Aalto University
School of Business

A Framework for Evaluating Inventory Management in Healthcare Case: HUS Logistics

Logistics

Master's thesis

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Department of Information and Service Economy
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Master's Thesis
Severi Saraste
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AALTO UNIVERSITY SCHOOL OF BUSINESS ABSTRACT

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ABSTRACT

Objectives of the Study

This thesis assembles a new framework for evaluating the relative monetary impact of one inventory management process when compared to another. The purpose is to compare the inventory management processes in a holistic way, evaluating them from three different perspectives. These are defined in this study as (1) process quality, (2) process efficacy and the (3) strength of inventory control.

This framework was then applied, and used to assess the merits of a logistical service performed by HUS Logistics, *Täyttöpalvelu*, translated here as Replenishment Service (RS), comparing the inventory management process it forms with the inventory management process that exists in hospital units that have not adopted the service, referred to here as NRS.

Academic background and methodology

The framework is founded on ideas borrowed from several strands of literature, including logistics, inventory management, process quality, and process management literature. The hypotheses on the possible benefits of RS that guide this study are based on supply chain integration literature, and models such as Third-Party Logistics and Vendor-Managed Inventory. The framework is applied to the case study of HUS's RS and NRS by subjecting each of the elements of the framework to a mostly quantitative analysis that is based on data acquired from HUS Logistics inventory management systems, as well as observations and process times collected at two HUS hospital sites.

Findings and conclusions

The findings of the study relate to the usefulness of the new framework in comparing inventory management processes. It is deemed a useful tool, and the effectiveness of using a novel method for analyzing inventory efficiency is assessed. With regards to the case study, the thesis concludes that RS is a superior process. Out of the three perspectives considered, the results were fairly clear for two, and ambiguous for one. The study calls for the choice of subscription to RS to concentrate more on system-level benefits, which are even more significant than unit-level ones.

Keywords

Inventory management, Process Quality, Process management, Healthcare logistics

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TIIVISTELMÄ

Tutkimuksen tavoitteet

Tutkimus rakentaa uuden teoreettisen kehyksen varastohallinnan arvioimiseen. Teoreettisen kehyksen perusteella prosessien *hyvyyttä* arvioitiin kolmesta eri näkökulmasta. Tutkimuksessa nämä kantavat nimiä *process quality* (prosessin laatu), *process efficacy* (prosessin tehokkuus) ja *inventory control strength* (varastohallinnan lujuus).

Teoreettista kehystä sovelletaan HUS Logistiikan Täyttöpalvelun (*Replenishment Service, RS*) ansioiden arviointiin, vertaamalla palvelun luomaa varastonhallintaprosessia siihen prosessiin, joka toteuttaa varastonhallintaa niissä yksiköissä, joissa täyttöpalvelua ei olla otettu käyttöön (tunnetaan tekstissä nimellä NRS).

Kirjallisuuskatsaus ja metodologia

Teoreettinen kehys perustuu kirjallisuuskatsauksessa läpikäytyihin prosessi- ja logistiikkakirjallisuuden suuntauksiin, jotka käsittelevät varastonhallintaa, prosessilaatua ja prosessinhallintaa. Hypoteesit Täyttöpalvelun tuomista hyödyistä perustuvat niin ikään esimerkiksi toimitusketjun integraatiota käsittelevään kirjallisuuteen.

Rakennettua kehystä sovellettiin case-tutkimukseen. Kehyksen esille nostamat näkökulmat arvioitiin hyödyntämällä HUS Logistiikan järjestelmistä hankittua dataa sekä tutkimusta varten Meilahden ja Jorvin sairaaloissa kerättyjä prosessimittauksia ja havaintoja.

Tulokset ja päätelmät

Tutkimuksen päätelmät liittyvät uuden teoriakehyksen. Tutkimuksen perusteella Täyttöpalvelun (RS) edustama varastonhallintaprosessi on perinteistä prosessia (NRS) parempi. Tutkimuksen kolmesta näkökulmasta tulokset olivat kahden osalta selkeät; viimeisen osalta yksiselitteisiä johtopäätöksiä ei voi tutkimuksen perusteella tehdä. Tutkimus kehottaa päättävien tahojen keskittyvän Täyttöpalvelun tuomiin hyötyihin organisaatiotasolla, sillä nämä ovat vielä merkittävämmät kuin palvelun hyödyt yksittäisen hoitoyksikön tasolla.

Avainsanat

Varastonhallinta, prosessilaatu, prosessijohtaminen, terveydenhuollon logistiikka

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Helsinki, December 4, 2013

Severi Saraste

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Key Abbreviations and Concepts

HUS: *Helsingin ja Uudenmaan sairaanhoitopiiri,* the Hospital District of Helsinki and Uusimaa.

Order: a list of SKUs and associated quantities requested by the ordering unit.

Order row: a request for an SKU that forms part of an order.

NRS: Non-replenishment service. NRS is used as shorthand to refer to the process that is being replaced by RS, which is a less inclusive service where the unit perseveres much of the responsibility for inventory management.

