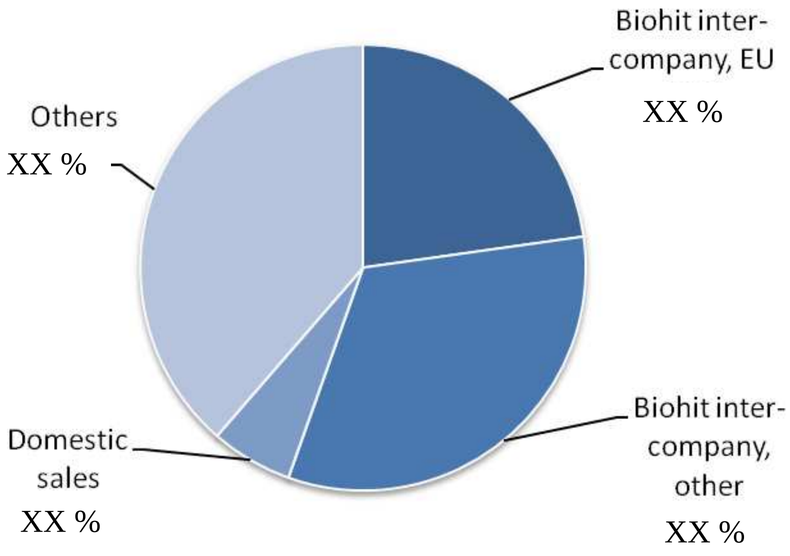

Figure 4.2. *Division of liquid handling sales of Biohit Oy 1.7.2008 – 30.6.2009 (Axapta 30.7.2009).*

4.2. Time frame

The data gathered represents a time frame of one year. This period was agreed to be long enough to understand the current state in adequate accuracy. A period longer than that is laborious to analyze due to a large amount of data, and additional benefit is not considerable. In order to get as accurate and fresh results as possible the most recent data available was utilized. Data gathering started in the beginning of July 2009 so the data covers twelve months backwards starting from the 1st of July 2008.

4.3. Acquisition of data

Data was acquired from the parent company as well as from all the subsidiaries. Although time-consuming, collecting data from such many sources is necessary when trying to understand corporate-wide logistics. Without doubt such extensive data more or less hinders in-depth analyses.

Two means of data gathering used were *on-the-spot interviews* and *a questionnaire*. Interviews were used to avoid as much as possible the pitfall of lacking in-depth understanding. Logistics processes were also observed in practice because interviews were carried out in working environment of interviewees. This made it possible to learn how lean concepts such as waste and flow, discussed in chapters 3.1.1 and 3.2, appear in each company.

The questionnaire comprises of open-ended questions presented in Appendix 1 and numerical data that was entered into an Excel template found in Appendix 2. Open-ended questions are indirectly based on lean literature covered in chapter 3. The purpose of questions is to learn how material and information flow inside the corporate group and to external customers. This understanding serves as basis for value stream maps discussed in the chapter 3.5. Numerical data is above all used to project state of inventory management which is discussed in theory in chapter 2.2. In addition, the quantitative data can be used to evaluate the validity of subjective answers. Three kinds of numerical data were gathered.

1.1 Orders of the subsidiaries' customers per month
1.2 Subsidiaries' purchases from Biohit Oyj per month
1.3 Subsidiaries inventory in the end of each month

All data was asked to be divided into four main product categories.

2.1 Mechanical pipettes
2.2 Electronic pipettes
2.3 Tips
2.4 Liquid handling spare parts

These were to include only Biohit products kept in stock, that is to say, OEM and PL products were left out. All data was to be stated in number of pieces on monthly basis covering the time frame of one year. All subsidiaries except for Biohit SAS filled in the Excel template. Biohit SAS is using the same ERP system, Axapta, as Biohit Oyj, which is why it was possible to access the required numerical data directly without intermediaries. Biohit Ltd. was able to fill in the Excel template only partially, and its purchases from Biohit Oyj (numerical data 1.2) were extracted from Axapta.

Naturally data of stock keeping units instead of aggregate product categories would have generated more exact results. Similarly data on daily basis instead of monthly basis would have brought more in-depth understanding of sales and orders. Despite of some shortcoming, the chosen level of detail brings along benefits: acquisition and analysis of data is more straightforward and faster when only twelve periods and four product categories are studied.

Throughout this research report the reference *Questionnaire Study 2009* is used when a respondent of an open-ended question is unknown or summaries of numerical data are presented. Thus data based on the questionnaire is distinguished from other facts and face-to-face interviews. The interviews were carried out on the basis of the open-ended questions in Biohit Oyj, Biohit SAS, Biohit OOO, Biohit Ltd. and Biohit Japan Co., Ltd. Several people involved in logistics processes and warehouse management were interviewed in each of these companies. The rest of the companies gave answers in writing to the same open-ended questions and returned them by e-mail.

4.4. Accuracy of data

Numerical data about sales of Biohit Oyj to the subsidiaries is present in Axapta. By contrast, majority of required data (see Chapter 4.3; numerical data 1.1, 1.3) is stored in the subsidiaries' own ERP systems that are not integrated to the parent company's Axapta. Thus these figures are received from secondary sources, and so there is a chance for inaccuracies.

4.4.1. Possible sources of discrepancies

When comparing the data about sales of Biohit Oyj to the subsidiaries, stored in Axapta, with the data of purchases from Biohit Oyj, received from the subsidiaries, there are some discrepancies. That is to say, figures do not match exactly. There are three explanations for these mismatches:

1. Recording practices applied are different.
2. Human errors have occurred.
3. Raw data is not filtered according to the requirements.

The first explanation suggests that the parent company and the subsidiaries have different recording practices, which reflects to the figures. For instance, the date of sales acquired from Axapta is the date when items were recorded dispatched. By contrast, the perceived date of purchase can vary. For example, it can be the date when an ordered batch physically arrived to a subsidiary's warehouse or the date when ordered items were entered into a subsidiary's ERP system or possibly the date when an order was paid. Therefore, the points of time are not exact but more suggestive. When considering the twelve-month time frame the first month, July 2008, and the last month, June 2009, are especially problematic. Items dispatched in June 2008 do not appear in those figures extracted from Axapta but can be included into the figures of the subsidiaries. Besides the recording practices of any single subsidiary and the parent company can differ, also practices among the subsidiaries can be inconsistent. Each one of the subsidiaries can have unique way of processing data because no corporate-wide standard procedures are established.

According to the second explanation accuracies are due to human errors. OEM and PL products were to be filtered out. Most probably this has been done manually, which leaves room for mistakes. The third explanation suggests that filtering has not been done according to the instructions and the figures include items that were to be excluded. This can have occurred due to disinterest, lack of understanding or because the instructions were not clear enough.

4.4.2. Evaluation of accuracy

Two sets of values, the ones provided by the subsidiaries and the ones acquired from Axapta, are compared in table 4.2. Values represent total purchases from Biohit Oyj in number of pieces within one year. Spare parts are excluded for simplicity because Axapta does not support sorting out PL and OEM spare parts. In the first column is the numerical value given by a subsidiary, in the second column is the corresponding figure acquired from Axapta, in the third column is difference of the previous ones and in the last column is the difference in percentage. Figures of Biohit SAS and Biohit Ltd. were extracted from Axapta so that there is no comparison material, and these two companies are therefore left out.

Table 4.2. *Comparison of values provided by the subsidiaries and values acquired from Axapta (Questionnaire Study 2009; Axapta 19.8.2009).*

	Value provided by the subsidiary (1)	**Value from Axapta (2)**	**Difference (1) – (2)**	**Difference (1) - (2) in %**
Biohit Deutschland GmbH				
Mechanical pipettes	XX	XX	XX	XX %
Electronic pipettes	XX	XX	XX	XX %
Tips	XX	XX	XX	XX %
Biohit Biotech Co., Ltd.				
Electronic pipettes	XX	XX	XX	XX %
Tips	XX	XX	XX	XX %
Biohit OOO				
Mechanical pipettes	XX	XX	XX	XX %
Electronic pipettes	XX	XX	XX	XX %
Tips	XX	XX	XX	XX %

Biohit Japan Co., Ltd.				
Mechanical pipettes	XX	XX	XX	XX %
Electronic pipettes	XX	XX	XX	XX %
Tips	XX	XX	XX	XX %
Biohit Inc.				
Mechanical pipettes	XX	XX	XX	XX %
Electronic pipettes	XX	XX	XX	XX %
Tips	XX	XX	XX	XX %

The absolute differences between the two sets of figures are relatively small in case of Biohit Deutschland GmbH. Number of electronic pipettes provided by Biohit Deutschland GmbH appears considerably bigger than numerical value extracted from Axapta when viewing difference in percentages. This figure is reviewed in Biohit Deutschland GmbH, which rules out the third explanation presented in chapter 4.4.1. Therefore possible sources of discrepancies are different recording practices and human errors.

Values of Biohit Biotech Co., Ltd. differ somewhat from those extracted from Axapta when considering percentage values. Slight difference is most probably due to different recording practices. The company has not purchased any mechanical pipettes from Biohit Oyj, which is why these figures do not appear in the table.

Values of Biohit OOO match quite well. The differences are substantial when considering the number of items, but the percentages instead are minor. The negative difference of tips is interesting because it is not in line with other deviations. Respondents of the questionnaire cannot come up with a fair reason to explain the gap. The size of one order of Biohit OOO can be relatively big, and so few orders not included in the subsidiary's figures can cause major differences in absolute figures.

Figures of Biohit Japan Co., Ltd. match quite well with figures from Axapta when it comes to pipettes. By contrast, the difference of value provided by the subsidiary and value extracted from Axapta for tips is XX %. Raw data was acquired from Biohit Japan Co., Ltd. but filtering and analyzing was executed at Biohit Oyj. The possibility of human errors or poor filtering of data is minimized by re-analyzing the raw data. Therefore, the differences can be due to different recording practices or mistakes when entering data.

The data of Biohit Inc. is accurate enough when it comes to pipettes. There is a remarkable gap between the two quantities of tips. The value is moderate when stated in percentage. Negative difference is interesting because it cannot be explained by inclusion of OEM and PL items. No fair reason to explain the gap came up.

None of the figures in the two sets of data match exactly. Observed differences can be used suggestively to evaluate overall accuracy of the subsidiaries' data because there is no suchlike comparison material for the subsidiaries' sales figures and inventory values. Supposedly any discrepancies due to different recording practice and unfiltered data (see chapter 4.4.1) are repeated in all data sets provided by one subsidiary. In general, the values extracted from Axapta are smaller except for single figures provided by Biohit OOO and Biohit Inc. Thus even discrepancies exist, most deviations are in line. This suggests that figures provided by the subsidiaries are comparable among each other. One must be careful of drawing conclusions of any absolute figures. Instead, data acquired from the subsidiaries is suggestive and proportionate values are favored.

4.5. Data analysis

Data analysis combines numerical data, answers to open-ended questions and observations. Each company is first studied separately starting from Biohit Oyj. Two value stream maps based on open-ended questions and observations are drawn for each subsidiary: one illustrates ordering and reception of goods from Biohit Oyj and other one order processing and dispatching to local customers. In addition, answers to open-ended questions and observations are considered from perspective of lean concepts such as kanban and 5S covered in chapters 3.4 and 3.7.

Numerical data is utilized rating the subsidiaries. This is done to understand their proportionate significance in number of items purchased and sold, and also to rate their performance in terms of inventory turnover. Spare parts are analyzed separately and discussed in chapter 5.4. Final conclusions are given in general level based on similarities between the subsidiaries.

5. RESULTS

5.1. The parent company's end in the logistic chain

The empirical study starts at the parent company's end of the logistic chain. Ordering patterns of the subsidiaries are covered first since those affect directly operations in the logistics department, the dispatching department and the production of Biohit Oyj. After this, the processes of order processing and dispatching in Biohit Oyj are studied. This is followed by identifying requirements for change in Biohit Oyj.

5.1.1. Ordering patterns of the subsidiaries

Each subsiriary buys an unique mix of products from Biohit Oyj. Figure 5.1 illustrates relative purchases of mechanical pipettes by the subsidiaries within the one-year time frame under review. It is worth noting that Biohit Biotech Co., Ltd. is not buying mechanical pipettes from Biohit Oyj. Purchases of Biohit OOO, Biohit Inc. and Biohit SAS account for roughly XX% of all subsidiaries purchases. The rest is divided quite evenly between Biohit Deutschland GmbH, Biohit Japan Co., Ltd. and Biohit Ltd.

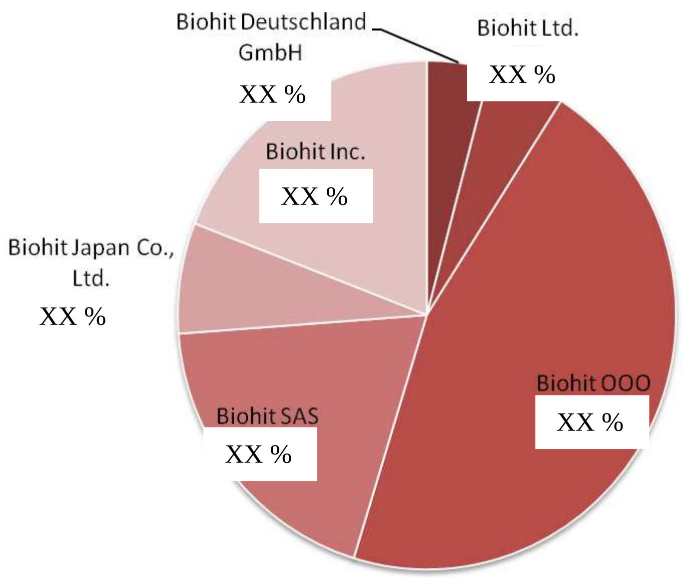

Figure 5.1. *Subsidiaries purchases of mechanical pipettes (Questionnaire Study 2009).*

Figures 5.2 and 5.3 present corresponding figures for electronic pipettes and tips. The majority of electronic pipettes was sold to Biohit Inc. The two subsidiaries located in

Asia, Biohit Biotech Co., Ltd and and Biohit Japan Co., Ltd., have together bought one third of electronic pipettes. Meanwhile, Biohit Inc., Biohit SAS and Biohit OOO together have bought roughly XX% of all tips sold to the subsidiaries. According to these three figures performance of Biohit OOO, Biohit Inc. and Biohit SAS affects remarkably performance of production and logistics functions corporate-wide.

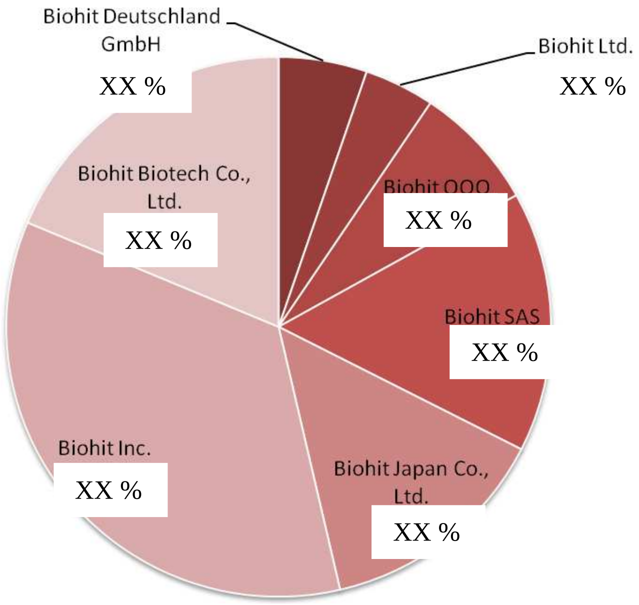

Figure 5.2. *Subsidiaries purchases of electronic pipettes (Questionnaire Study 2009).*

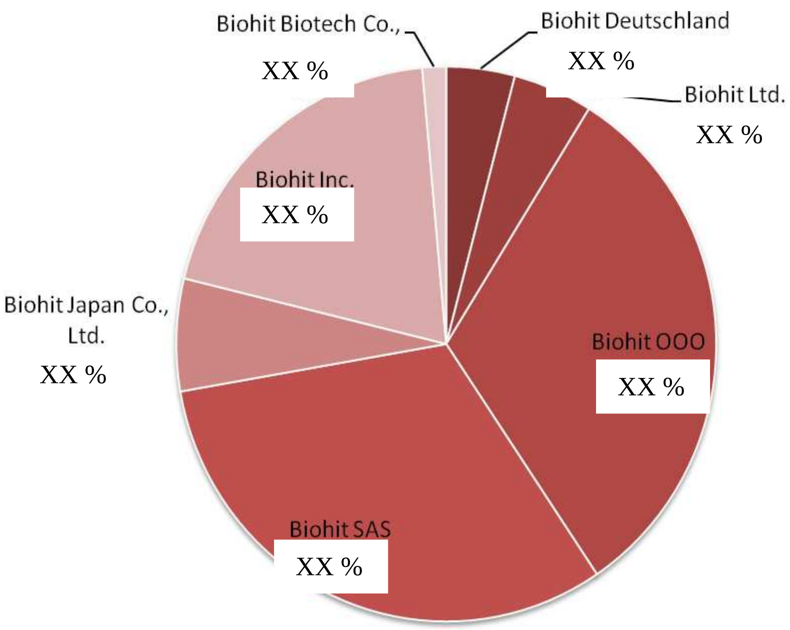

Figure 5.3. *Subsidiaries purchases of tips (Questionnaire Study 2009).*

Size of the subsidiaries’ orders varies substantially because each has its unique ordering pattern. For example, Biohit SAS places a big order once per month whereas Biohit OOO orders bigger batches biweekly. These are supplemented randomly with additional orders. Meanwhile, Biohit Ltd. orders on Fridays whereas Biohit Japan Co., Ltd. orders at random point of time. (Questionnaire Study 2009.) Staff of the logistics department and the dispatching department of Biohit Oyj does not fully know the ordering logic of the subsidiaries. For example, according to Ristimäki (2009b) Biohit Ltd. wants spare parts delivered separately by courier whereas the other subsidiaries receive spare parts along with tips and pipettes. Meanwhile Ricketts (2009b) of Biohit Ltd. tells that spare parts are ordered separately because it is considered the corporate policy, not because it is the most convenient way for Biohit Ltd. The example demonstrates that there is lack of information flow and plenty of room for standardization of order policies inside the corporate group. Lean thinking emphasizes smooth information flow and commonly shared process targets (see chapter 3.2 Flow).

Frame orders, meaning rolling orders updated once per month covering three months period, were required in the past. The remains of the old system complicate the present ordering. Some subsidiaries are not using frame orders at all and some have created their own adaptation. This leads to unequal and unpredictable amount of work in Biohit Oyj. Unevenness of workload, mura, is a problem since it causes waste in processes (see chapter 3.1.1 Seven waste). Occasionally several big orders arrive at the same time from different subsidiaries causing rush (Tervonen 2009). Overlapping orders are one cause of the bullwhip effect as discussed in chapter 2.2.2. Varying and unpredictable order sizes hinder standardized way of working. According to Ohtonen (2009a) preparing big dispatches ties all workers so that no one has time to fill new pipettes into Kardex automated warehouse system as they arrive. This complicates and even delays picking of following orders.

Figure 5.4 illustrates how the sales of tips to the subsidiaries have fluctuated. Different sources of variation are not analyzed, and hence possible seasonal variation is present in the data. Regardless of sources of variation, the up- and downswings in sales complicate both production and logistics operations. For example in April the volume of tips was almost double compared to the volume in June.

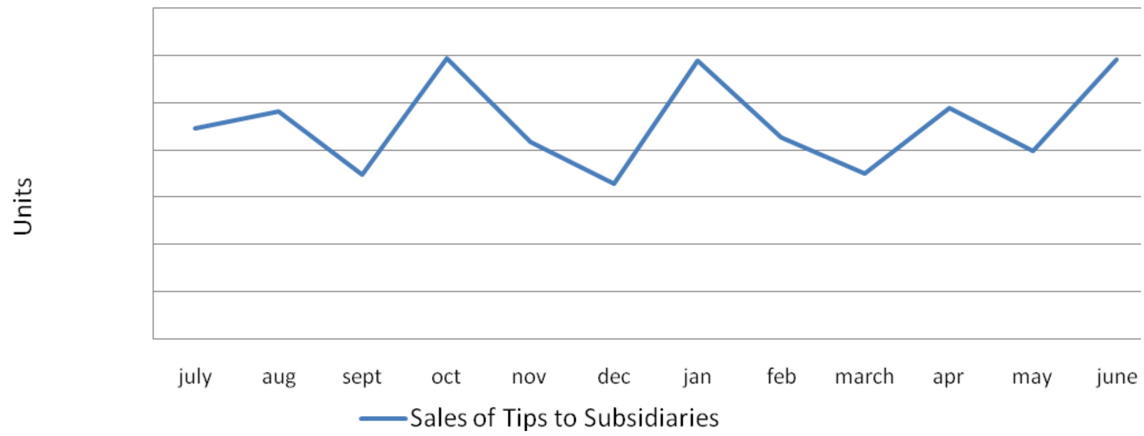

Figure 5.4. *Monthly sales of tips (Axapta 4.8.2009).*

5.1.2. Value stream map

Idea of value stream mapping is covered in chapter 3.5. A value stream map covering export order processing and dispatching in Biohit Oyj is presented in Appendix 3. Export and domestic order processing cannot be mapped jointly because the procedures are slightly different.

5.1.2.1 Distribution of time

The value stream map shows that lead time for the process ranges between 2 and 24 working days depending if items are in stock. Respectively, processing time and value adding time change depending on the size of order. Processing time is the time used to carry out an activity, and it can be either value adding or non-value adding. Proportional values of processing time and value adding time are calculated in proportion to lead time and represented in the value stream metrics box of the value stream map. Lead time consists of only working days which duration is assumed to be eight hours.

Minimum processing time for an order of few line items is less than an hour. This is possible when all items are in stock and price information is correct. In that case, value adding time accounts for roughly 4% of the minimum lead time of two working days. If order is outstandingly big, picking takes more than one working day and value adding time is roughly two working days. In that case, value adding activities account for approximately 7% of the maximum lead time of 24 working days. Figures are indicative estimates. However, they give a general idea about the portion of value adding time relative to total lead time. Value adding time is both at worst and at best well below ten percent. Majority of lead time is due to waste of waiting and excess movements discussed in chapter 3.1.1 Seven waste.

5.1.2.2 Review of order processing

Asking for delivery dates is the most laborious task of order processing (Kujansuu 2009; Ristimäki 2009a). Each line item has to be considered separately. A logistic assistant checks which items are available in stock and then asks production planning department for delivery dates for the rest of items. Scheduling data in Axpata is not relied on due to constant changes. Production planning department is supposed to inform the logistics department about changes in production lead times but sometimes communication is poor. (Ristimäki 2009a.) According to production planning department delivery times for products not available in stock normally range between seven and twenty-one days. Changes and wide range of delivery times suggest there is some uncertainty in production planning which is one symptom of the bullwhip effect (see chapter 2.2.2 Bullwhip effect). Teuronen (2009) states that almost every order she processes contains some line items that cannot be delivered directly from stock. Therefore, few single items delay confirmation for a whole order. In consequence, order processing is delayed due to waste of waiting and inventory of information.

When all items are in stock process flow is continuous as intended in any lean system (see chapter 3.2 Flow). Stock-outs disrupt first-in-first-out order processing because some orders have to wait for settling delivery dates while some flow through directly. Therefore, communicating delivery dates should be made as easy and standardized as possible. Teuronen (2009) estimates that a lead time of order processing and dispatching can be as long as two months if some items are not in stock.

Prices in Axapta, that a sales staff is responsible for, are not always up-to-date (Ristimäki 2009a; Teuronen 2009). This causes extra work in the logistics department when updated price information has to be asked for. From time to time wrong prices are used which leads to laborious process of creating a credit note (Ristimäki 2009a). Hence, order processing is delayed due to the waste of defects discussed in chapter 3.1.1 Seven waste.

There are some minor problems related to allocating products to customers. First of all, first-in-first-out priority rule does not always happen because several persons are processing orders and reserving items simultaneously. Oldest available items are reserved in Axapta before creating a picking list. Some orders are reserved later but dispatched earlier than other orders. This implies that older items stay reserved while more fresh items are dispatched, which disturbs first-in-first-out rule. This also complicates picking. (Ohtonen 2009a; Tervonen 2009.) In addition, domestic orders overtake export orders because no delivery time is needed for a domestic order (Ahola 2009). This can delay an export order if items have not yet been reserved. In such case export orders are exposed to the waste of waiting (see chapter 3.1.1 Seven waste).

5.1.2.3 Review of dispatching

Previously the logistics department reserved items and created picking lists three working days before a delivery date of an export shipment. During the study this time frame was reduced to two working days. The dispatching department organizes picking lists according to their due dates. Earliest-due-date priority rule is generally followed. Exceptions are outstandingly big orders, whose picking is time consuming, and orders, whose collecting is arranged by a customer so that the exact hour of collecting cannot be known. (Ohtonen 2009a.)

Tips are kept on shelves whereas most of pipettes are stored in Kardex automated storage. Not all pipettes fit in Kardex which complicates picking activities. Tips are arranged on shelves according to their package size. Meanwhile, in a picking list they are organized in increasing order according to product code numbers. This complicates picking and creates waste of unnecessary movements. Activity of collecting items and reading bar codes can stretch from five minutes to three working days depending on a dispatch's size (Ohtonen 2009a). Ohtonen (2009a) estimates, that the time could be halved if tips were arranged in same order as in a picking list. Also modifying picking lists could be considered to solve the issue.

The lead time in the dispatching department is almost always the maximum accepted time. Small orders wait for picking most of this time implying that the flow is not smooth (see chapter 3.2 Flow). The actual processing time for small orders in the dispatching department is roughly twenty minutes which is 0.5% of the lead time. Meanwhile, picking of big orders is started earlier and majority of waste is due to unnecessary movements when collecting tips. Processing time can be three working days but value adding time is approximately half of this.

Picking pipettes is straightforward, and there is no room for human errors. An item number is entered into Kardex, and the system automatically finds the right product. Correctness of items is double-checked when reading their bar codes. The dispatching department e-mails copy of a picking list and a bill of freight to the logistics department that creates invoice and packing slip. These in turn are sent to the dispatching department where all necessary documentation is attached to a dispatch. It is then moved to the dispatching area where collected by a contract carrier or a forwarding agent arranged by a customer.

5.1.2.4 Summary of the value stream

Table 5.1 summarizes problems of order processing and dispatching experienced by the logistics department and the dispatching department of Biohit Oyj.

Table 5.1. *Problems of order processing and dispatching.*

Logistics department	• Asking for delivery dates is time-consuming • Few items can delay confirmation for a whole order • Production planning does not always inform about changes in production lead times • Price information in Axapta is not always up-to-date • Domestic orders can delay export orders
Dispatching department	• First-in-first-out priority rule does not always happen • Tips are physically arranged differently than in picking lists • Not all pipettes fit in Kardex automated storage

Targets for development of the process are marked on a value stream map found in Appendix 4. Kaizen bursts clearly indicate where and what kind of improvements are needed to solve problems listed in table 5.1. Below, each kaizen burst is discussed separately in their numerical order.

1. Communicating of delivery times with the production planning prolongs and complicates order processing and so it has to be reduced. Therefore, less variation of lead times is called for. If lead times were standard and up-to-date in Axapta, logistics assistants could estimate delivery times without having to consult the production planning.

2. Some communication with the production planning will be needed. It should be standardized and simple. Under the best of circumstances, logistics assistants would never have to ask for delivery times but the production planning would automatically report any exceptional lead times.

3. Sales staff must assure that all prices in Axapta are up-to-date. Logistics staff has to quit confirming prices.

4. Arrangement of items in the warehouse has to be changed to support efficient picking. In practice this means that

    - tips have to be arranged according to their usage
    - tips have to be in logical order in relation to picking lists
    - pipettes have to be placed either in Kardex or on flow racks

    Ohtonen (2009b) suggests that the most convenient way to arrange tips would be according to product code numbers, except for dispenser tips and some individual items that are dispatched seldom. These infrequently needed tips could be located on the back of the warehouse. This simple practice is supported also in lean theory (see chapter 3.1.2 Lean logistics).

5. Variation in sizes and timing of orders has to be reduced. Order processing and dispatching is more standardized when amount of work spreads evenly. Reduction of large orders reduces rush in the dispatching department, and leaves time for placing items onto shelves and into Kardex.

6. Amount of paper work should be reduced as much as possible to save time, costs and environment. It should be evaluated which documents really have to be printed and filed physically.

5.2. The subsidiaries’ end in the logistic chain

The subsidiaries’ end of the logistic chain is covered first in the aggregate as it appears in Biohit Oyj. In order to identify similarities and differences between the subsidiaries they are compared against each others. Hence, the most problematic companies can be identified.

5.2.1. Sales per subsidiary

Subsidiaries operate in markets very different from each other. Besides the overall sales volumes vary, also the mix of products sold is different for each subsidiary. Figure 5.5 illustrates each subsidiary’s sales of mechanical pipettes during the one-year time frame. The data is in number of pieces. Intercompany sales of Biohit Biotech Co., Ltd. are filtered out. The figure shows that Biohit Biotech Co., Ltd in China has sold substantially more mechanical pipettes than any other subsidiary. Sales of Biohit OOO in Russia are also significant.

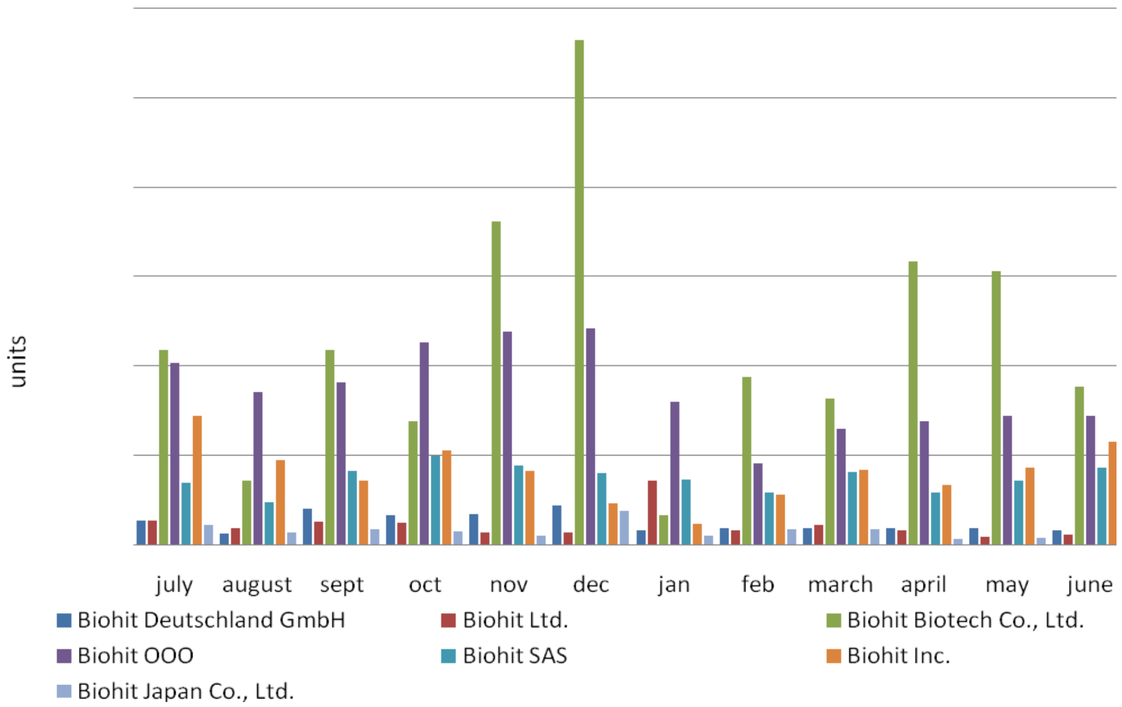

Figure 5.5. *Subsidiaries' sales of mechanical pipettes (Questionnaire Study 2009).*

Figures 5.6 and 5.7 present the corresponding sales for electronic pipettes and tips. The nature of different markets is apparent when comparing the three figures 5.5, 5.6 and 5.7. For example the sales of mechanical pipettes are high in Chinese market where Biohit Biotech Co., Ltd. operates but the sales of pipette tips are relatively low instead. Meanwhile, Biohit SAS in France, Biohit Inc. in U.S.A. and Biohit OOO in Russia have sold plenty of tips. The sales of electronic pipettes boom in Asia where Biohit Biotech Co., Ltd. and Biohit Japan Co., Ltd. operate. Also Biohit Inc. has sold a great number of electronic pipettes.

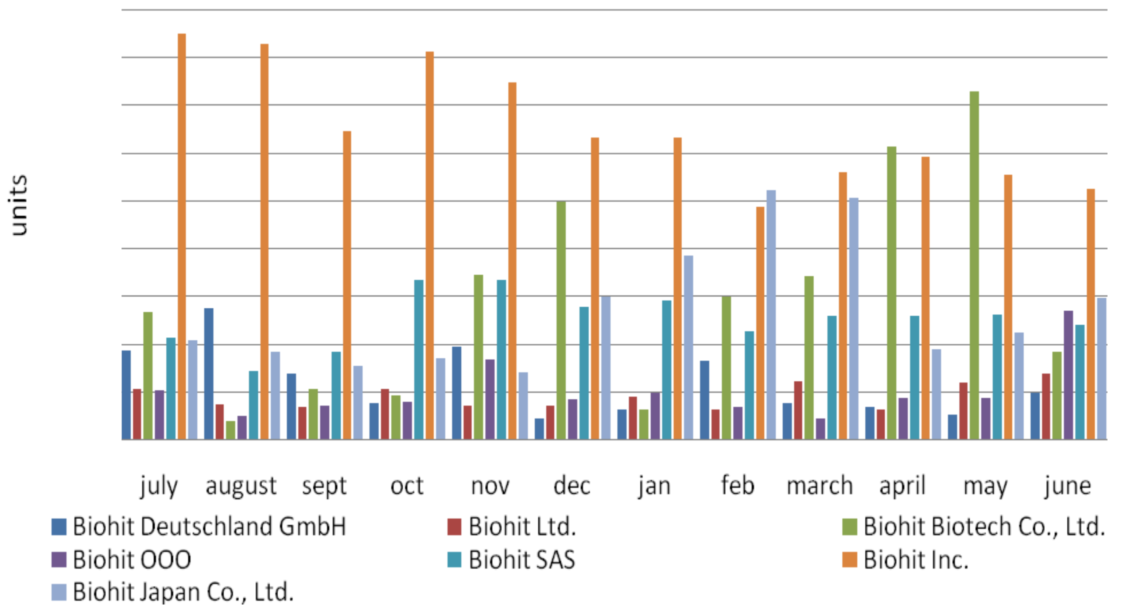

Figure 5.6. *Subsidiaries' sales of electronic pipettes (Questionnaire Study 2009).*

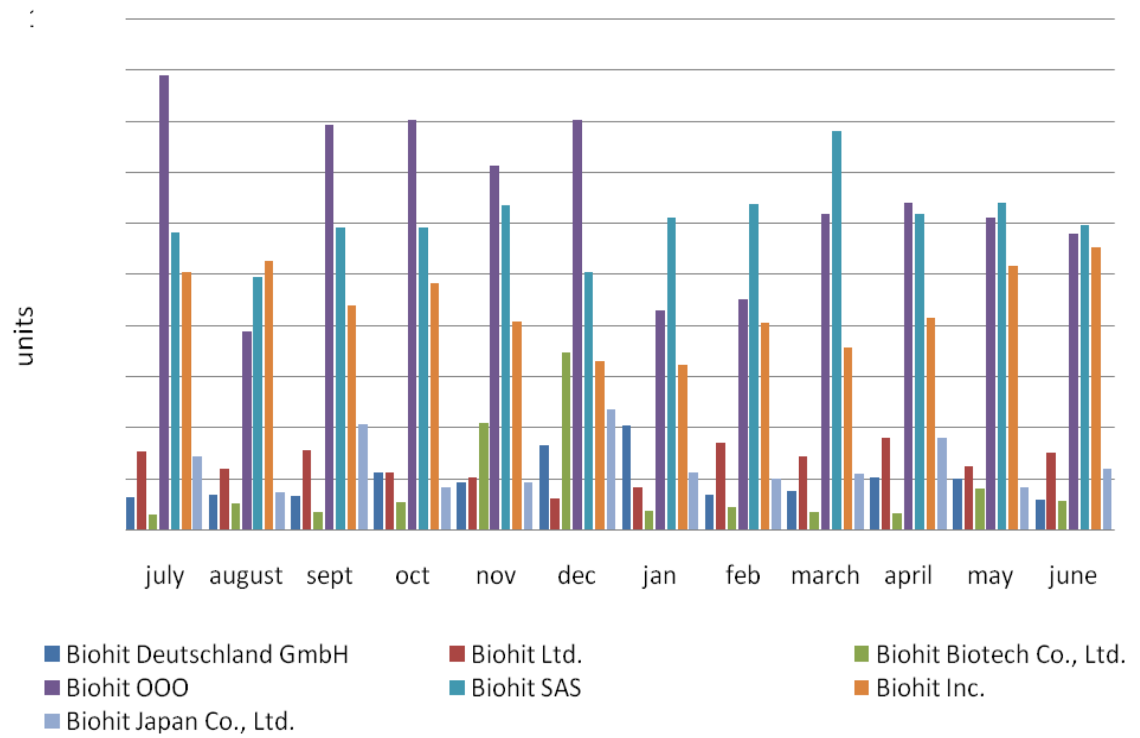

Figure 5.7. *Subsidiaries' sales of tips (Questionnaire Study 2009).*

These figures indicate that each subsidiary has its unique requirements for inventory control. Tips and pipettes are handled and stored differently due to their different size and packaging. In addition, customers consider tips and pipettes differently: Tips are simple, disposable products that customers expect to get almost immediately when ordering. Meanwhile, pipettes are more expensive and have longer operating life than tips. This results in that, to some extent, customers are willing to wait for a dispatch of pipettes (Questionnaire Study 2009). This has to be considered when planning inventory control.

Demand amplification mapping (see chapter 2.2.2.2 Measuring the bullwhip effect) is used to compare the subsidiaries' monthly purchases against monthly sales. Figure 5.8 presents demand amplification mapping of mechanical pipettes. The data includes all subsidiaries besides Biohit Biotech Co, Ltd. which is left out because mechanical pipettes are produced on site in China. Both sets of figures, the sales and the purchases, are given in proportion to the subsidiaries' average aggregate monthly sales.

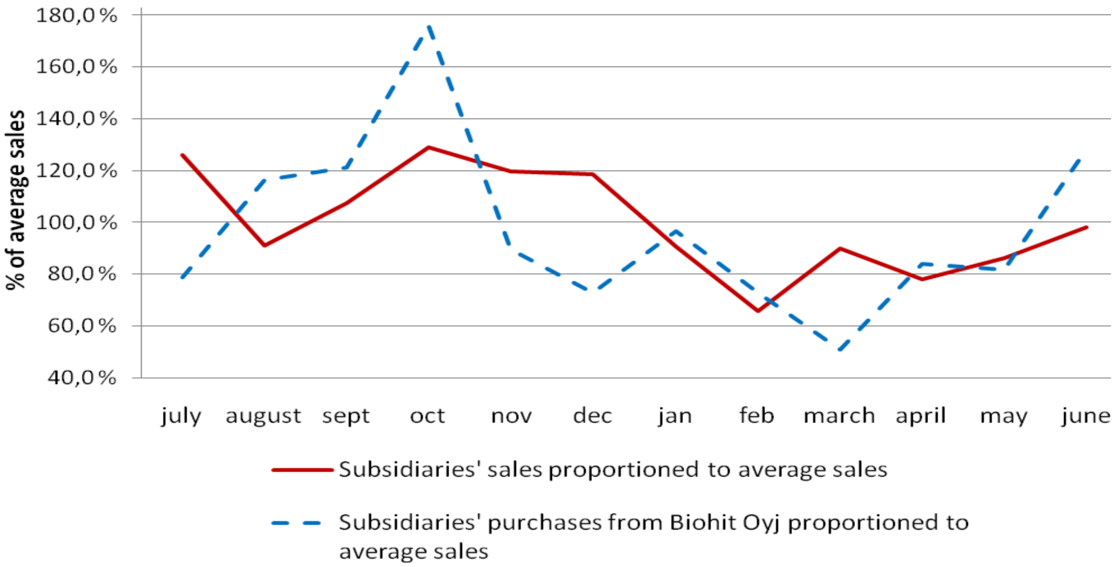

Figure 5.8. *Subsidiaries' aggregate purchases against aggregate sales for mechanical pipettes (Questionnaire Study 2009).*

The figure suggests that total purchases and total sales do not differ substantially. However, there are differences between the two when studying any single point of time. For example, in October sales were 129.0% higher than average and purchases exceeded the average sales by 175.8%. The difference between the highest and the lowest selling months is roughly XX mechanical pipettes whereas difference between months with the most and the least purchases is around XX mechanical pipettes (Questionnaire Study 2009). The more extensive fluctuations in purchases than in sales suggest the bullwhip effect discussed in chapter 2.2.2 is present. Sources of fluctuations, such as seasonal changes or random variation in demand, or human errors in ordering, are not tracked here.

The figure also suggests that purchases lag sales. Slight drop in sales after October resulted in significant dip in purchases in November that continued also in December thought sales had already stabilized. Drop in sales after December caused drop in purchases after January, and respectively the following upward movement lags behind by one month. Figures 5.9 and 5.10 show demand amplification mapping of electronic pipettes and tips. Biohit Biotech Co., Ltd. is included in these figures. The bullwhip effect is again visible. Total sales are relatively stable but purchases fluctuate. Difference between the most and the least selling month for electronic pipettes is roughly XX, and difference between months with the most and the least purchases is around XX. Corresponding figures for tips are XX and XX. (Questionnaire Study 2009.)