RS: Replenishment Service (*täyttöpalvelu*). Initials used in this thesis as shorthand to refer to the service being studied.

RS operator: a member of the HUS Logistics staff that specializes in performing the RS process

Process Efficacy: the ability to minimize labor resources in performing the process.

Process Quality: the ability to minimize errors in the process.

Inventory Control Strength: the ability to simultaneously maximize availability of inventory and minimize holding costs. In other works, the ability to keep stock levels between optimal minima and maxima.

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1. INTRODUCTION

Materials management with a specific focus on healthcare has been studied extensively. The interest in healthcare supply chains is likely the result of two factors: complexity and potential. Healthcare supply chains stand out because of the particularly high service levels that they need to adhere to (Beier, 1995). In addition, materials management represents a significant proportion of total healthcare costs, and has a great deal of unmet potential in terms of cost savings.

As an industry, healthcare has traditionally seen itself as being governed by principles that are different to those of business more generally (Jarrett, 1998). As healthcare has gradually become a more privatized and contested sector, opportunities for efficiency have been identified and indeed forced upon the industry. At the same time as it grapples with downward pressure even on the revenue side, the industry is facing upward pressure on the cost side (Wilson, Cunningham, & Westbrook, 1992). Depending on the country and healthcare system, cost pressures may be coming from factors including wages of certain types of staff, medical equipment, supplies and medicines.

Advances in medical procedures have meant that the required medical supplies have also become more specialized. In 1974 an average 200-bed facility's medical storeroom had 600 unique supply items, by 1995 it contained 1400 (Born & Marino, 1995). This development increases the complexity of the entire supply chain, and puts upward pressure on required inventory levels: having more individual items tends to increase aggregate safety stocks.

In this context, supply chain management systems have been seen as fertile ground for cost reductions (A. Kumar, Ozdamar, & Zhang, 2008; Wagner, 1990). Estimates for the cost of logistics related activities generally range from around 30-40% of overall healthcare costs (Born & Marino, 1995; Huarng, 1998; Nachtmann & Pohl, 2009; Nathan & Trinkaus, 1996), second only to labor expenses as a priority for healthcare cost containment (Nachtmann & Pohl, 2009). Importantly, supply chain management in the healthcare context is not simply a financial issue; its reliability and speed also has a direct effect on clinical outcomes (Iannone, Lambiase, Miranda, Riemma, & Sarno, 2013).

One of the most interesting macro-level trends in logistics (both applied and theoretical) is supply chain integration (also, logistical integration) (see e.g. Bask, 2001; Fabbe-Costes, Jahre, & Roussat, 2008; Min & Mentzer, 2004). This integration takes many forms, from increasing information flows between different actors in the supply chain to the transfer of process ownership. Increased integration is also assumed to ameliorate inventory management systems.

Literature on the benefits of logistics integration was used as one of the starting points for identifying possible benefits associated with a more integrated inventory process. But what does this actually mean? Although the effectiveness of inventory management has been studied from a number of perspectives, the logistics literature has paid relatively little attention to overall performance measurement (Gunasekaran, Patel, & McGaughey, 2004); the literature does not contain a framework evaluating inventory management systems in a comprehensive way.

This thesis assembles a new framework for comparing the relative monetary impact of one inventory management process when compared to another. The purpose is to compare the inventory management processes in a holistic way, evaluating them from three different perspectives. These are defined in this study as (1) **process quality**, (2) **process efficacy** and the (3) **strength of inventory control**. The framework is primarily relevant to inventory management in healthcare, but can be transferred to other industries, given certain changes (e.g. required service levels, implications of shortages).

In order to test the framework, it is then applied to a case study that compares two parallel inventory management processes that are currently operated by HUS Logistics. The study uses the framework to guide the type of questions and perspectives that need to be taken into account when comparing the processes. The specific methodology used in applying the framework is dependent on the type of data that is most readily available in the setting at hand. Nonetheless, the methodology that is applied represents one way of addressing the issues laid out in the framework. These methodologies are quantitative, but will be complemented with observational findings of the processes themselves. One of the key aims, and challenges, of this thesis is to offer a framework for inventory management evaluation that is sufficiently inclusive, data-driven and easily measurable.

HUS Logistics is owned by HUS, a large hospital district, which is also its primary client. In 2006, HUS Logistics introduced a new service that would significantly expand its service offering. It increased its role from taking care of the supply chain of medical supplies for all of HUS's hospital units to now offering to take nearly full control of the ordering and stock replenishment processes as well.

The response to the service, *täyttöpalvelu*, translated here as *replenishment service* (RS), has been very positive, but not all units have been convinced that the service is worth the 300 euro monthly fee that HUS Logistics charges. The service transfers nearly all logistics functions from the hospital unit to HUS Logistics. It seems at the moment to be difficult for some managers to quantify the hidden costs of performing some tasks "in-house", or to see some of the hidden benefits of the outsourced model. This framework will be used to evaluate the current merits and future potential of RS, relative to the process it has partially replaced (referred to here as the traditional process, NRS), and also with respect to its rapid expansion.