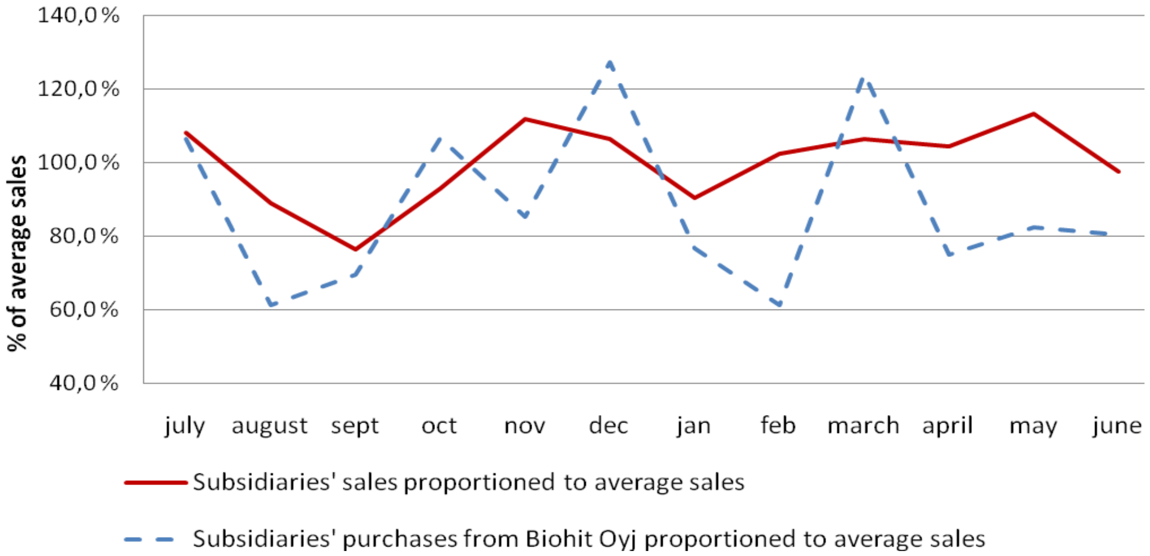

Figure 5.9. *Subsidiaries' aggregate purchases against aggregate sales for electronic pipettes (Questionnaire Study 2009).*

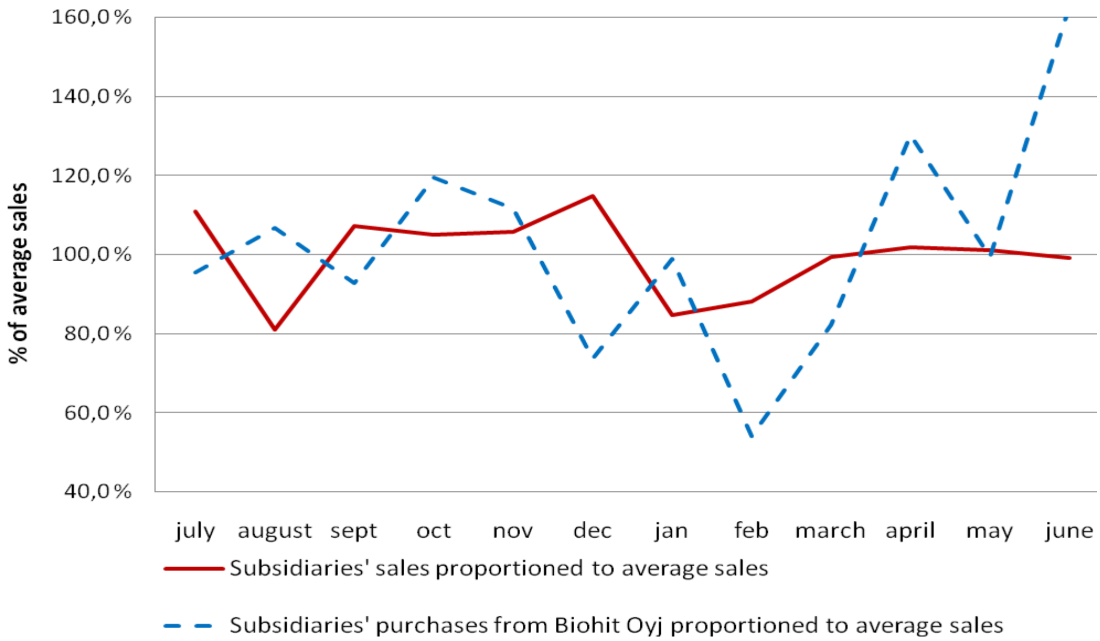

Figure 5.10. *Subsidiaries' aggregate purchases against aggregate sales for tips (Questionnaire Study 2009).*

In each product category purchase volumes systematically fluctuate more than sales volumes though the total amounts of sales and purchases do not substantially differ. Explanations for behaviour of the graphs are discussed together with subsidiary-specific demand amplification mapping in chapter 5.3 In-depth study of the subsidiaries.

5.2.2. Turnover per employee

Another way to compare the subsidiaries is to examine their sales and number of employees. Table 5.2 presents turnover per employee for each subsidiary in 2008 excluding intercompany sales. PL and OEM items are included in the figures. Turnover has been converted into Euros which slightly distorts the figures due to changing exchange rates. Biohit Biotech Co., Ltd. has production facilities unlike the other subsidiaries that are purely marketing and sales companies. Therefore, the organization structure is distinctly different. Two different figures are illustrated for Biohit Biotech Co., Ltd.: number of employees working in non-production activities and corresponding turnover are presented first, and statistics including all employees are given in parenthesis.

Table 5.2. *Turnover per employee for Biohit subsidiaries excluding intercompany sales (Biohit group sales 2008; Henkilöstö yhtiöittäin 2008).*

	Average number of employees	Turnover in 2008 (€)	Turnover per employee in 2008 (€)
Biohit SAS (France)	XX	XX	XX
Biohit OOO (Russia)	XX	XX	XX
Biohit Inc. (U.S.A.)	XX	XX	XX
Biohit Ltd. (U.K).	XX	XX	XX
Biohit Biotech Co., Ltd.(China)	XX (YY)	XX	XX (YY)
Biohit Japan Co., Ltd. (Japan)	XX	XX	XX
Biohit Deutschland GmbH (Germany)	XX	XX	XX

Although production staff is excluded, turnover per employee in Biohit Biotech Co., Ltd. in China is remarkable low. The major reason is that the sales of mechanical pipettes assembled in China sold to Biohit Oyj and Biohit Ltd. do not appear in the sales figures presented here. Intercompany sales of Biohit Biotech Co., Ltd in 2008 were XX € (Sales IC 2008). In addition, level of wages in China is low compared to for example the European countries. Relatively more personnel can be employed in Biohit Biotech Co., Ltd. which lowers turnover per employee.

A company that stands out positively is Biohit Inc. that has relatively high turnover per employee. This can be explained by the mix of products sold by the subsidiary. Biohit Inc. has bought XX% of all Biohit electronic pipettes and XX% of tips sold to the subsidiaries during the one year period under review (Questionnaire Study 2009). The company has managed to sell only XX% of the electronic pipettes bought in from the parent company but the sales still account for XX% of all electronic pipettes sold by the subsidiaries (Questionnaire Study 2009). In conclusion, Biohit Inc. has sold a lot of high value products. In addition, the sales of tips have boomed in Biohit Inc. for the company has sold more tips than bought in (Questionnaire Study 2009).

5.2.3. Overview of shipments

Key figures of outbound logistics are the number of shipments and shipments' sizes. Figure 5.11 summarizes the number of shipments that were dispatched from Kajaani dispatching department of Biohit Oyj in 2009 by the end of July.

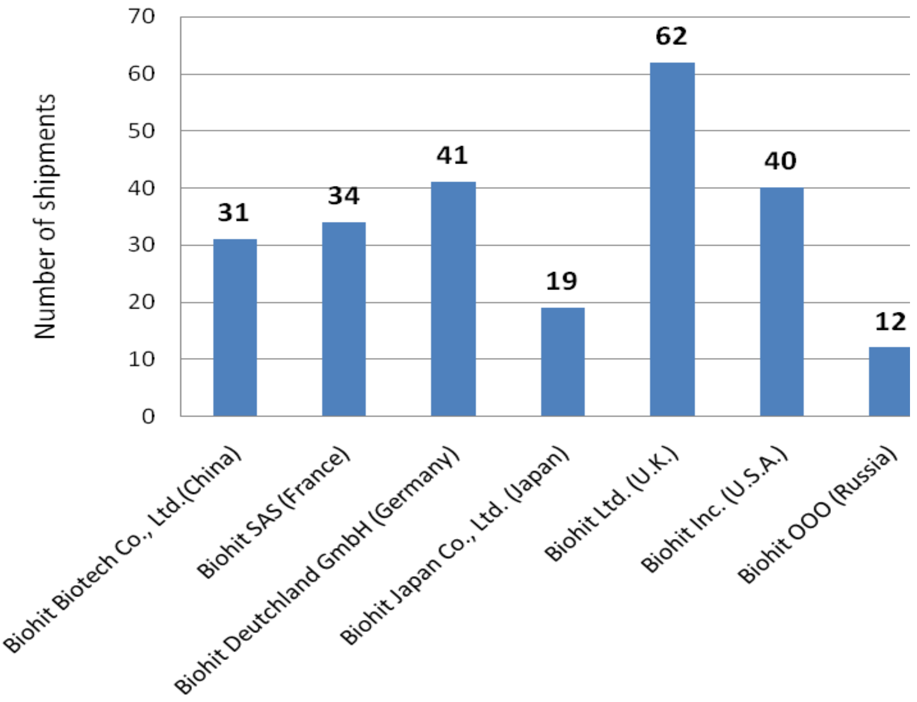

Figure 5.11. *Number of shipments year-to-date in the end of July 2009 (Kuljetustilasto Vienti 2009).*

A striking number is the one of Biohit Ltd. As many as 62 shipments were delivered to Biohit Ltd. within the seven months. That on average accounts for more than two shipments per week. Biohit Ltd. wants spare parts delivered separately by courier which increases the total number of shipments. The other subsidiaries receive spare parts along with tips and pipettes. Biohit Japan Co., Ltd. and Biohit OOO stick out because of their low figures. Biohit OOO receives goods biweekly because of complicated customs clearance in Russia. According to Tiainen (2009) the low number of shipments to Biohit Japan Co., Ltd. is due to an attempt to save in transportation and handling costs. This is one of the typical pitfalls of inventory management discussed in chapter 2.2.1 Typical problems (see table 2.1).

The first column of table 5.3 illustrates an average number of shipments per week based on the values in figure 5.11. An average number of purchase orders per week is given in the second column, and an average number of sales orders in the third column. There are calculated based on numerical data of the questionnaire. Average number of sales orders per month in Biohit Ltd. is not available. Time span of number of shipments is slightly different than that of number of purchase and sales orders, and therefore values in table 5.3 are indicative.

Table 5.3. *Average number of shipments per week (Axapta 17.8.2009; Axapta 19.8.2009; Kuljetustilasto Vienti 2009; Questionnaire Study 2009).*

	Average number of shipments per week	Average number of purchase orders per week	Average number of sales orders per week
Biohit SAS (France)	1,1	2,2	278,3
Biohit OOO (Russia)	0,4	1,8	157,6
Biohit Inc. (U.S.A.)	1,3	1,9	121,6
Biohit Ltd. (U.K).	2,1	2,5	n/a
Biohit Biotech Co., Ltd.(China)	1	2,6	23,5
Biohit Japan Co., Ltd. (Japan)	0,6	1,3	100,6
Biohit Deutschland GmbH (Germany)	1,4	2,5	39,0

Table 5.3 clearly points out that number of purchase orders exceeds the number of shipments. This strains the logistics department that processes the orders in Helsinki and implies that ordering logic or length of dispatching cycles could be rationalized. In addition, the table illustrates that amount of sales orders is significant compared to amount of purchase orders. The proportion of these two varies among the subsidiaries.

The sizes of the shipments to the subsidiaries are shown in table 5.4. Data is of items dispatched from Kajaani dispatching department of Biohit Oyj in 2009 by the end of July. Sizes are given in pallets.

Table 5.4. *Key figures of shipments year-to-date in the end of July 2009 (Kuljetustilasto vienti 2009).*

	Average number of pallets per shipment	Standard deviation	Biggest shipment in number of pallets
Biohit SAS (France)	8	10,7	36
Biohit OOO (Russia)	13	4,3	20
Biohit Inc. (U.S.A.)	10	7,6	25
Biohit Ltd. (U.K).	2	1,9	14
Biohit Biotech Co., Ltd.(China)	2	1,4	7
Biohit Japan Co., Ltd. (Japan)	5	4,4	17
Biohit Deutschland GmbH (Germany)	2	0,7	3

On average, Biohit Ltd. has received shipments as small as two pallets. Although the number of small-sized shipments to Biohit Ltd. is high the standard deviation is relatively low, which means that the range of shipment sizes is narrow. By contrast, the standard deviation of shipment sizes of Biohit SAS is extensive. Such variation typically cause variation in the amount of work needed, that is mura (see chapter 3.1.1), when dispatching and receiving. Other noteworthy figures are the standard deviations of Biohit Inc., Biohit Japan Co., Ltd. and Biohit OOO that appear relatively high.

5.2.4. Controlling logistics

The subsidiaries were asked about indicators they use to control the logistic processes and their inventories (see Appendix 1). Indicators refer to any control parameters that are monitored and periodically updated in order to understand trends or highlight deviation from normal. More precisely, they were asked if inventory turnover is calculated and used as a control indicator of stock. The subsidiaries were also asked if they have explicit process descriptions, and if they re-pack the products received from Biohit Oyj. The purpose is to indentify how systematic or inconsistent planning and controlling activities are. The summary of the results is presented in table 5.5.

Table 5.5 *Indicators and controlling methods used in the subsidiaries (Questionnaire Study 2009).*

	Biohit SAS (France)	Biohit OOO (Russia)	Biohit Inc. (U.S.A.)	Biohit Ltd. (U.K).	Biohit Biotech Co., Ltd.(China)	Biohit Japan Co., Ltd. (Japan)	Biohit Deutschland
There are products sold in smaller/bigger units than their standard selling unit, and so have to be re-packed	NO	YES	YES	NO	NO	YES	YES
Process description for ordering and receiving exists	NO	NO	NO	YES	YES	YES	YES
Systematic indicators (KPI) for ordering and receiving process exist	NO	NO	NO	NO	NO	NO	NO
Process description for sales order processing and dispatching exists	NO	NO	NO	YES	YES	YES	YES
Systematic indicators for sales order processing and dispatching process exist	NO	NO	NO	NO	YES	NO	NO
ABC-categories are used	NO	NO	NO	NO	NO	NO	NO
Inventory turnover is calculated for product groups regularly	NO	NO	NO	NO	YES	NO	NO
Delivery reliability to external customers is calculated	NO	NO	NO	YES	YES	NO	YES

Results presented in table 5.5 suggest that there is room for more systematic operations and standardization in the subsidiaries. Lack of key performance indicators and process descriptions can imply that there are no shared targets and abnormalities are not easily noticed. This indicates that information flow is poor. (See chapter 3.2 Flow, table 2.3.)

Following figures 5.12, 5.13 and 5.14 present inventory turnover separately for mechanical pipettes, electronic pipettes and tips in each subsidiary. Turnover is calculated using formula (3) presented in chapter 2.2.3 Inventory turnover. Because calculation of one year's performance is done afterwards and only data covering a limited time frame is available, constant annual sales are used instead of rolling time horizon: total sales during the one year period under review are divided by each end-of-month inventory value. Number of pieces is used for all the subsidiaries except for Biohit Ltd. that was only able to provide monetary values. Figure 5.12 excludes Biohit Biotech Co., Ltd. because its turnover for mechanical pipettes is significantly higher than that of the other subsidiaries and would distort the scale. Average inventory turnover for mechanical pipettes in Biohit Biotech Co., Ltd. during the one year period under review is XX.

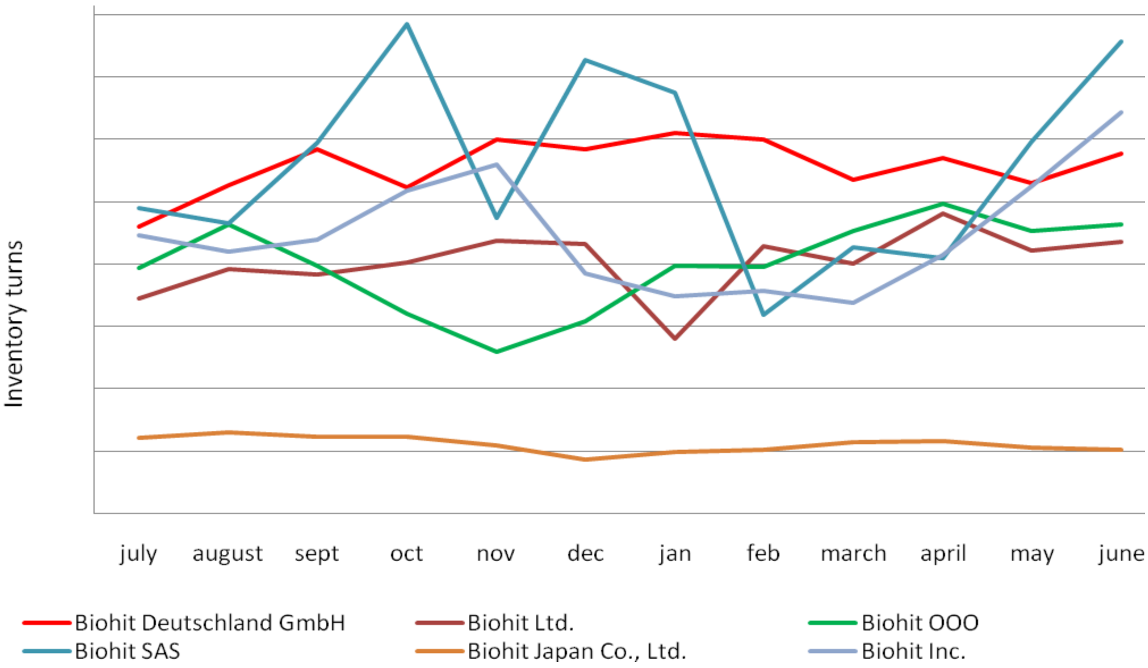

Figure 5.12. *Subsidiaries' inventory turnover for mechanical pipettes (Questionnaire Study 2009).*

In terms of period of storage (see chapter 2.2.3 Inventory turnover) the best value is one and a half months that is achieved momentarily in October by Biohit SAS. The best average period of storage of XX months is the same for Biohit SAS and Biohit

Deutschland GmbH. Biohit Japan has the worst average period of storage of XX months. (Questionnaire Study 2009.)

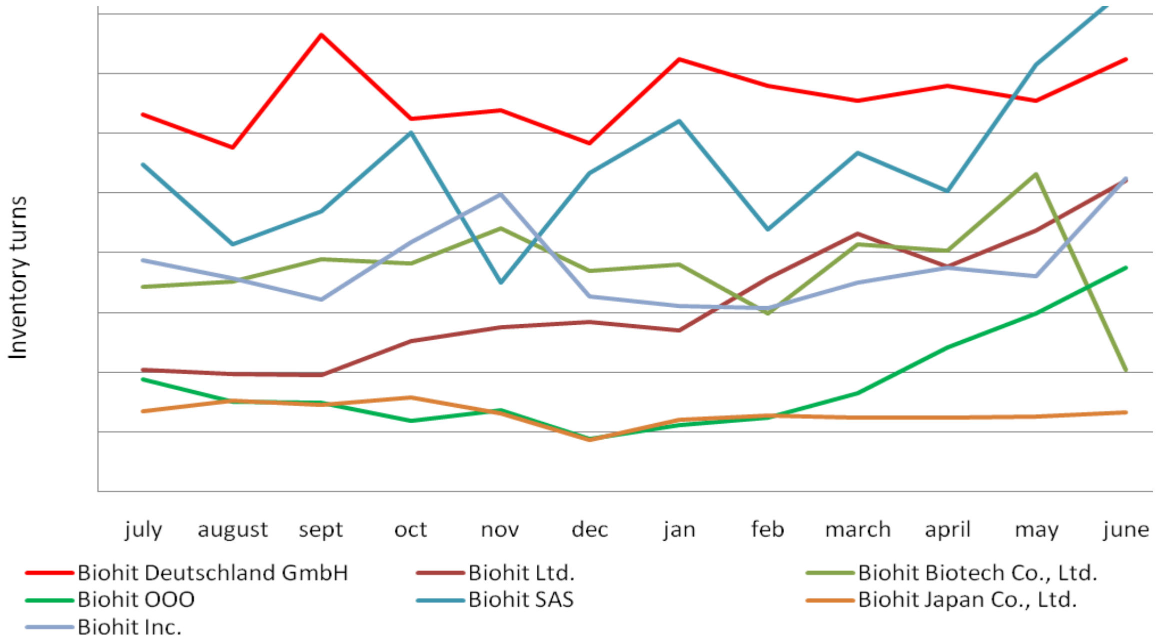

Figure 5.13. *Subsidiaries' inventory turnover for electronic pipettes (Questionnaire Study 2009).*

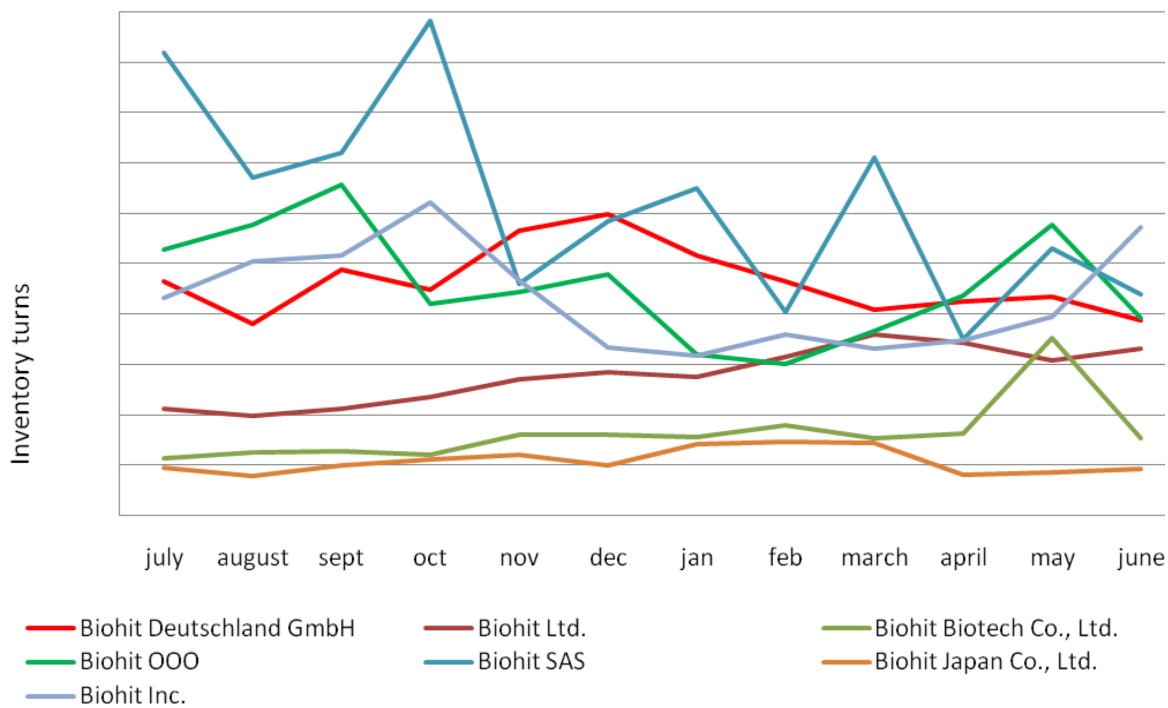

Figure 5.14. *Subsidiaries' inventory turnover for tips (Questionnaire Study 2009).*

Inventories of tips turn better than inventories of pipettes. Turnover ratios presented in the figures 5.12, 5.13 and 5.14 are on average low, which means that inventory levels are high. The best average period of storage of electronic pipettes is XX months and the worst is XX months. Respectively, the best average period of storage of tips is one month and the worst is XX months. (Questionnaire Study 2009.) It was concluded earlier that excess inventory can be one symptom of the bullwhip effect (see chapter 2.2.2 Bullwhip effect).

Table 5.6 summarizes all turnover figures. It presents average turnover per product group for each of the subsidiaries. Turnovers equal or less than three times per year are highlighted red. Respectively turnovers equal or more than eight times per year are highlighted green. Poor inventory turnover implies that items jam in stock and hence the flow (see chapter 3.2 Flow) is unsatisfactory.

Table 5.6. *Average inventory turnovers (Questionnaire Study 2009).*

	Biohit SAS (France)	Biohit OOO (Russia)	Biohit Inc. (U.S.A.)	Biohit Ltd. (U.K).	Biohit Biotech Co., Ltd.(China)	Biohit Japan Co., Ltd. (Japan)	Biohit Deutschland GmbH (Germany)
Mechanical pipettes	XX	XX	XX	XX	XX	XX	XX
Electronic pipettes	XX	XX	XX	XX	XX	XX	XX
Tips	XX	XX	XX	XX	XX	XX	XX
Spare parts	XX	XX	XX	XX	XX	XX	XX

Table clearly shows that management of spare parts' inventory is poor in all the subsidiaries besides Biohit Ltd. whose stock of spare parts turns quite well. In general tips are the least problematic product group. The only subsidiary that struggles with all product groups is Biohit Japan Co., Ltd. Hence overall operations of Biohit Japan Co., Ltd. should be studied with extra caution.

5.3. In-depth study of the subsidiaries

Each subsidiary is discussed individually in three sections: Subsidiary-specific issues are covered in an overview chapter. Then, intercompany logistics are discussed in a separate chapter followed by a chapter dedicated to outbound logistics. In the overview chapter demand amplification mapping (see chapter 2.2.2.2 Measuring the bullwhip effect) is carried out to compare purchases from Biohit Oyj against sales to final customers. Demand amplification mapping is supplemented with figures indicating changes in end-of-month inventory value. Hence, the vertical axes of the figures have two scales: on the left hand side there is the scale for demand amplification mapping and on the right hand side the scale for changes in end-of-month inventory. Only the most significant product group in terms of purchases is selected (see figures 5.1, 5.2 and 5.3.) for detailed discussion. Whether it is mechanical pipettes, electronic pipettes or tips, depends on a subsidiary.

Discussion in the chapters dedicated to intercompany logistics and outbound logistics is indirectly based on the value stream maps sketched for each of the subsidiaries. Value stream mapping was introduced in chapter 3.5. Since there are two fairly large value stream maps for each of the seven subsidiaries, the maps themselves are not attached to this thesis. However, the main points of the value stream maps are covered in the text.

5.3.1. Biohit SAS

Biohit SAS in France is one of the three biggest Biohit subsidiaries measured by purchase volume from the parent company. Within the one year period under review the monetary value of its purchases accounts for XX% of all subsidiaries purchases when considering the liquid handling products. (Axapta 10.7.2009.) Hence, the subsidiary’s purchasing patterns greatly affect production and logistics in Biohit Oyj.

Demand amplification mapping of tips supplemented with the change in end-of-month inventory value is illustrated in figure 5.15. The lines show purchases from Biohit Oyj against sales to final customers, and the bars illustrate changes in monthly inventory level. Sales and purchase data is given in percentage of Biohit SAS’s average sales in units within the one year period. End-of-month inventory values are given in number of sales units. Since the purchases fluctuate more than the sales, the bullwhip effect (see chapter 2.2.2 Bullwhip effect) seems to be present.

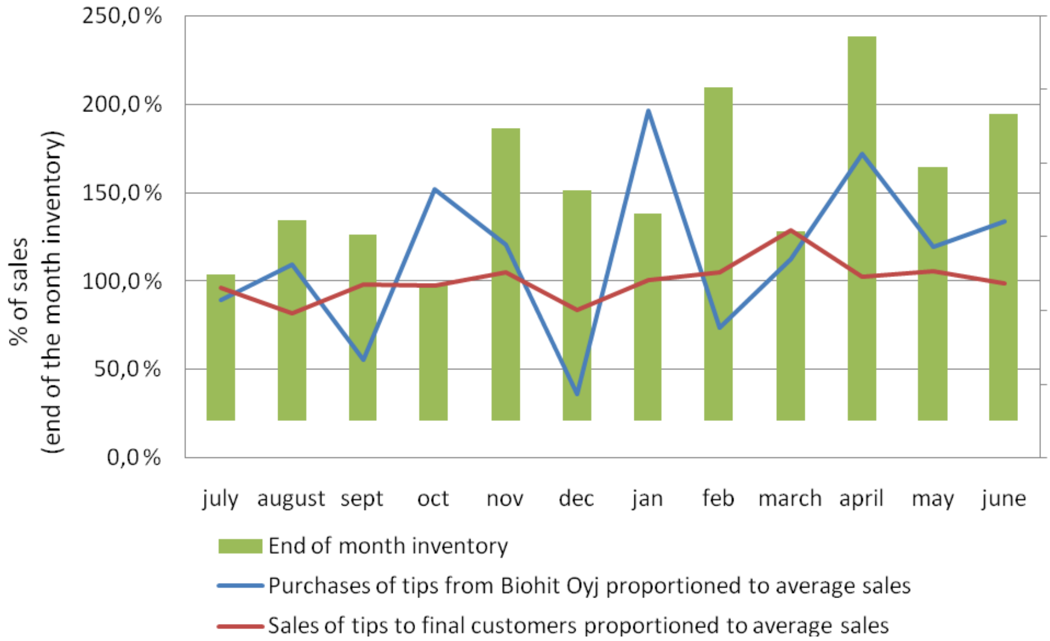

Figure 5.15. *Comparison of the purchases of tips from Biohit Oyj with the sales of tips to final customers (raw data acquired from Axapta, 8.7.2009).*

The figure 5.15 shows that the sales from Biohit SAS to final customers are fairly stable and fluctuations around the average are moderate. By contrast, the purchases from Biohit Oyj vary considerably compared to the average sales of Biohit SAS. A slight change in sales seems to precede an extreme shift in purchases. For example, the sales to final customers decreased from July to August but the purchases increased instead, dropping only just in September. Extreme low and high peaks in purchases follow one another. It seems that the subsidiary either underestimates or overestimates the monthly needs, and an estimation error is balanced out with another extreme estimate that does not match real consumption rate.

When comparing the overall purchases from Biohit Oyj (Axapta 6.7.-9.7.2009) with the overall sales to final customers (Questionnaire Study 2009) the two figures are almost equal for each product group. This implies that the correct amount of goods has been shipped from Biohit Oyj but it has been unequally dispersed within the time frame. Goods are accumulated into batches and batch sizes vary substantially.

5.3.1.1 Biohit SAS - Ordering and reception of goods from Biohit Oyj

Orders of Biohit SAS are based on forecasts. They are calculated item by item based on previous year's average sales and adjusted according to the managing director's personal opinion. Frame orders are placed in the beginning of month, and they cover approximately 70 - 80% of order volume. (Carnis 2009.) According to Andre (2009) additional orders are placed when needed, typically as often as few times per week. The high frequency of extra orders suggests that frame orders based on historical data are not functioning well. Poor forecasting was identified as one symptom of the bullwhip effect (see chapter 2.2.2 Bullwhip effect).

Reception of goods is done without a bar code reader. Warehouse workers check items against a packing slip, and a sales assistant updates inventory values in Axapta. Layout of the warehouse does not support first-in-first-out order that is, according to Carnis (2009), tried to maintain. For the moment, first-in-first-out system is vulnerable and exposed to human errors. The warehouse consists of several rooms, and shelves do not have addresses. Received tips are placed in the back of the warehouse and moved closer to a dispatching area when there is enough room. This causes excess movements which is one of the seven wastes covered in chapter 3.1.1. Rationalizing items' locations in a warehouse is one way of executing lean logistics (3.1.2 Lean logistics).

According to Gire (2009) workload caused by receiving goods is not even throughout a month. Order sizes are varying and that causes a rush period normally in the end of a month (Andre 2009; Gire 2009). It is stated in table 5.4 that standard deviation of number of palettes dispatched to Biohit SAS is as high as 10.7. This figure supports staff's opinion that workload is dispersed rather unequally. Hence, leveled cycles of ordering would facilitate the operations in Biohit SAS. Another way to improve the process would be assigning a process owner. At the moment the managing director carries responsibility for the overall business, and logistics operations are taken care of by several persons.

5.3.1.2 Biohit SAS - Sales order processing and dispatching

Biohit SAS provides delivery within 24 hours directly to final customers. In 2008 the company had some 3500 customers (Gire 2009). Carnis (2009) estimates that 1200 deliveries are dispatched monthly and orders are usually relatively small. Order processing is handled by same workers as ordering from Biohit Oyj, and so the office personnel are multi-skilled.

The process is fairly straightforward apart from packing and backorder processing. Items are packed in one of four standard-sized boxes or Biohit packing is reused. According to Carnis (2009) the period of storage of packing material is one and a half months. It is located in several places in the warehouse, and waste of excess movements is therefore apparent (see chapter 3.1.1 Seven waste). 5S, discussed in chapter 3.7, should be applied to maintain rational order in the warehouse. To avoid backorder processing, mix of products ordered from Biohit Oyj should better match final customers' needs. In addition, delivery times of Biohit Oyj should be more accurate.

Dispatched goods are not traced by their serial number because that is perceived too laborious (Carnis 2009). Yet, serial numbers must be traced in case of recall. Introduction of bar code readers would solve the dilemma. Since no bar code reader is currently in use, inventory in Axapta has to be reduced by the office personnel (Carnis 2009). If warehouse workers do not report any problems in dispatching, an office worker automatically reduces inventory (Carnis 2009). This is a straightforward way of working since communication is needed only when an exception occurs.

Table 5.7 lists the strengths and weaknesses of logistic activities at Biohit SAS. The main points discussed above are repeated and some other relevant observations added.

Table 5.7. *Summary of the strengths and the weaknesses of Biohit SAS.*

	Strengths and best practices	**Weaknesses and targets for development**
Ordering and reception of goods from Biohit Oyj	• Axapta is in use • Four people handling ordering from Biohit Oyj and sales order processing are multi-skilled	• Axapta is not integrated into Axapta company account used in Biohit Oyj • Quantities to order are based on past sales • Remains of the frame order system complicate ordering • Deviation in order batch sizes is high and workload is dispersed unequally • Process has no owner • Management responsibility is concentrated and depends heavily on the managing director
Sales order processing and dispatching	• Standard-size boxes are used • Reporting from the warehouse to sales assistants is done only when exceptions occurs	• Serial number tacking is not used
Inventory management	• New office and warehouse premises enable rationalizing layout	• Layout does not support first-in-first-out order • Excess transportation occurs in the warehouse • Bar code reader is not in use despite of high sales volume • Packing material is located in several places

5.3.2. Biohit OOO

Biohit OOO in Russia is one of the three biggest Biohit subsidiaries measured by purchase volume from the parent company. Within the one year time frame the monetary value of its purchases accounts for XX% of all subsidiaries' purchases when considering the liquid handling products. (Axapta 24.8.2009.) Biohit OOO operates in two locations that are St. Petersburg and Moscow. The main warehouse is located in St. Petersburg where dispatches from Biohit Oyj are received.

The business environment in Russia is very unique, which is why Biohit OOO faces some exceptional challenges. Majority of customers prepay their orders, and goods are delivered as soon as possible after receiving a payment (Mikhaylova 2009). Therefore, customers are not provided with delivery dates. By a rough estimation, only 70% of all orders are dispatched because the rest of them are never paid (Peppi 2009).

The subsidiary's purchases of mechanical pipettes account for XX% of all subsidiaries' purchases (see figure 5.1). These are compared against sales to final customers in figure 5.16. Interestingly, purchases seem to precede sales. This can be explained by the prepayment system that results in long lead times between receiving an order and dispatching. Purchases exceed average sales momentarily by more than 200%, which has led to especially poor inventory turnover between August and November (see figure 5.12). Hence, anticipation of sales provokes the bullwhip effect (see chapter 2.2.2.1 Houlihan effect).

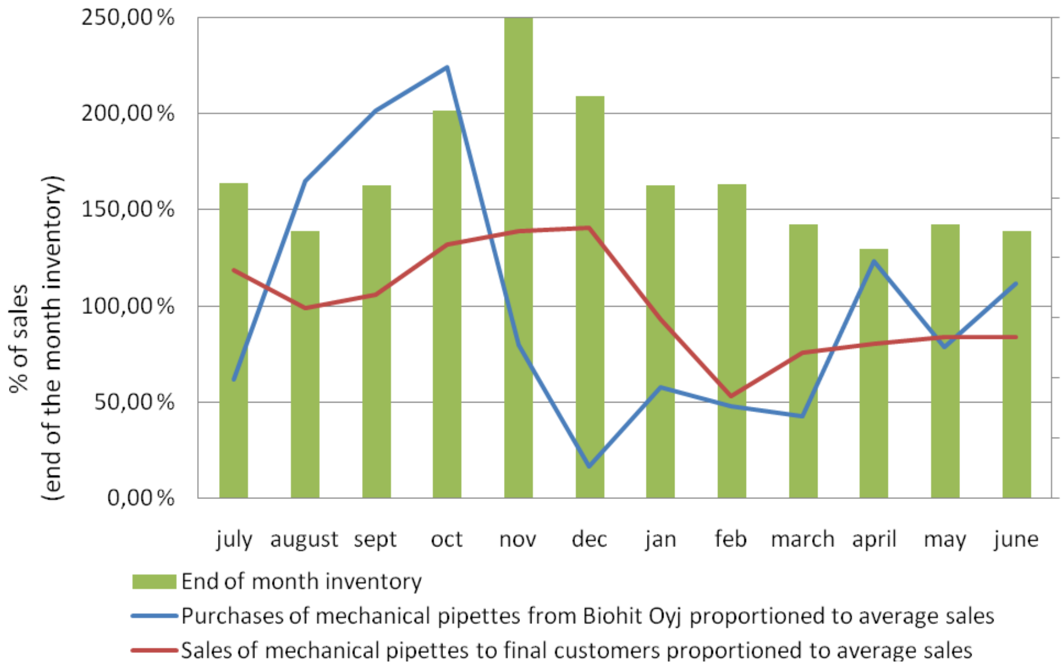

Figure 5.16. *Comparison of the purchases of mechanical pipettes from Biohit Oyj with the sales of mechanical pipettes to final customers (Questionnaire Study 2009).*

5.3.2.1 Biohit OOO - Ordering and reception of goods from Biohit Oyj

In the end of each month a warehouse superintendent calculates needs for the upcoming month. Monthly requirements are divided into two separate orders that are to be delivered one two weeks after another. Additional minor orders are placed when necessary, normally once or twice per week. The customs clearance in Russia is long and complicated, which is why Biohit OOO receives goods from Biohit Oyj only biweekly. Order quantities are based on prevailing inventory levels, order backlog for each item and the warehouse superintendent's experience. No explicit re-order levels are used. (Nikolskaya 2009.) Hence, several conditions can trigger an order, and so further standardization of ordering process is required. Main ordering cycles are two-weeks long but frequent additional orders hinder the benefits of standard-length intervals.

The value stream map is long and complicated, which suggests the process includes a lot of waste (see chapter 3.1.1 Seven waste). Besides pure waste, a lot of incidental work exists that is necessary to support the local customs clearance. The waste of over-processing occurs in the office when same data is processed several times. For example, the warehouse superintendent calculates quantities to order and writes them down on paper. A logistic assistant then enters the quantities into an Excel template that is later sent to Biohit Oyj. After this the logistics assistant enters the same data into ERP system.

The waste of unnecessary transport occurs in the warehouse. Also the waste of unnecessary movements is unavoidable because there is no standard place for packing materials. Nor all tips have standard location in stock so tip boxes are placed wherever there is room. 5S (see chapter 3.7 5S) should be implemented so that each item and material would have assigned and unambiguous place. All items must be recorded in ERP system so that reliable inventory turnover can be calculated.

Some sales units are smaller than standard sales units used in Biohit Oyj which causes extra work in the warehouse as well as in the office. Besides items have to be re-packed, product codes have to be modified to match new selling units. According to Nikolskaya (2009) manipulating product codes takes as much as half of the time used to create an order for those products. Selling units should be uniform throughout the corporate group in order to eliminate such extra work.

A bar code reader is in use to check in serial numbers of pipettes. Despite of processing each pipette separately in the warehouse, the accounting department still manually confirms received pipettes. This practice suggests that a bar code reader is not utilized as much as possible.

All the waste hinders the process flow: there are several activities that do not add any value to final customers thus making the process longer. Inventory turnovers per product groups suggest the material flow of pipettes and spare parts is not continuous because items jam in stock (see figures 5.12, 5.13 and 5.22). For example the mechanical pipettes spend on average three months in the warehouse. Yet, Nikolskaya (2009) estimates that lead times of Biohit Oyj are on average ten working days. If stock can be replenished in a couple of weeks, there is no need to hold inventory covering three months' consumption. Information flow can be simplified by standardizing ordering. Reducing the number of additional orders would bring down the number of confirmations and invoices sent from Biohit Oyj. In order to do this, main orders have to be more accurate. Current system of calculating needs based on several factors is too unreliable.

5.3.2.2 Biohit OOO - Sales order processing and dispatching

Customers consist of both distributors and end customers, which is why there is a lot of variation in order batch sizes and customers' ordering frequency. Major distributors order several times per week whereas final customers order once per month or less frequently (Mikhaylova 2009). According to Gureev (2009) also the lead times between receiving an order and dispatching goods vary substantially depending on when a payment is carried out.

Sales orders are created in ERP system as orders arrive. A pro forma invoice is created and delivered to a customer. (Mikhaylova 2009.) The finance department provides the sales department with a list of paid pro forma invoices daily. The head of sales department re-creates the list with some slight changes causing the waste of over-processing (see chapter 3.1.1 Seven waste). The status of paid orders is changed in ERP system and a picking list is created. Warehouse personnel do not necessarily exploit a picking list but might use a corresponding pro forma invoice instead. (Mikhaylova 2009.) This causes unnecessary work and once more suggests the process is not standardized.

Orders are picked the same day when the finance department has shared the list of prepayments (Mikhaylova 2009). According to Gureev (2009) products are picked in first-in-first-out order. This system is exposed to human errors. Flow racks and fixed locations would reduce the risk of mistakes. Collected items are placed on a shelf waiting for final packing. Items do not flow from one value adding step to the next one which is a prerequisite of lean flow (see chapter 3.2 Flow). Eliminating in-process inventories is needed to improve material flow in Biohit OOO. Collected items are labeled with post-it notes whose different colors indicate different types of transport. For example dispatches collected by a customer are marked with a specific color. This is an effective means of visual management.

The waste of over-processing and excess transport occurs when already collected items have to be removed from the shelf for final packing (see chapter 3.1.1 Seven waste). The reason for preparing outward freight like this is that some customers occasionally ask for additional items to be dispatched with an outgoing batch (Peppi 2009). Nikolskaya (2009) estimates, that 30% of orders need to be adjusted this way. Accordingly, the process is built to support exceptions that account for less than one third of all occurrences. The flow, discussed in chapter 3.2 Flow, of the non-exceptional items is discontinued when they are placed onto shelves before packing though otherwise ready for dispatching.

Table 5.8 lists the strengths and the weaknesses of logistic activities at Biohit OOO. The main points discussed above are repeated and some other relevant observations added. Most of remarks listed in the column of weaknesses and targets for development relate to long process flow due to several kinds of waste.

Table 5.8. *The strengths and the weaknesses of Biohit OOO.*

	Strengths and best practices	**Weaknesses and targets for development**
Ordering and reception of goods from Biohit Oyj	• Process does not depend on one person: responsibilities have been divided among several people • Bar code reader is used to save time and to avoid typing errors when reading in pipettes	• Calculation of needs is rather complicated, and additional orders are placed weekly • Several process steps are repeated by different persons, which causes waste of over-processing • Lot of work is manual so that there is room for human errors • Process flow is fragmented due to waste and slow-turning inventory of pipettes and spare parts • Bar code reader is not fully utilized to receive incoming goods

	Strengths and best practices	Weaknesses and targets for development
Sales order processing and dispatching	• Picked goods waiting to be dispatched are labeled with post-it notes whose color indicates the type of transport • Limited number of standard-size boxes are used	• Several types of communication means are used • Some process steps are repeated • Unnecessary paperwork occurs when picking lists are created and not used • Sales units are not equal to sales units of Biohit Oyj, which causes re-packing • The process flow is discontinued before final packing
Inventory management		• First-in-first-out system is exposed to human errors • There are no standard locations for tips and packing materials in stock • Products for commercial purposes are not recorded in ERP system

5.3.3. Biohit Inc.

Orders of Biohit Inc. in U.S.A. account for XX% of all subsidiaries' liquid handling orders (Axapta 7.8.2009). In this respect it is one of the three biggest subsidiaries. As presented in figure 5.2, Biohit Inc. buys a significant portion of electronic pipettes compared to the other subsidiaries. Figure 5.17 illustrates the subsidiary's purchases of electronic pipettes against sales to final customers. The figure reveals the bullwhip effect (see chapter 2.2.2). Variation in monthly orders from the parent company is apparent.

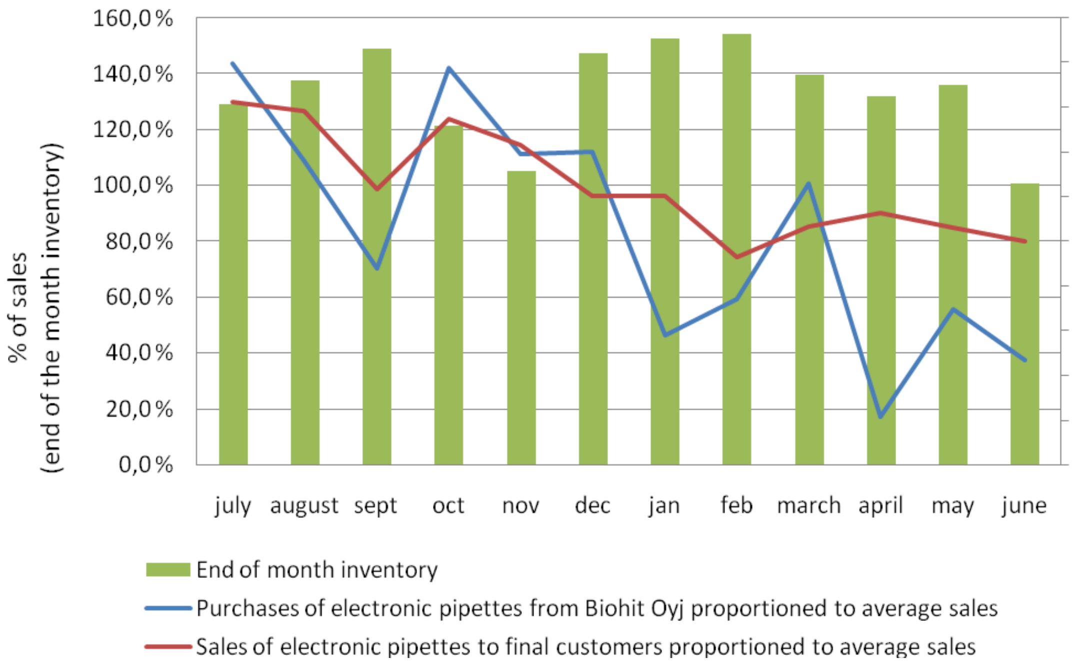

Figure 5.17. *Comparison of the purchases of electronic pipettes from Biohit Oyj with the sales of electronic pipettes to final customers (Questionnaire Study 2009).*

The average end-of-month inventory for electronic pipettes during the one year period under review is 836 pipettes whereas the average monthly sales is 327 pipettes (Questionnaire Study 2009). These figures indicate that average period of storage of electronic pipettes is XX months. The corresponding inventory coverage of mechanical pipettes is XX months and that of tips is XX months (Questionnaire Study 2009). This suggests that instead of flowing steadily through the system it is possible that pipettes jam in stock. Hence, amount of items in stock should be reduced to improve inventory turnover and release working capital. This would improve material flow (see chapter 3.2 Flow) in Biohit Inc.

5.3.3.1 Biohit Inc. - Ordering and reception of goods from Biohit Oyj

There are several incidents that trigger an order. Frame orders, based on sales history, are placed in the beginning of each month for delivery two months later (Questionnaire

Study 2009). Ordering this way is risky because it is not possible to accurately estimate customers' needs several months in advance. It is stated in Questionnaire Study (2009) that normal lead times for orders other than frame orders are from two to three weeks Additional orders triggered by customers' special orders are created whenever needed. In the end of a month all liquid handling Biohit products' inventory levels are compared to average demand. Then, an order is placed for items that have less than two months inventory on hand. For some items as much as four months' inventory is kept in stock. In addition, spare parts have special ordering logic and those are ordered in intervals of two weeks. (Questionnaire Study 2009.) Even if all these triggers are systematically followed, the ordering process is still multi-phased. There is plenty of room for standardization.

Order batch sizes vary due to frame order system and variation in demand (Questionnaire Study 2009). Figure 5.17 suggests that despite of downward trend, fluctuation in demand of electronic pipettes has been minor. Therefore, the frame order system is at fault for variation in order batch sizes. The frame orders of Biohit Inc. contain normally 19 to 25 pallets whereas other orders are size of 3 to 10 pallets. Paper work varies in proportion to orders' size. (Questionnaire Study 2009.) Leveling ordering cycles by giving up the frame order system would help operations and provide more flexibility.

An order is first entered into an Excel sheet which is sent to Biohit Oyj. After receiving a confirmation purchase order is created in ERP system. (Questionnaire Study 2009.) Hence, the same data is processed twice. All kind of douple-handling should be eliminated in order to streamline the process flow. Reducing printouts is another issue to consider because copies of several documents are handled and filed at many stages of the process.

Almost every shipment is incomplete compared to the origial purchase order because some individual items are delayed. Serial numbers of incoming items are recorded by hand and loaded into ERP system by customer service staff. Items are located to their designated places and kept there untill dispatched to customers. Some products, mostly tips, occasionally become overstocked which leads to re-locating inside the warehouse. (Questionnaire Study 2009.)

5.3.3.2 Biohit Inc. - Sales order processing and dispatching

Biohit Inc. has approximately 50 regular customers, an amount that consists of dealers and OEM customers. A few big customers order every day. In addition, roughly 30 orders from regular small customers and direct customers are processed daily. Order handling and dispatching is considered straightforward. Only problems arising are due to human errors since mis-picking and mis-dispatching occur time to time.

(Questionnaire Study 2009.) A bar code reader could reduce this kind waste. It would also facilitate serial number tracing that is currently done manually.

Orders are processed as they arrive and dispatching is done as soon as possible. Lead time can be as short as a couple of hours. Delays are mainly due to back order items which cause exceptions. Some items are re-packed and sold in larger units. Customers that buy these bigger units get quantity discount. (Questionnaire Study 2009.) This practice can accelerate the bullwhip effect because changes in prices are one cause of the phenomenon (see chapter 2.2.2 Bullwhip effect). Need for back order processing should be reduced by better matching orders from Biohit Oyj to local customers' needs. This has to apply to mix and timing of items.

Table 5.9 lists the strengths and weaknesses of logistic activities at Biohit Inc. The main points discussed above are repeated and some other relevant observations added.

Table 5.9. *The strengths and the weaknesses of Biohit Inc.*

	Strengths and best practices	**Weaknesses and targets for development**
Ordering and reception of goods from Biohit Oyj		• There are several triggers for orders • Order batch sizes vary substantially • Repeating process steps causes waste of over-processing
Sales order processing and dispatching	• Lead times can be as short as two hours	• Human errors occur due to manual process steps • Some items are re-packed and sold in larger units which inevitably lowers profit margins
Inventory management		• Tips occasionally become overstocked • Items' fixed locations are not recorded in ERP system

5.3.4. Biohit Ltd.

Biohit Ltd. in U.K. is a medium-sized subsidiary (see table 5.2), and its impact on aggregate purchases from Biohit Oyj is minor (see figures 5.1, 5.2 and 5.3). However, the number of shipments to Biohit Ltd. exceeds the corresponding figure of all the other subsidiaries (see figure 5.11). This is due to the practice of dispatching the subsidiary's spare parts separately from other items.

Figure 5.18 illustrates the sales of tips to final customers against the purchases from Biohit Oyj. Data concerning purchases is extracted from Axapta and data concerning the sales is provided by Biohit Ltd., which can cause slight distortion in ratio of the two sets of figures. End-of-month inventory levels in number of pieces are not available and hence are not plotted here.

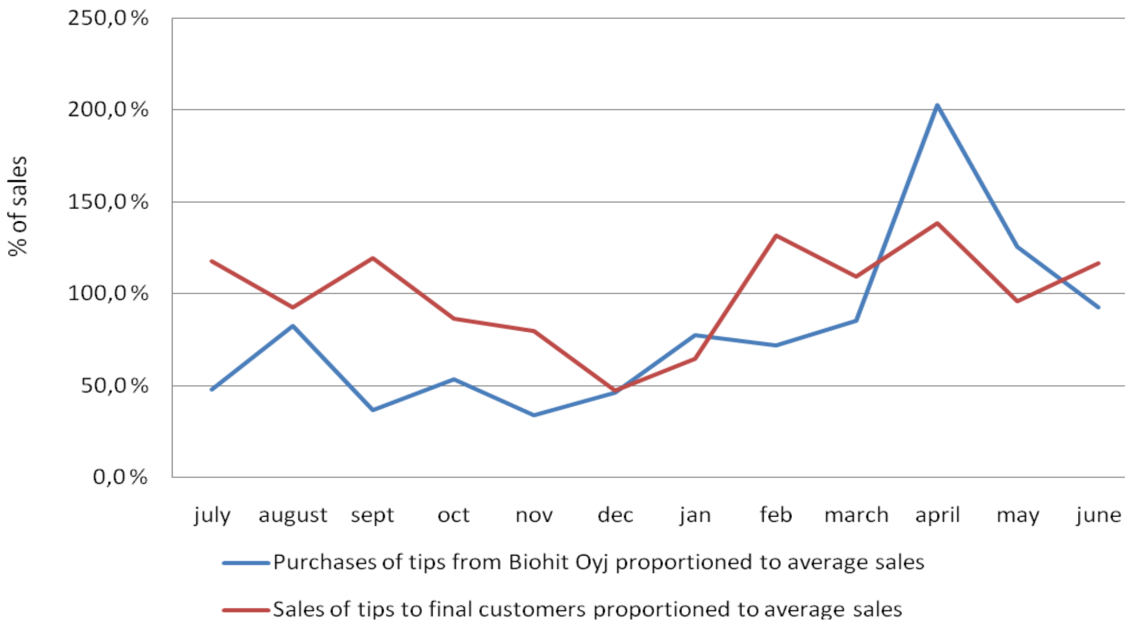

Figure 5.18. *Comparison of the purchases of tips from Biohit Oyj with the sales of tips to final customers (Axapta* 20.7.2009; *Questionnaire Study 2009).*

Fluctuation in purchases is more extreme than fluctuation in sales. It seems that constant low purchase volumes before March resulted in extremely high purchasing peak in April. Ordering should be rationalized to better mach the two graphs.

Noteworthy in case of Biohit Ltd. is that processes of ordering, receiving, sales order processing and dispatching are arranged remarkably efficiently: process flows are fairly short and standardized. There are written description for warehouse standard operating procedure and sales order processing. Processes have an owner, the operations manager, who understands and manages overall processes. The warehouse is clean, well organized and there are fixed places for all items. Each shelf has an address that can be found in ERP system as well as on the label attached to the shelf. In this respect Biohit Ltd. can serve as an example for the other subsidiaries.

5.3.4.1 Biohit Ltd. - Ordering and reception of goods from Biohit Oyj

Orders for liquid handling products are placed once per week, normally on Friday. Order quantities are based on item-specific re-order levels and re-order quantities available in ERP system. Re-order figures are updated at intervals of few months. This labor-consuming task takes each time several days to complete. (Ricketts 2009a.) Calculation of order quantities is also multi-phased and exposed to human errors. It has to be automated or need for calculation must be eliminated.

According to Ricketts (2009a) transport cost is an important issue when deciding what items to order. Pipettes that have not reached their re-order level are sometimes ordered alongside with tips to decrease the proportion of transport costs relative to value of freight. (Ricketts 2009a.) This is one of the common pitfalls of inventory management (see chapter 2.2.1 Typical problems, pitfall 9) that increases the waste of excess inventory discussed in chapter 3.1.1 Seven waste.

Placing an order and reception of goods are fairly straightforward. A warehouse worker checks an incoming shipment against a delivery note and creates a goods-inward note manually. After this items are entered into ERP system. Items are moved to their correct locations after backorders have been identified and separated from rest of the goods. This way backorders can be dispatched directly and excess relocation is avoided. Items put onto shelves are maintained in first-in-first-out order. The most selling items are closest to the dispatching area. (Ewing 2009.) According to Ricketts (2009a) greater utilization of ERP system and other device could complicate the straightforward way of working and decrease flexibility. However, if sales boom in the future more automated methods should be considered. Manual work is time consuming and exposed to human errors.

According to Ricketts (2009a) delivery times of Biohit Oyj have historically been from four to five weeks but recently have shortened for some items to three weeks or even less. Re-order quantities cannot be dropped unless delivery times are constantly short and reliable. Ricketts (2009a) also states, that communication about changed delivery times has not been satisfactory. Therefore, length of lead times and transparency in operations of Biohit Oyj is essential when carrying out changes in the subsidiaries.

5.3.4.2 Biohit Ltd. - Sales order processing and dispatching

Biohit Ltd. has roughly 1600 customers that order liquid handling products. Approximately half is final customers and another half is distributors. (Dickinson 2009.) The process flow is fairly short and straightforward. Re-packing is minimal. However, eight different package sizes are used. The amount is double compared to the number of package sizes used for example in Biohit SAS.

Items are dispatched the same day or the next day after the order has arrived. Backorders cause exceptions. According to Dickinson (2009) almost each purchase order includes items that go on backorder. If a customer does not accept a partial delivery, items in stock are reserved until items gone on backorder are acquired. Customers accept backorders because they are mainly for OEM and PL products and some infrequently ordered pipettes (Ricketts 2009a). Yet Dickinson (2009) remarks that allocating back order items to customers is one of the most time consuming activity of sales order processing.

One warehouse worker picks and packs items, and places ready dispatches on a designated area. The form of transport determines where items are to be placed: dispatches called for by different transport companies are separated. A list of dispatched goods is created manually by the warehouse worker. This is done to trace serial numbers. A bar code reader could quicken this task and reduce the possibility of human errors.

Table 5.10 lists the strengths and weaknesses of logistic activities at Biohit Ltd. The main points discussed above are repeated and some other relevant observations added. The company has good practices that can be applied in the other subsidiaries.

Table 5.10. *The strengths and the weaknesses of Biohit Ltd.*

	Strengths and best practices	**Weaknesses and targets for development**
Ordering and reception of goods from Biohit Oyj	• There is a person dedicated to the process • Re-order level and re-order quantities are calculated and available in ERP system • Written process descriptions exist • Ordering is done weekly, basing orders on re-order levels • Workers are multi-skilled	• Re-order figures rely on historical data • Manual process steps are exposed to human errors • Transport costs relative to value of freight are kept low, which does not necessarily optimize total costs
Sales order processing and dispatching	• Backorders are processed immediately • There is a person dedicated to the process • Written process descriptions exist • Delivery reliability is monitored	• Many package sizes are used • Manual process steps are exposed to human errors • Delivery reliability data excludes back orders
Inventory management	• Warehouse is well-organized and shelves have addresses • Most selling items are located closest to a dispatching area • Dispatches called for by different companies are separated	

5.3.5. Biohit Biotech Co., Ltd.

Biohit Biotech Co., Ltd. in China differs from the other subsidiaries in respect that one of the three Biohit factories is located there. Part of mechanical pipettes are produced on site and dispatched to Biohit Oyj, Biohit Ltd. or directly to Chinese customers. Therefore, management of material flow and inventories is vitally important. Inventory control is well considered and so Biohit Biotech Co., Ltd. can serve as an example for the other subsidiaries.

Purchase volumes of end products except for electronic pipettes from Biohit Oyj are moderate (see figures 5.1, 5.2 and 5.3). Figure 5.19 below illustrates monthly purchases of electronic pipettes from Biohit Oyj against monthly sales to final customers in proportion to average monthly sales. As in case of the other subsidiaries the two graphs differ. Still, purchases do not dramatically lag sales. In December the figures overlap, which means the monthly purchases have been almost equal to the monthly sales. Sources of the remaining deviation are unknown and should be further studied and eliminated.

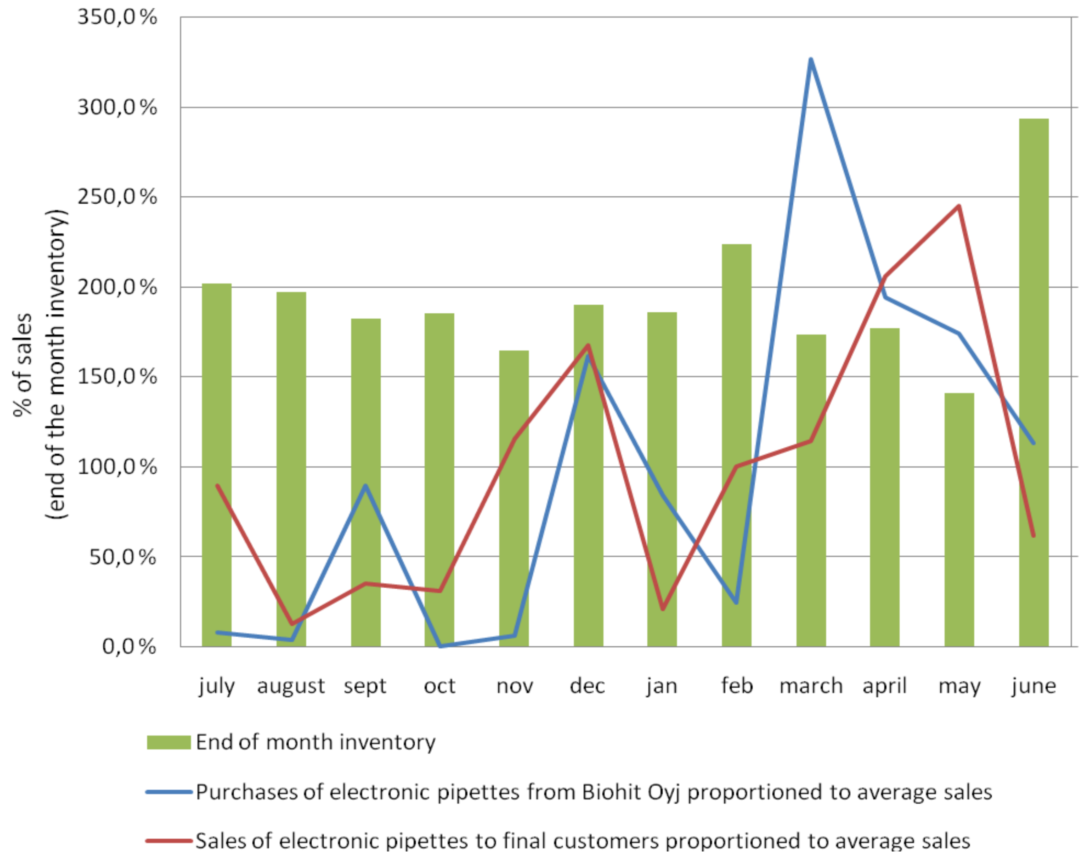

Figure 5.19. *Comparison of the purchases of electronic pipettes from Biohit Oyj with the sales of electronic pipettes to final customers (Questionnaire Study 2009).*

5.3.5.1 Biohit Biotech Co., Ltd. - Ordering and reception of goods from Biohit Oyj

Inventories are controlled using kanban system (see chapter 3.4 Kanban). A warehouse worker collects kanban cards throughout a week and brings them to the logistics office each Monday. Needed items are entered into a ready-made Excel template which is then sent to Biohit Oyj. Customer orders that exceed the maximum inventory trigger an additional order. (Questionnaire Study 2009.) Length of ordering cycles is standard and order sizes are based on real consumption rate. Logistics personnel in Biohit Biotech Co., Ltd. are content with the current system (Questionnaire Study 2009).

When receiving goods, the quantity of items is checked and quality is inspected using random sample items. Kanban cards are attached to handling units which are then moved to their correct locations. Serial numbers are recorded manually at the logistics department. (Questionnaire Study 2009.) According to Teuronen (2009) order processing is straightforward, and kanban system has simplified work at the logistics department in Finland making it more predictable.

5.3.5.2 Biohit Biotech Co., Ltd. - Sales order processing and dispatching

There are roughly XX customers in China. Domestic orders are dispatched the same day as an order arrives. The biggest customer accounts for XX% of total domestic sales of Biohit Biotech Co., Ltd. This customer orders almost daily. In addition, orders are received from Biohit Oyj and Biohit Ltd. Production orders are opened after receiving an order from either one of the companies. Export shipments to Finland leave once per week and to U.K. as soon as the goods are ready for dispatching, usually five workdays after receiving an order. (Questionnaire Study 2009.)

Items are kept in only one location in the warehouse. Exceptions are goods reserved for tenders that are moved to a reservation area. These exceptional positions are recorded in the ERP system. First-in-first-out priority and serial number tracking are maintained in Axapta. (Questionnaire Study 2009.) Warehouse management is systematic, and process performance is evaluated by calculating monthly delivery reliability and stock-outs. During the time frame under review the average delivery reliability was XX% and stock-out rate XX%. Inventory turnover for each item is also calculated monthly, and the amount of kanbans is adjusted accordingly. (Questionnaire Study 2009.) Kanban system ensures that mix of items in stock matches customers' needs and inventory has a maximum limit. Hence, inventory control follows systematic rules.

Table 5.11 lists the strengths and weaknesses of logistic activities at Biohit Biotech Co., Ltd. The main points discussed above are repeated and some other relevant observations added.

Table 5.11. *The strengths and the weaknesses of Biohit Biotech Co., Ltd.*

	Strengths and best practices	**Weaknesses and targets for development**
Ordering and reception of goods from Biohit Oyj	• Orders are based on real consumption rate • Order cycles from and to Biohit Oyj are standard-length • Working methods are systematic	• Several documents are prepared and sent at many stages of the processes • Bar code readers are not in use in spite of a great number of items handled
Sales order processing and dispatching	• Performance indicators are calculated for sales order processing and dispatching	
Inventory management	• Items have fixed places in the warehouse • First-in-first-out system and serial number tracking are maintained in the ERP system • Inventory turnover is calculated and used controlling the inventory • Kanban system enables systematic inventory control	

5.3.6. Biohit Japan Co., Ltd.

Immediate actions are required in Biohit Japan Co., Ltd. whose inventory turnover for each product group is poor (see figures 5.12, 5.13, 5.14 and table 5.6). The subsidiary is strongly marketing-oriented. Insufficient consideration is given to stock management, and currently inventory-related decisions are mostly operational. Hence, more proactive and holistic thinking is needed. Three persons affect inventory related decision-making: a service manager calculates requirements for spare parts, a logistics specialist calculates needs for other liquid handling items and the managing director approves all items to order. The logistics specialist creates and delivers purchase orders to Biohit Oyj. She also handles the physical reception of goods, processes Japanese customers' purchase orders and prepares them in the warehouse. Hence, the only person fully dedicated to logistics is busy with operational issues.

Purchases of electronic pipettes from Biohit Oyj against sales to final customers are illustrated in figure 5.20. Purchase volumes vary substantially from month to month. Interestingly, the sales have boomed between November and March due to a yearly campaign period but purchases after January were moderate. Despite low purchase volumes in the beginning of 2009, inventory turnover did not improve (see figure 5.13) because the inventory level was remarkably increased in batch in December.

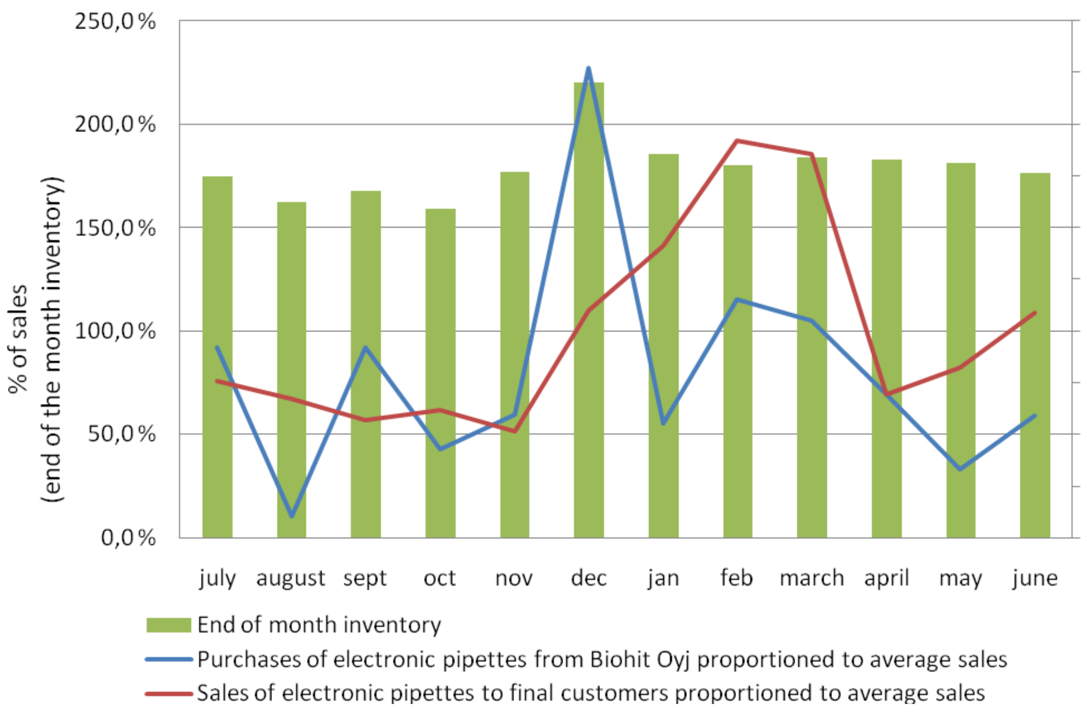

Figure 5.20. *Comparison of the purchases of electronic pipettes from Biohit Oyj with the sales of electronic pipettes to final customers (Questionnaire Study 2009).*

An average end-of-a-month inventory of electronic pipettes was XX pieces during the one year period under review. Respectively, the average sales were XX pieces per month. This implies that an average inventory is sufficient to satisfy more than five months' demand. According to the same logic, average inventory of mechanical pipettes is enough to meet eleven months' demand, and average inventory of tips is enough to meet six months' demand. Number of mechanical pipettes purchased during the one year period under review was XX pieces while sales were only XX pieces. (Questionnaire Study 2009.) Figures imply the company holds wrong mix of items in stock. Need for better inventory control is further supported by the fact that average stock levels and safety stock are unknown (Questionnaire Study 2009).

5.3.6.1 Biohit Japan Co., Ltd. - Ordering and reception of goods from Biohit Oyj

The subsidiary orders intermittently once or twice per month and shipments are dispatched respectively irregularly. According to Tiainen (2009) settling delivery dates is complicated because there are no fixed dates for dispatching. The relatively high standard deviation of shipment sizes (see table 5.4) could possibly be reduced if ordering was more frequent and regular. In other words, ordering could be done in standard-length leveled cycles. The idea of leveling is presented in chapter 3.3.

According to Mizoguchi (2009) monthly amount to order is based on historical records. When necessary, orders for required items are supplemented with other items to avoid extra for small orders. (Questionnaire Study 2009.) This practice suggests that stock levels are too high: although orders are placed infrequently, there are not always enough required items to form one minimum order. Requirements are entered into an order sheet by the logistics specialist and approved by the managing director (Questionnaire Study 2009). According to Mizoguchi (2009) approving one order can take half an hour. Asking for managing director's approval complicates the ordering process, adds bureaucracy and ties up the managing director's time to a non-value-adding operational task. If ordering logic is standardized and based on explicit rules, such as kanban discussed in chapter 3.4, the managing director does not have to re-check and approve an order.

According to Nakamura (2009) spare parts' orders are placed once per month and they usually cover three months' consumption. Lead time for spare parts delivered from Biohit Oyj to Biohit Japan Co., Ltd. is approximately two weeks. Hence, order batch sizes are too big. Due to large orders some of the items in spare part stock are left unused. According to Nakamura (2009) one quarter of items have not been needed during previous twelve months.

The logistics specialist manually maintains a list of arriving items and their delivery dates because orders are usually split into several shipments. Part deliveries are problematic because they add paper work of the subsidiary. (Yanagawa 2009.) This can be avoided if ordering cycles and batch sizes are leveled so that production does not have to react to unpredicted demand peaks. Hence, ordered products can be delivered in one shipment and lead times can be kept relatively constant. According to Yanagawa (2009) arriving shipments are checked against an invoice and against the list of arriving items. Unexpected discrepancies are common and new delivery dates have to be asked for separately (Yanagawa 2009). Information sharing with the parent company has to be improved and standardized.

Pipettes and spare parts are located into the company’s own warehouse and most of the tips are in a warehouse managed by an external company. Some tips are needed in the own facilities. Arriving shipments are split after customs clearance depending on which items are to be delivered to which warehouse. This causes double transport cost. The logistics specialist estimates the number of tip boxes needed in the own warehouse. She gives instructions to a forwarding agent about how to split the shipment. Frequently, tips have to be transferred from the external warehouse to the own facilities. Sometimes transfers to the opposite direction take place as well. (Mizoguchi 2009; Yanagawa 2009.) This is pure waste that has to be eliminated. Most convenient way is to transport all tips to the external warehouse so that instructions to a forwarding agent are always the same and no estimation is needed. In addition, overall inventory level of tips has to be brought down: at the moment 41 pallet locations are reserved for Biohit in the external warehouse and the oldest items are from the year 2006.

Modes of transport from Biohit Oyj to Biohit Japan Co., Ltd. are air and sea freight. According to Mizoguchi (2009) sea freight arrives often slightly damaged, and lead times can be several months. Biohit Japan Co., Ltd. has ordered on average one third of the amount of tips delivered to the United States per month. This comparison suggests that volume purchased by Biohit Japan Co., Ltd. is relatively small. (Questionnaire Study 2009.) Considering the facts covered above, only air freight should be used.

5.3.6.2 Biohit Japan Co., Ltd. - Sales order processing and dispatching

Biohit Japan Co., Ltd. serves 200 dealers and 5 wholesalers located in 600 destinations. Most of them place orders monthly, and some order weekly. Deliveries are done mainly within 24 hours after receiving an order except for some distant locations. If a product cannot be delivered immediately due to a stock-out, a maximum two-week delivery time is accepted by customers. Hence, delivery times of Biohit Oyj have to be shorter and more accurate. (Questionnaire Study 2009.) Unsatisfactory service due to unavailable products is one symptom of the bullwhip effect (see chapter 2.2.2 Bullwhip effect). According to Mizoguchi (2009) also information sharing should be improved since changes in delivery times of Biohit Oyj are not always communicated to the subsidiary, which can lead to lost sales in Japan.

Full cartons of tips are delivered directly from the external warehouse. When one order consists of full cartons of tips and some pipettes, two delivery notes and invoices are created. This is waste that can be avoided by re-locating all items into one warehouse as already considered in Biohit Japan Co., Ltd. If tips are sold in racks so that cartons have to be opened, they are first delivered to the own warehouse, which causes additional transport costs. Therefore, customers are given a discount if they buy full cartons (Mizoguchi 2009). Profit margins are lowered because of inefficiency of inventory control. This practice is not reasonable. Inventory management overall is quite fragmented considering that Biohit Japan Co., Ltd. is a relatively small organization.

Order processing, picking and packing is responsibility of the logistics specialist. The whole process depends heavily on one person's professional skills, which is a risk. After confirming an order in the office upstairs the logistics specialist walks downstairs to pick items. The part of tips kept in the own warehouse is placed in several locations and moved closer to a packing area when needed (Mizoguchi 2009). This practice suggests that the current layout of the warehouse is not optimal.

After picking the logistics specialist adds Japanese manuals to pipette boxes and takes electronic pipettes to testing. When electronic pipettes are more than one-year old batteries have to be replaced, which causes extra cost (Questionnaire Study 2009). The problem is a clear consequence of poor inventory management: the subsidiaries should not have one-year old pipettes in their stock. Not assessing all inventory costs, such as reworking existing inventory, is one of the pitfalls of inventory management discussed in chapter 2.2.1 Typical Problems (see pitfall 10). This waste can be avoided when inventory turns faster resulting in less pipettes becoming obsolete. Three standard-sized boxes are used for packing. In addition, boxes with other brand labels are re-used. This practice deteriorates Biohit brand image and should be cut out.

Table 5.12 concludes the strengths and the weaknesses of Biohit Japan Co., Ltd. The main points discussed above are repeated and some other relevant observations added.

Table 5.12. *The strengths and the weaknesses of Biohit Japan Co., Ltd.*

	Strengths and best practices	**Weaknesses and targets for development**
Ordering and reception of goods from Biohit Oyj	• The logistics specialist is experienced and understands the logistic processes in aggregate	• Process depends heavily on the logistics specialist's personal skills • Order intervals are irregular • Ordered amounts are based on historical records • Orders are supplemented with additional items to avoid extra for small orders • Bureaucracy exists as orders have to be approved by the managing director • Ordering logic is poor which leads to too high inventory levels • Information sharing with the parent company has to be improved • Sea freight is not convenient mode of transport • Same information is recorded in Excel-format and in the information system
Sales order processing and dispatching	• There is a large number of customers to level aggregate demand • Three standard-size boxes are used for packing	• Process depends heavily on the logistics specialist's personal skills • Boxes with other brands' labels are used for packing

	Strengths and best practices	Weaknesses and targets for development
		• Customers buying full cartons of tips are given discount to avoid excess transport between two warehouses
Inventory management	• The first concrete steps for improvement have been taken	• There is lack of holistic inventory management • Keeping items in two separate warehouses causes excess transport and cost • Safety stocks and average stock levels have not been specified • First-in-first-out control of tips is not based on lot numbers • Layout of the own stock is not optimal

5.3.7. Biohit Deutschland GmbH

Biohit Deutschland GmbH in Germany is a small organization whose performance in terms of inventory turnover and standard deviation of shipment sizes is fairly good (see figures 5.12, 5.13, 5.14 and table 5.4). Its impact on the overall logistic performance of Biohit Group is minor.

The two lines in figure 5.21 below illustrate monthly purchases of tips from Biohit Oyj against monthly sales to final customers in proportion to average monthly sales. The bars indicate changes in end-of-month inventory. The up- and downswings of the two lines do not overlap which might indicate that purchases lag sales: For example in August slight increase in sales is followed by upswing in purchases one month later in September. Sales have fallen from August to September resulting in decrease in purchases in October. The gaps between purchases and sales suggest that instead of flowing steadily through the system it is possible that tips jam in stock. Flow (see chapter 3.2) ought to be improved.

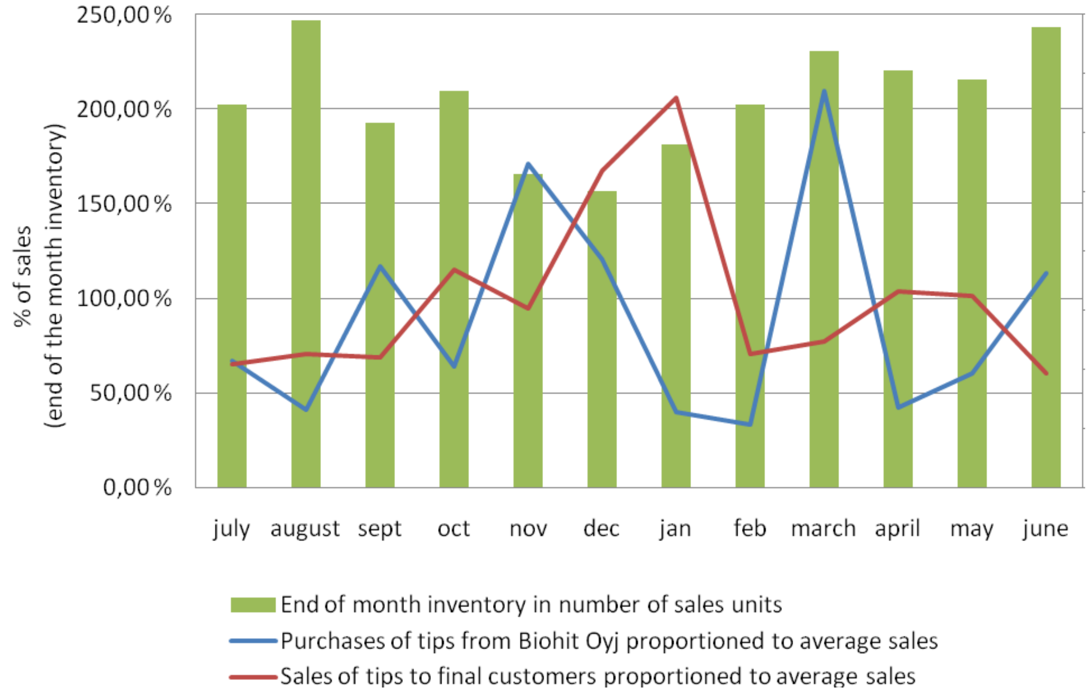

Figure 5.21. *Comparison of the purchases of tips from Biohit Oyj with the sales of tips to final customers (Questionnaire Study 2009).*

As shown in figure 5.21 inventory level of tips has maintained high. The difference between the highest value in August and the lowest value in December is approximately 600 units. The lowest end-of-month inventory level equals average monthly sales during the period under review (Questionnaire Study 2009).

5.3.7.1 Biohit Deutschland GmbH - Ordering and reception of goods from Biohit Oyj

At the moment, no buffer stock is inputted in ERP system. Orders based on forecasts and prevailing inventory levels are placed once or twice per week. Forecasts are average sales of past two years adjusted with consumption rate and personal opinions. (Questionnaire Study 2009.) Ordering is laborious considering that orders based on forecasts are placed several times per month.

When receiving goods the process flow is quite straightforward. However, tips have to be moved inside the own warehouse which causes the waste of excess transport discussed in chapter 3.1.1 Seven waste. (Questionnaire Study 2009.) This can be avoided by rationalizing the warehouse layout and usage of space. Additionally, process steps could be reduced if using bar code readers instead of entering data into ERP system manually (Questionnaire Study 2009). Printing of inventory statistics is additional process step, and its necessity is arguable.

Lead times for ordering and receiving products from Biohit Oyj are estimated to vary on average between ten days and three weeks but at the worst even three months lead times are possible. Long delivery times are problematic. Requests for delivery dates are usually ignored, and approximately 90% of confirmed delivery dates do not match with the requested dates. (Questionnaire Study 2009.) According to Tiainen (2009), who is working at the logistics department of Biohit Oyj, ordering of Biohit Deutschland GmbH is relatively straightforward and systematic. This controversy in opinions suggests that better communication is needed.

5.3.7.2 Biohit Deutschland GmbH - Sales order processing and dispatching

Biohit Deutschland GmbH has roughly 500 customers. Less than 10% of customers order weekly and approximately 15% order monthly. (Questionnaire Study 2009.) Hence, the majority of the customers place their orders irregularly and therefore accurate forecasting is difficult.

Normal delivery time is between 24 and 48 hours. Items are delivered in first-in-first-out order and serial number tracking is in place. Sales order processing and dispatching is considered uncomplicated except for back order processing due to long delivery times or delayed dispatches from Biohit Oyj. As much as 11.3% of mechanical pipettes, 30.7% of electronic pipettes and 21.4% of tips went on backorder during the time frame under review. Number of items on backorder has fluctuated randomly, which can be explained by variation in demand and supply. (Questionnaire Study 2009.) Because demand patterns are hard to predict or change, delivery times of Biohit Finland have to be shorter and more predictable in order to reduce the amount of back orders.

Table 5.13 lists the strengths and weaknesses of logistic activities at Biohit Deutschland GmbH. The main points discussed above are repeated and some other relevant observations added.

Table 5.13. *The strengths and the weaknesses of Biohit Deutschland GmbH.*

	Strengths and best practices	**Weaknesses and targets for development**
Ordering and reception of goods from Biohit Oyj	• Frequency and sizes of orders are fairly stable when ordering from Biohit Oyj • Process descriptions exist	• Ordering is based on historical sales records
Sales order processing and dispatching	• Delivery reliability is calculated every three months	• No standard box sizes are used • Amount of back order items is considerable
Inventory management	• Need for better minimum stock management is identified and stock level reduction is considered possible • 5S is applied to some extent	• Tips are relocated inside the warehouse

5.4. Spare parts

Spare parts differ from tips and pipettes in that they are used in internal service business. Inventories of spare parts are commonly managed differently than other stock items in the subsidiaries. Inventory levels of spare parts are high, and managing less systematic than managing of tips and pipettes. First-in-first-out control of spare parts in the subsidiaries is inadequate or nonexistent. Subsidiary-specific inventory turnover rates for spare parts are illustrated in figure 5.22.

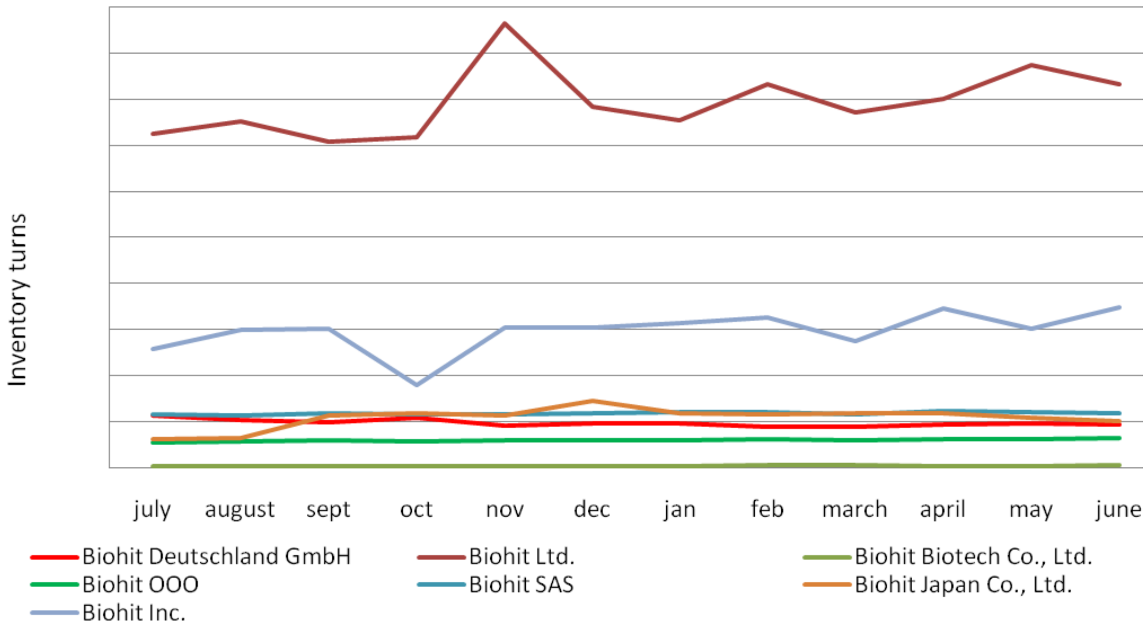

Figure 5.22. *Inventory turnover of spare parts.*

Only Biohit Ltd. has reached an acceptable inventory turnover rate of spare parts. Figure 5.22 shows that most of the subsidiaries' spare part inventories turn less than twice per year. Hence the risk of parts becoming obsolete is significant. Not assessing all inventory costs, such as cost of obsolescence, is one on the common pitfalls of inventory management (see chapter 2.2.1 Typical problems, pitfall 10). Since the importance of service and spare part business is growing, managing of spare part inventories should be given more attention. Inventory management and ordering processes have to be standardized by harmonizing spare parts inventory management with management of the other stock items.

Currently different persons calculate need of spare parts and need of other items. Hence, more than one forecasting practice might be applied in one subsidiary. Sometimes, as in case of Biohit Ltd., spare parts are delivered in a separate dispatch. This implies there are different ordering and dispatching cycles for spare parts and other items, which inevitably adds the amount of paper work. To reduce this kind of waste and transport costs, spare parts have to be ordered and delivered along with other items.

5.5. Key findings

The subsidiaries base their orders mainly on past sales and simple forecasts. Therefore the so called decision point, discussed in chapter 2.2.2.2 Measuring the bullwhip effect, is in the subsidiaries' warehouses. This is illustrated in figure 5.23. The point 1 represents the current location of decision point. The point 2 shows the desirable location of decision point in the near future. Ideally, when lean concepts are adapted more extensively in the production of Biohit, the decision point is shifted further away from customer's end of the supply chain.

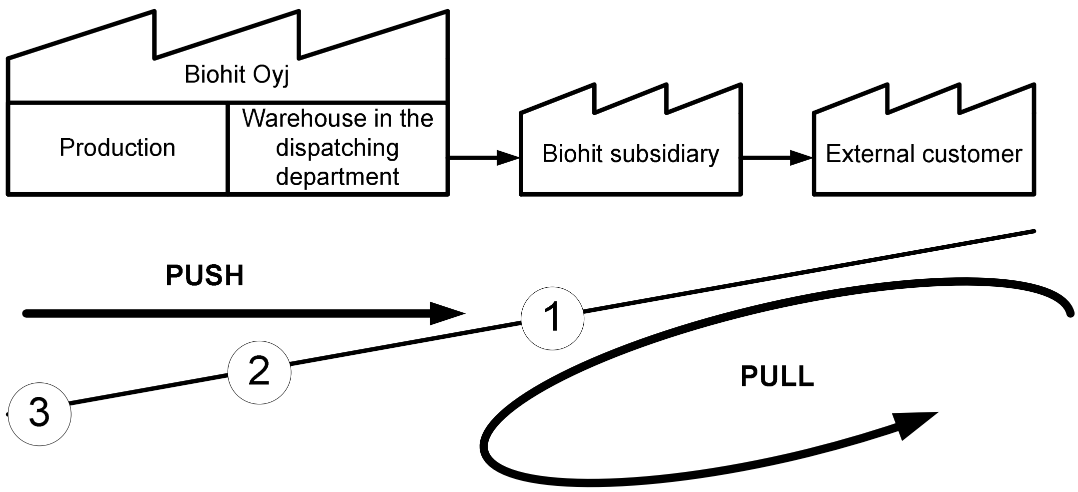

Figure 5.23. *Decision point analysis.*

All external customers, both distributors and final customers, are treated the same in figure 5.23. In reality, distributors form an extra echelon in a supply chain. Since demand patterns of different types of external customers are outside the scope of this study, this simplification is made here.

The subsidiaries place orders in batches, what accelerates the bullwhip effect as discussed in chapter 2.2.2 Bullwhip effect. Each subsidiary has its unique way of calculating needs, and no corporate-wide standard procedures exist. However, waste is similar among all subsidiaries. Generally little thought is given to realization of logistics processes, which caused that estimation of lead times and process steps for this study was found difficult in most of the subsidiaries. Typical waste present in the subsidiaries' logistics processes is listed in table 5.14.

Table 5.14. *Typical waste of logistics processes.*

Process of ordering and receiving	• Manually calculating number of items to order • Controlling correctness of documents and items at several stages of the process • Manually entering received items into ERP system • Placing additional small orders to supplement big orders • Processing same data several times or producing unnecessary data such as unused picking lists
Sales order processing and dispatching	• Processing backorders • Manually listing serial numbers of outward freight • Opening packages received from Biohit Oyj and repacking • Relocating items inside own warehouse

Several points stated in the table above cannot be left out of the processes but they can be performed more effectively or less frequently. For example, number of backorders can be reduced if delivery times of Biohit Oyj are shorter and more accurate. As discussed in chapter 2.2.2, the bullwhip effect can be partly tackled by simplifying ordering process and reception of goods because that encourages placing small and frequent orders.

The subsidiaries except for Biohit Biotech Co., Ltd. do not evaluate their own processes systematically. This is one of the common pitfalls of inventory management (see chapter 2.2.1 Typical problems, pitfall 2). The subsidiaries lack basic knowledge such as data of inventory turnover or delivery reliability. Data is not collected because it is seen time-consuming and unnecessary activity. The major reason for this is that processes are considered very simple and straightforward. This kind of thinking leads to decision making based on personal opinions. Figures 5.12, 5.13 and 5.14 presenting subsidiaries' inventory turnover suggest that current decision making could be improved. Most of the subsidiaries found data gathering for the questionnaire laborious because data was not easily accessible. It had to be collected from several sources. This is a common pitfall of inventory management (see chapter 2.2.1 Typical Problems, pitfall 3). Some subsidiaries were not able to provide all required data, which further suggests there is room for more systematic operations and standardization of data gathering.

First-in-first-out priority is strived to maintain throughout the corporate group. The system is very vulnerable if warehouse layout and information system do not support this, as it is the case in most of the subsidiaries. Mostly, a couple of experienced warehouse workers maintain the first-in-first-out order and know by experience how items are arranged. The likelihood of errors increases if experienced employees have to be replaced. Items should be kept in one standard place in the warehouse because displacing goods can easily confuse the first-in-first-out system. Flow racks can be used to ensure the order. In addition, items should be reserved by their lot numbers for those indicate the date of production.

6. CONCLUSIONS

6.1. Vicious cycle of accumulating inventories

High inventories that turn slowly are an outcome of a vicious cycle. First of all, Biohit Oyj has had problems delivering certain products timely and informing about changes in delivery times. This was noted for example in Biohit SAS (see chapter 5.3.1), Biohit Ltd. (see chapter 5.3.4) and Biohit Japan Co., Ltd. (see chapter 5.3.6). The subsidiaries' solution to long and unreliable delivery times is to hold more buffer stock. Low inventory turnover figures (see chapters 5.2.4 Controlling logistics and 5.4 Spare parts) suggest items spend considerable time in the subsidiaries' stock. In-depth study of the subsidiaries in chapter 5.3 reveals that the subsidiaries' orders are based on forecasts and opinions. The subsidiaries have reacted on unreliable delivery times by ordering bigger batches. The tendency of ordering in batches is shown in the figures of demand amplification mapping presented for each one of the subsidiaries (see chapter 5.3 In-depth study of the subsidiaries). Several big orders have further decreased the production's ability to meet requirements on time. This vicious cycle is presented in figure 6.1. The theoretical approach, Houlihan effect, is discussed in chapter 2.2.2.1. The subsidiaries do not easily forget delivery problems of the past, and breaking the cycle is a challenging task.

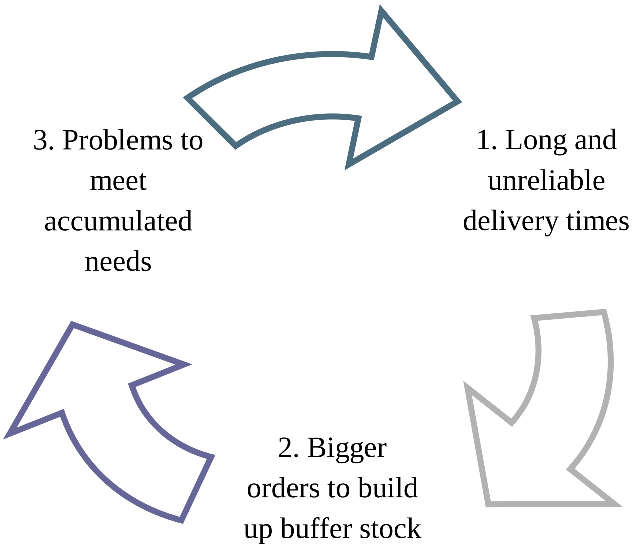

Figure 6.1. *Vicious cycle of unreliable delivery times and high inventories.*

In order to reduce their inventories and order batch sizes the subsidiaries need support from Biohit Oyj. Therefore the measures of the parent company greatly affect the success of the actions in the subsidiaries. The following requirements came up during the process of data gathering.

1. In order to maintain lower inventory levels in the subsidiaries, delivery times from Biohit Oyj have to be shorter, more accurate and more foreseeable.

2. In order to develop logistic operations in the subsidiaries, communication between Biohit Oyj and the subsidiaries have to be more efficient.

6.2. Systematic communication

The importance of sharing data in a supply chain was discussed in chapter 2.2.2 Bullwhip effect. It was noted that coordinating information and planning in co-operation are means to control the bullwhip effect. Besides reducing uncertainty, standardized way of communicating could reduce e-mail and telephone traffic. Ricketts (2009a) presented a practical proposal of sharing lead time information once per week. The idea is that Biohit Oyj would inform the subsidiaries about the expected production lead times in a weekly bulletin. Hence, the subsidiaries could anticipate the delivery dates and inform their customers. This is an application of information sharing system to reduce anticipation of shortages and exaggeration of needs discussed in chapter 2.2.2.1 Houlihan effect.

In order to be efficient, information sharing has to be two-way: besides the subsidiaries need information about lead times, Biohit Oyj needs to know about fluctuation in final customers' demand. As discussed in chapter 2.2.2 Bullwhip effect, promotion campaigns such as price discounts alter normal buying patterns. Therefore, the subsidiaries have to communicate potential major promotion campaigns ahead of time to the parent company. Hence, the production can act proactively, which in turn counteracts the vicious cycle.

It was mentioned in several contexts throughout the data gathering process of this study that a common ERP system could improve overall information sharing (Questionnaire Study 2009). Implementing a corporate wide information system is a time-consuming and complex project so further information about opportunities, costs, and risks should be gathered and analyzed. Idea is worth of considering, and could be useful in the future.

6.3. Systematic inventory management

To break the vicious cycle, common practices for the subsidiaries are called for. All companies within the corporate group have to commit to follow same rules of inventory management. If one company starts building up extensive buffer stock it can affect production lead times, which again disrupts delivery reliability. This can trigger the cycle. Required actions are presented in the following sub-chapters.

6.3.1. Kanban

Kanban, discussed in chapter 3.4, is a means to control the level of inventory and inventory turnover rate. It is relatively easy to implement since no sophisticated computer system is required, and no additional resources are needed to maintain it. This is important because all Biohit subsidiaries are small companies. Forecasting is no longer needed when orders are triggered by kanbans. In literature (see chapter 2.2.2 Bullwhip effect) as well as in Biohit subsidiaries (see chapter 5.3 In-depth survey of the subsidiaries) forecasting was identified to be one major source of demand fluctuation. Hence, intensity of the bullwhip effect can be reduced with help of kanban system.

In practice this implies that kanban system is to be implemented in the subsidiaries' warehouses. Maximum inventory level is set by kanbans that also serve as triggers for ordering. Orders are placed in multiples of kanbans, and only an empty kanban can trigger an order. Therefore, the subsidiaries' warehouses serve as supermarkets (see chapter 3.3.1 Using supermarkets to level the volume of work). A supermarket helps to pace the demand of the subsidiaries so that it better matches with the demand of their local customers. The idea is to shorten and level the flow of products from Biohit Oyj to end customers, or in other words, to reduce the waste of excess inventory and to reduce unevenness of workload. Ideal lean flow was discussed in chapter 3.2 Flow.

Setting up kanban system and better reacting to changes in demand regarding mix and volume of items can be nontrivial. Therefore, it is important that sufficient support is provided to the subsidiaries by the parent company. Even though there is a risk of miscalculating adequate kanban sizes or number of kanbans, the system brings along benefits such as systematic monitoring of inventories and uniform logic throughout the corporate group. It is essential not to set initially too low stock levels because stock-out problems can create distrust in the new system.

6.3.2. Inventory turnover

Most of the subsidiaries do not currently calculate inventory turnover for individual items or for product groups. Local logistic personnel usually have a general idea about which items sell well and which tend to stay in a warehouse for a long time. Therefore, calculations for sufficient stock levels are mainly based on experience and previous sales figures. Usually this means that there is a decent buffer stock for well-selling items and small or almost non-existent buffer stock for low-selling items. Although this might be sufficient arrangement at the moment, there are several risks related to such system relying on opinions and implicit information. Risks and drivers for improvement are listed below.

- The past sales figures do not necessarily reflect the prevailing situation.
- The system relies on one person’s experience, and information is lost if that person leaves the organization.
- There is no sales data about new products.
- Assumption about well-selling and low-selling items might be incorrect or subjective.
- Inventory turnover rates presented in chapters 5.2 The subsidiaries’ end in the logistic chain (see figures 5.12, 5.13 and 5.14) and 5.4 Spare parts (see figure 5.22.) suggest that the current arrangement could be improved.

Monthly-updated figures of inventory turnover would provide more exact and explicit information. Currently the subsidiaries relay on Biohit Oyj to provide the inventory turnover figures. Calculating the figures on the spot would give the subsidiaries more control over their own operations and involve them in the corporate-wide effort of improving inventory performance. Monitoring inventory performance using rolling turnover rate (see chapter 2.2.3 Inventory turnover) is found reasonable in Biohit Biotech Co., Ltd and should be implemented in the other subsidiaries as well.

Since inventory turnover combines sales with stock data, one numerical figure can be used to show sales and inventory performance of any individual item. In order to such calculation to be useful there has to be a standard procedure to update figures and react to changes, as in Biohit Biotech Co., Ltd. Figure 6.2 presents the authors’ own idea how inventory turnover can be used to control stock.

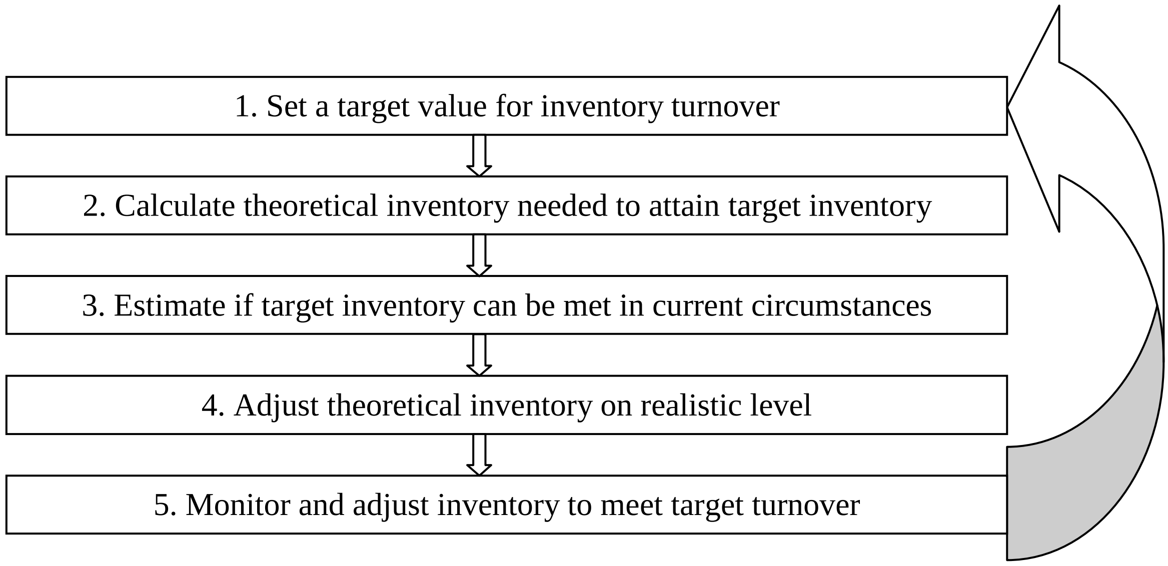

Figure 6.2. *How to use inventory turnover to manage stock.*

In case of Biohit the procedure illustrated above has to be carried out for all products. *The first step*, setting target values for inventory turnover, can be realized for categories of stock items. This has been already tested and approved in Biohit Biotech Co., Ltd. Hence, data about suitable target inventory turnover values exists, and it can be applied in the other subsidiaries. *The second step* is to be carried out for individual products within all the categories. The issue of how much of inventory to hold when implementing kanban system (see chapter 3.4 Kanban) signifies of calculating the size and amount of kanbans. Sudden increase in sales can be compensated with help of temporary kanbans introduced in chapter 3.4 Kanban. In *the third step* the feasibility of previously calculated inventory level is evaluated. It must be noted that Biohit tips have to be available immediately when a customer places an order. Otherwise customer orders from competitors. Meanwhile, the need for pipettes is not usually that urgent and a customer is more willing to wait for the product. Also the length and uncertainty of delivery times have to be considered. Uncertainty increases the need of safety stock in *the step four* where theoretical inventory levels are fine-tuned to match the reality. The target is to increase delivery reliability in the future so that the inventory levels can be later reduced as a part of *the fifth step*. Inventory turnover is to be used as a trigger to increase or decrease the quantity of items kept in stock. The process is iterative and the idea is to periodically alter target values.

In short term, roughly within the next half year, kanban system can be implemented in the subsidiaries to control level of inventory. In long term applicability of vendor managed inventory should be considered since it can reduce the Houlihan effect. A shared ERP system is a prerequisite for vendor managed inventory. (see chapter 2.2.2.1 Houlihan effect.) In vendor managed inventory the responsibility is shifted from the subsidiaries to the parent company, which can cause resistance. Kanban system involves the subsidiaries in inventory management and retains the responsibility on site.

6.3.3. Standard order cycles

To even out the bullwhip effect, order cycles have to be spread out evenly throughout the week, as discussed in chapter 2.2.2 Bullwhip effect. Overlapping of big orders from the subsidiaries should be avoided because that can affect the parent company's overall delivery reliability (see chapter 5.1.1 Ordering patterns of the subsidiaries). In addition, steadily inputted demand and frequent deliveries generate benefits as discussed in chapter 3.1.2 Lean logistics. Hence, to standardize inventory management and logistics, fixed dates for ordering and dispatching have to be used. This implies *fixed-time and variable-quantity* pattern (see chapter 3.4 Kanban). The remaining source of uncertainty relates to quantity and mix of products to order. At the moment some of the subsidiaries are already operating this way but practice should be made explicit and introduced throughout the corporation.

A schedule for leveling order processing and dispatching in Biohit Oyj is prepared by the logistics department in Helsinki. It is presented in table 6.1. In the schedule *order* indicates the date when a subsidiary sends in an order, *booking* indicates the date when items are reserved, *delivery* is the date when items have to be packed ready for dispatching, and *exit Fin* means the date when a haulage contractor exports products. As indicated in table 6.1, the dispatching department has two working days to prepare a dispatch.

Table 6.1. *Schedule of order processing and dispatching.*

	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri
Biohit Inc.		order		booking				delivery		exit Fin		
Biohit Japan Co., Ltd.	order		booking		delivery	exit Fin						
Biohit Deutschland				order				booking		delivery		exit Fin
Biohit SAS					order				booking		delivery	exit Fin
Biohit Ltd.				order				booking		delivery		exit Fin
Biohit OOO		order		booking				delivery				exit Fin
Biohit Biotech Co., ltd.	order							booking		delivery		exit Fin

In addition to fixed time intervals, order batch sizes have to be more leveled. Leveled volume and timing support each others. This is why it is essential that the subsidiaries give up what is left of frame orders and substitute kanban system for the old system. Ideally no lead time has to be given when timing of orders is known and sizes do not substantially vary. The target is that all make-to-stock items can be dispatched with the next shipment after an order is placed. When exceptions happen standard way of communicating is to be used as discussed in chapter 6.2 Systematic communication.

6.3.4. Improving efficiency

Individual activities can be improved by eliminating several kind of waste in offices and warehouses of the subsidiaries (see chapter 3.1.1 Seven waste). Waste of unnecessary movements and excess transport occurs in many subsidiaries. In most of the cases this can be reduced by organizing warehouse better. 5S is a systematic tool that can be helpful (see chapter 3.7 5S). The basis for better warehouse layout and order is assigning fixed place for each type of item. This enables standardizing picking routes which is one form of standardization exploited successfully in Toyota (see chapter 3.1.2 Lean logistics). Giving shelves unambiguous addresses helps keeping a warehouse in order. Addresses should be visible on shelves and can be loaded into ERP system, too. In addition, most selling items should be located closest to a dispatching area as in Toyota (see chapter 3.1.2 Lean logistics).

Using bar code readers can quicken both reception of goods and dispatching. It also simplifies serial number tracing and reduces likelihood of human errors. This reduces the waste of defects (see chapter 3.1.1 Seven waste). Especially subsidiaries whose order and sales volumes are big could benefit from bar code readers. Disadvantages and obstacles are to be taken into consideration as well. Devices have to communicate with ERP system, and not all systems currently used within the corporate group necessarily support bar code readers. In addition, buying and integrating device and software requires investments. Suitability of the idea has to be evaluated separately for each company.

Using a small number of standardized packages in the subsidiaries can make dispatching more efficient. Ideally the subsidiaries would use the same selling units as Biohit Oyj and standard-size packaging would be utilized if additional packing was required. The bigger the number of different kind of package, the more complicated the packing process. This also provides potential for costs savings. The benefits of standardizing containers' size were discussed in chapter 3.6 Standardization.

6.4. Time table

The research problem formulated in chapter 1.3 is *how should non value adding activities occurring in ordering, order processing, dispatching and reception of goods be eliminated or improved in order to make logistic value streams of Biohit more efficient*. A summary of solution to the research problem is illustrated in table 6.2.

Table 6.2. *The most significant proposals for action.*

Subsidiaries	**1.a**	Improving efficiency of the warehouse: 5S, intercompany training
	1.b	Improving efficiency of the warehouse: layout changes, fixing self addresses
	2.	Calculating target inventory turnover, establishing inventory levels for each product and creating kanban system
	3.	Launching kanban ordering in weekly cycles, fixed days for ordering
	4.	Starting monthly monitoring and reporting of inventory turnover
Biohit Oyj	**1.**	Standardizing communication with the subsidiaries
	2.	Stabilizing delivery times by improving production performance
	3.	Improving warehouse efficiency in the dispatching department

Objectives and benefits of lean logistics were discussed in chapter 3.1.2 Lean logistics. The above-listed actions of the subsidiaries strive for benefits discussed in literature such as reduced number of picking errors, better accuracy of inventory, higher productivity of logistic activities, saving in warehouse space and safer working environment.

A tentative time table for execution is presented in table 6.3. The detailed actions in the subsidiaries listed in the table 6.2 are left out for simplicity. They are to be carried out in the presented order indicated by numbering. The most problematic and the biggest subsidiaries are to be approach first. Biohit Biotech Co., Ltd. is left out since development projects have already been carried out in China resulting in superior performance within the corporate group. Final timing of actions has to be scheduled in co-operation with the subsidiaries. Actions in Biohit Oyj are to be carried out simultaneously with the actions in the subsidiaries.

Table 6.3. *Tentative time table.*

ID	Task Name	2009				2010					
		sept	oct	nov	dec	jan	feb	march	april	may	june
1	Biohit Japan Co., Ltd.	■	■								
2	Biohit OOO			■	■	■	■				
3	Biohit SAS					■	■	■			
4	Biohit Inc.						■	■	■		
5	Biohit Deutschland GmbH							■	■	■	
6	Biohit Ltd.								■	■	■
7	OYJ: Standardizing communication	■	■	■	■	■					
8	OYJ: Stabilizing delivery times	■	■	■	■	■	■	■	■	■	■
9	OYJ: Improving warehouse efficiency						■				

The supportive role of Biohit Oyj is apparent. The first step to prevent uncertainty is to establish standardized communication between Biohit Oyj and the subsidiaries. Secondly, the parent company has to improve production performance and delivery reliability in order to prevent the Houlihan effect (see chapter 2.2.2.1). Supply-orientated variability and uncertainty has to be reduced as much as possible. The content of development projects in production is outside the scope of this study. Changes in production dictate the phase of layout changes in the dispatching department.

6.5. Risks

No corporate-wide improvement programs have been implemented previously. There is a risk that the subsidiaries' management feels they are losing the independence and control over own business. This can cause resistance when introducing the new management policies in the subsidiaries. Hence, it is essential to empower local management and personnel. Reporting system has to be implemented to ensure that new policies are maintained in the subsidiaries.

Another risk is that the rules of kanban system are not followed, which can lead to stock-out situations and trigger the vicious cycle of accumulating inventories. This can happen if the staff in the subsidiaries does not trust kanban system to work. It is essential to give training and share information about kanban to prevent such situation. In addition, use of the new rules has to be obligated. No own application of the rules is allowed without confirmation from Biohit Oyj as occurred in case of frame orders.

6.6. Limitations of the results

The focus of the study is on Biohit liquid handling products excluding accessories such as pipette stands. This is the standpoint of production function because production of liquid handling items and other business area's items, diagnostic products, are managed separately. In addition, liquid handling products are dealt with differently depending on if they are make-to-stock Biohit items or make-to-order OEM and PL items. This standpoint brings about two limitations of the results.

1. Some data and analyses are not completely isolated from other product groups.

2. Some data and analyses are restricted due to limited focus.

The first limitation, leaving out OEM and PL items as well as diagnostic products, was somewhat problematic. The same logistics personnel in Biohit Oyj and the subsidiaries operate equally with all product groups, and focusing on only one part of the product mix was sometimes considered inconsistent. For example, many purchase and sales orders include products subject of the study as well as other products. Therefore, these cannot be always separated. So, some data and conclusions presented in this study cover logistics more extensively than intended. It is hard to evaluate how data and analyses would be different if total isolation of Biohit liquid handling products had been possible.

The second limitation poses reverse concerns. Some subsidiaries, such as Biohit Ltd., purchase and sell a plenty of non-Biohit products. Hence, some conclusions can be imperfect because certain data is artificially left out. Precise evaluating of the effects of limited data is difficult.

There are two other limitations of the results that are caused by the level of raw data and analysis of data.

3. The raw data collected from the subsidiaries is on aggregate level.

4. Causes of up- and downswings in the subsidiaries' order sizes are not classified.

The third limitation implies that only rough conclusions can be made based on aggregate data. The time frame of one year was divided into periods of months. Studying the data on weekly or daily basis would have provided more exact results. Respectively, studying stock keeping units instead of product categories would surely have deepened the analysis. If similar study is to be carried out, it is highly recommendable to use more detailed level of data.

The fourth limitation of the results implies that the bullwhip effect is not profoundly analyzed in this study. All up- and downswings in the subsidiaries' orders against their sales are called the bullwhip effect. Since the definition of the phenomenon provided in chapter 2.2.2 is somewhat extensive, seasonal variations or other potential explanations of up- and downswings are not extracted from the data when talking about the bullwhip effect.

6.7. Need for further research

Need for further research is derived from both theory and empirical findings. Two especially interesting issues emerged during the theoretical phase of the study and one when carrying out the empirical phase. The two concepts discussed in literature or previous studies whose applicability in Biohit could be studied are the following:

- *Leagility* that implies combining paradigm of agility with lean thinking. Agility deals with same issues as lean thinking but the perspective is different. Idea of agility is to build a robust and flexible organization when demand fluctuates (Naylor et al. 1999). Hence, it addresses the problem of variation that cannot be always eliminated or leveled.

- *Vendor managed inventory* and its applicability in Biohit should be studied in more detail since it can be an effective means when improving logistics in the long run. It would free the sales-oriented Biohit subsidiaries from the logistic issues. In the current circumstances several ERP systems are in use within the corporate group, and so vendor managed inventory is not a realistic option at the moment.

Observations made during the empirical study of the thesis generated another field of further study:

- *The significance of Biohit's external customers in reducing the bullwhip effect*. It ought to be studied if certain distributors' ordering patterns are erratic. Problematic external customers should be identified and difficulties addressed to further improve operations of Biohit.

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APPENDIX 1: OPEN-ENDED QUESTIONS

The question categories 1 to 4 are about Biohit liquid handling products and related spare parts ordered from Biohit Finland.

1. Ordering and receiving process

1.1 How is a purchase order triggered, in other words, how do you know when you have to place an order? Describe all possible methods*. E.g. orders are triggered when inventory level reaches a certain point, orders are based on forecasts, orders are based on requests from your customers etc.*

1.2 How do you place a purchase order? Describe the process step by step starting from the moment you notice the need for an order till the moment your order is confirmed. Describe all possible scenarios if there are several possibilities. *E.g. (1) a material handler notices we are running out of product X, (2) the material handler calls the logistics department and defines the amount needed, (3) a logistic assistant looks for the exact product information stored in an information system, (4) the logistic assistant sends a purchase order by e-mail with all necessary product information etc.*

1.3 Describe the process of receiving products step by step starting from the moment you receive an order confirmation till the moment you document the ordered batch received and paid. Describe all possible scenarios if there are several possibilities.

1.4 Describe any set-ups occurring. *E.g. in production environment a set-up consists of all actions needed to prepare a machine for a new batch. Respectively, in office environment a set-up means preparatory actions that enable processing a new order or a batch of orders, for example opening the transactions needed in the information system and finding related customer base data. Also interruptions of work can cause set-ups because the worker might have to take extra actions to discontinue and continue the work in progress.*

1.5 Are received products re-packed? Why? Explain how this happens.

1.6 How many people perform each step described in the questions 1.2 and 1.3 and what percentage of their time is used for each step? *E.g. there is one material handler who uses 10% of his time checking that ordered goods are correct.*

1.7 Do you have an explicit process description, such as a flow chart or a written description, for ordering and receiving process? Do all employees involved in the process know where to find it? You can attach it to your reply e-mail.

1.8 What size of batches is handled at each step described in the questions 1.2 and 1.3? If there is variation estimate the range of batch sizes. Batches can be made of physical goods or information. *E.g. Sending reports in batches of 5 - 10*

1.9 Is there a standard ordering batch size? Is there a method for batch size calculation?

1.10 Why do order batch sizes vary?

2. Allocation of time – if possible you may use stopwatch

2.1 In reference to the steps described in the questions 1.2 and 1.3, how much time does each step require? If there is variation, estimate the shortest and longest possibilities. When added up we get so called process time.

2.2 When and how much is there waiting or “inventory of information”? In other words, when the ordering process does not advance? What are sizes of these inventories in days? *E.g. a logistic assistant does not send an order right away but she waits until the end of a week for more requests from a material handler. This means orders wait 0 - 5 days.* When added up we get so called delay time.

2.3 Estimate the set-up times described in the question 1.4.

2.4 How long is the lead time for an ordering - receiving process in total? In other words, how long does it take from the moment you notice the need for an order till the moment your order is received? If there is variation, estimate the shortest and longest possibilities. If indicated correctly, this should be equal to the sum of total process time, total delay time and set-up times of the questions 2.1, 2.2 and 2.3.

2.5 In your opinion, which of the steps described in the questions 1.2 and 1.3 add the process value, in other words, which steps directly contribute to getting the product? *E.g. placing an order adds value while searching for missing information, getting approvals from others or re-entering data do not add value.*

2.6 In your opinion, which steps are non-value adding, in other words, they just make the process longer and more complicated, consume resources and add extra costs? *E.g. excess transportation: placing received products on receiving area and later moving them to storage. Why not avoid double-handling and place them directly to their right storage location!*

2.7 What is the effective daily working time in your company? *E.g. working time is 8 hours minus 45 minutes of breaks.* If individual process steps operate with different effective working time it should be stated, too.

2.8 How many days per year does your company operate?

3. Information needs

3.1 What information is needed in each step of the process described in the questions 1.2 and 1.3?

3.2 How is this information acquired and from where? How long does it take to get the required information? *E.g. a logistic assistant sends an e-mail to the logistics department in Helsinki and a reply arrives within 24 hours.*

4. Quality

4.1 For each step described in the questions 1.2 and 1.3, how often is output of pervious step complete and accurate from the perspective of the recipient? Give your answer in percentage (%). Output might be information or physical goods. *E.g. a logistic assistant placing purchase orders gets complete and accurate information 90 % of time right away without having to ask for specifications or corrections. 10 % of time she has to do re-work or ask for specifications before placing an order.*

4.2 During the last year (July 2008 - June 2009), how many products were returned back to the parent company? Why? *E.g. because the products didn't sell, they were not the products you ordered or they were faulty.*

4.3 During the last year (July 2008 - June 2009), how many times your order was delayed, in other words, delivery time was longer than promised?

4.4 Have you faced some other problems when ordering and receiving from Biohit Finland? Describe when and how they occur. What has been done to solve these problems?

4.5 Are any meters / indicators calculated to evaluate the process performance? What are those and how often are they updated? Are they used to control the process? How?

The question categories 5 to 8 are about Biohit liquid handling products and related spare parts shipped from your company to your customers.

5. Order processing and shipping to end customers.

5.1 Describe the complete process of receiving orders and shipping products to your customers step by step starting from the moment you receive a customer's order till the moment you send an invoice and other final documents.

5.2 Is the shipping process same for LH products and spare parts?

5.3 Describe any set-ups occurring. *E.g. in production environment a set-up consists of all actions needed to prepare a machine for a new batch. Respectively, in office environment a set-up means preparatory actions that enable processing a new order or a batch of orders, for example opening the transactions needed in the information system and finding related customer base data. Also interruptions of work can cause set-ups because the worker might have to take extra actions to discontinue and continue the work in progress.*

5.4 How many people perform each step described in the question 5.1 and what percentage of their time is used for each step? *E.g. there is one material handler who uses 40% of his time picking parts.*

5.5 What size of batches is handled at each step described in the question 5.1? If there is variation estimate the range of batch sizes. Batches can be made of physical goods or information. *E.g. sending reports in batches of 5 - 10.*

5.6 Is there a standard shipping batch size? Is there a method for batch size calculation?

5.7 If shipping batch sizes vary, why is there such variation?

5.8 How many customers did you have during the last 12 months? Which portion (%) of them order weekly? Which portion (%) of them order monthly?

5.9 Do you have an explicit process description, such as a flow chart or a written description, for the shipping process? Do all employees involved in the shipping process know where to find it? You can attach it to your reply e-mail.

5.10 In which order are customers' orders handled at each stage described in the question 5.1? Are priority rules such as first-in-first-out used? *First-in-first-out means the oldest products are processed before the newer ones*

6. Allocation of time - if possible you may use stopwatch

6.1 In reference to the steps described in the question 5.1, how much time does each step require? If there is variation, estimate the shortest and longest possibilities. When added up we get so called process time.

6.2 When and how much is there waiting or “inventory of information”? In other words, when the shipping process does not advance? What are sizes of these inventories in days? *E.g. a logistic assistant does not process a sales order request right away but waits until the end of the week for more orders from the sales department. This means the orders wait 0 - 5 days.* When added up we get so called delay time.

6.3 Estimate the set-up times described in the question 5.3.

6.4 How long is the lead time for the shipping process in total? In other words, how long does it take from the moment an order is received till the moment the order is shipped? If there is variation, estimate the shortest and longest possibilities. If indicated correctly, this should be equal to the sum of total process time, total delay time and set-up times of the questions 6.1, 6.2 and 6.3.

6.5 In your opinion, which of the steps described in the question 5.1 add the process value, in other words, which steps directly contribute to shipping a product? *E.g. picking adds value while searching for missing information, getting approvals from others or re-entering data do not add value.*

6.6 In your opinion, which steps are non-value adding, in other words, they just make the process longer and more complicated and could be rationalized? *E.g. excess transportation and double-handling.*

7. Information needs

7.1 What information is needed in each step of the process described in the question 5.1?

7.2 How is this information acquired and from where? How long does it take to get the required information?

8. Quality

8.1 For each step described in the question 5.1, how often is output of pervious step complete and accurate from the perspective of the recipient? Give your answer in percentage (%). Output might be information or physical goods. *E.g. a logistic assistant handling sales order gets complete and accurate information from a sales department 90 % of time right away without having to ask for specifications or corrections. 10 % of time she has to do re-work or ask for specifications.*

8.2 Has your delivery reliability been calculated? What has been done to improve it? How often is this figure updated?

8.3 During the last year (July 2008 - June 2009), how many times your shipment to your customers was delayed, in other words, delivery time was longer than promised? Why?

8.4 How often do you experience a stock-out, in other words, you do not have a required product in stock?

8.5 Have you faced some other problems when shipping? Describe when and how they occur. What has been done to solve these problems?

8.6 Are any meters / indicators calculated to evaluate the process performance? What are those and how often are they updated? Are they used to control the process? How?

9. Inventory

9.1 How do you control your physical inventory? How do you know how much of each item you have in stock? Do you know the exact location of each product?

9.2 Are you using ABC -categorization for the items kept in stock? Describe how you control different categories of items.

9.3 Do you know inventory turnover for the products you hold in stock? Is it calculated separately for each product, each group of products or aggregate inventory? How often is this information updated?

9.4 Is inventory turnover used as a control parameter for inventory management?

9.5 How do you assign products to customers' orders? Do you know which product number is assigned to which customer? Do you use rules such as first-in-first-out meaning that the oldest products are delivered before the newer ones?

9.6 How much safety stock do you hold? Define your answer separately for mechanical pipettes, electronic pipettes, pipette tips and spare parts in number of pieces.

9.7 How much is your safety stock worth in days? In other words, for how long could you satisfy your customers' demand with the safety stock?

9.8 How much is your average stock worth in days? In other words, for how long could you satisfy your customers' demand with your average inventory? Define your answer separately for mechanical pipettes, electronic pipettes, pipette tips and spare parts.

9.9 Are items kept in one location all the time after they arrive from Finland till they are shipped to final customers? Explain why items have to be moved. *E.g. newer items are moved closer to a shipping area as older items are shipped because there is not enough room next to a shipping area for all products.*

9.10 Do you think it would be possible to reduce your inventory? Why / why not? How much do you think it could be realistic to reduce your inventory?

10. Your opinions

10.1 What do you think it would require operating in level weekly cycles? Would it help your operations? *Weekly cycles mean that orders are placed once per week and delivery happens always once per week. Level weekly cycles mean that batch sizes are approximately same size week in week out.*

10.2 What do you think it would require basing your purchase orders on your customers confirmed demand, not forecasted demand? *This means you would **pull** products from the parent company at the same speed as your customers **pull** products from you. If you are already operating based on customer demand please explain how it is working.*

10.3 Do you think visual pull system (kanban) would support and simplify your inventory control and ordering? *Basically this means products are stored in certain size containers. There is a card (kanban) containing information about the product, its storage location and the container size attached to each container. An empty container is the signal to re-order. The card is detached from an empty container and a new purchase order is placed based on the card's information about the type of product and the batch size. New products arrive in containers and a card is attached to each full container. There are a predefined number of containers in the system and all stored products are inside containers. This way the inventory level has a visual maximum limit and orders are based on the real consumption rate. The number and size of the containers depend on the lead time and demand rate.*

10.4 Could order processing be simplified and standardized? How?

10.5 How could incomplete and inaccurate output of ordering and receiving process identified in the question 4.1 be improved?

10.6 Could the shipping process be simplified and standardized? How?

10.7 How could incomplete and inaccurate output of shipping process identified in the question 8.1 be improved?

10.8 What would be the effect if batch sizes were reduced? Remember that a batch can refer to material as well as to information.

APPENDIX 2: TEMPLATE OF NUMERICAL DATA

YOUR CUSTOMERS' MONTHLY DEMAND: NUMBER OF LINE ITEMS - How many items did your customers order
NOTE: units should be number of pieces (not monetary values)

	2008						2009						TOTAL
	july	august	sept	oct	nov	dec	jan	feb	march	april	may	june	
1. mechanical pipettes													
delivered timely from your stock													
customer demand that could not be satified on time													0
2. electronic pipettes													
delivered timely from your stock													
customer demand that could not be satified on time													0
3. pipette tips													
delivered timely from your stock													
customer demand that could not be satified on time													0
4. spare parts													
delivered timely from your stock													
customer demand that could not be satified on time													0
TOTAL	0	0	0	0	0	0	0	0	0	0	0	0	0

YOUR CUSTOMERS' MONTHLY DEMAND: NUMBER OF ORDERS - How many times did your customers order
NOTE: units should be number of pieces (not monetary values)

	2008						2009						
	july	august	sept	oct	nov	dec	jan	feb	march	april	may	june	TOTAL
number of purchase orders per month													0

MONTHLY PURCHASE ORDER LINE ITEMS FROM BIOHIT FINLAND - How many items did you order
NOTE: units should be number of pieces (not monetary values)

	2008						2009						
	july	august	sept	oct	nov	dec	jan	feb	march	april	may	june	TOTAL
1. mechanical pipettes													0
2. electronic pipettes													0
3. pipette tips													0
4. spare parts													0
TOTAL	0	0	0	0	0	0	0	0	0	0	0	0	0

MONTHLY PURCHASE ORDERS FROM BIOHIT FINLAND - How many times did you order
NOTE: units should be number of pieces (not monetary values)

	2008						2009						
	july	august	sept	oct	nov	dec	jan	feb	march	april	may	june	TOTAL
number of purchase orders per month													0

INVENTORY VALUES IN THE END OF EACH MONTH
NOTE: units should be number of pieces (not monetary values)

	2008						2009						
	july	august	sept	oct	nov	dec	jan	feb	march	april	may	june	TOTAL
1. mechanical pipettes													0
2. electronic pipettes													0
3. pipette tips													0
4. spare parts													0
TOTAL	0	0	0	0	0	0	0	0	0	0	0	0	0

APPENDIX 3: VSM OF BIOHIT OYJ

APPENDIX 4: VSM OF BIOHIT OYJ WITH KAIZEN