From the perspective of the case company, the importance of doing so is three-fold. First, as the service is offered to more and more hospital units, an objective case for the current and potential benefits of the service needs to be made. Second, as the service expands, HUS-Logistics should have a clearer understanding of how the eventual wider transition from NRS to RS will affect its resource needs, and those of HUS more generally. Third, the process' expansion provides a valuable opportunity for its improvement, and this study will shed light on where improvements are most readily available.

From an academic and a more general perspective, the framework that is constructed gives a visual representation of the key dynamics at play when assessing inventory management processes. It seeks to be sufficiently universal and straight-forward to encourage reapplication in other healthcare settings, and to inventory management systems in other industries with similar characteristics. In constructing the framework and applying it to the HUS Logistics case study, this study will seek to respond to the research questions, below. The secondary questions pertain to the case study.

Primary questions

What qualities need to be considered when evaluating inventory management processes healthcare context, and how should they be quantified? How should the dynamic interactions between these qualities be conceptualized? In what ways can integration in the inventory management process benefit the system?

Secondary questions

To what extent is the new process (RS) better than the old process (NRS)? What are the main reasons for possible differences? Is RS performing to its potential? Are there any ways to develop the current process in order to improve it further? What are the implications of RS's expansion?

The study will start with a literature review. This section will highlight the main bodies of academic literature that serve as the starting point for approaching the case and the associated research questions. The review is followed by an introduction to the case and how it should be viewed through the discussed literature. The literature will also lay the theoretical foundations for the framework that is constructed for the analysis. The methodology for each of these three components will be discussed separately. The framework also shows how these three elements fit.

Once this framework has been explained, the thesis will turn to tackling the actual case study. The first step will be to describe the data that will be used in executing the analysis. This will include a justification of the data's usability, and a description of how it was gathered. This section will also go through how the data was segmented and how a subset of the entire dataset(s) was demarcated.

If this were a cooking recipe, we have now become acquainted with the ingredients. What follows is the analysis itself. This analysis will address each of the three dimensions of the framework in turn, and explain the case-specific way in which the dimension is addressed. Each section will make explicit the underlying hypothesis that the section is concerned with, and seek to address it utilizing various components of the data. Most of the data is very raw, so this will mean first describing how the data was treated in order for it to help in conducting the analysis.

2. LITERATURE REVIEW

This literature review examines the strands of academic literature that form the foundation for the analysis that follows. This foundation will inform how the processes are understood, how they will be studied, and what hypotheses will be tested. First, the review gives some context to this case study, and to material management in healthcare more generally, by exploring academic literature that specifically examines logistics in the healthcare industry setting.

The literature review then focuses on how logistics is valued, how inventory is managed, and trends in logistical integration. It looks at different concepts that can be used to understand the roles of HUS Logistics and the RS process in the larger supply chain, such as third-party logistics and vendor-managed inventory. This literature also makes insightful assertions that guide the hypothesis of this study on the possible effects of inventory management reform.

Finally, process literature is visited in order to gain an understanding of how processes are modeled and tested more generally, tackling concepts that are important in evaluating the nature of the RS process. Literature on processes and process management informs the mapping, comparison, and measurement of the RS and NRS processes. Quality is also an important concept to this study. Table 1describes the connection of each section of the literature review to the rest of the study.

Table 1: Literature and this study

Sections	Link to study
Logistics in healthcare	Context of the study
Assessing logistics	What components form the value proposition of logistics?
Supply chain integration and redesign	Creating a hypothesis for the potential benefits of RS
Inventory control	Understanding RS as an inventory control system
Quality	Importance of process quality
Business processes	Modeling and assessing processes

2.1. Logistics in healthcare

The literature has identified several factors in healthcare logistics that hold the potential for significant efficiency gains. Inventory levels have been seen as one of the more interesting areas for improvement in healthcare materials management (Kumar Ordamar, Zhang, 2008). Academics have also given attention to replenishment processes in healthcare organizations. Processes have been in need of further standardization (Kilgore, Muller, 1996) and reform, suffering from too many handoffs and duplicated effort (ibid; Born, Marino, 1995). The assumption of significant gains from business process re-engineering in healthcare is supported by a characteristic of the industry: “operations are repetitive, have reasonably high volume and deal with tangible items such as mail, bills, soft goods and medical appliances” (Kumar Ordamar, Zhang, 2008, p. 98).

One general guiding principle in the literature has been a call for healthcare logistics to undergo the same mental shift as have its counterparts in other industries: from considering itself (and being considered by others) an obligatory secondary function toward acting like (and being thought of as) an important partner in meeting the operational and strategic objectives of the organization (e.g. Kilgore & Muller, 1996).

The industry has already come a long way, with flagships of efficiency showing the way for others, notably in the US and Japan. Several trends are for improving efficiency have gotten attention in both academic and industry literature, including stockless inventory and RFID.

Stockless inventory and Just In Time (JIT)

Stockless inventory is one of the long term, interesting trends in the healthcare industry, and one which HUS has also experimented with regarding certain types of supplies. Stockless systems shift some functions of inventory management up the supply chain, from the purchaser to the supplier (Wilson et al., 1992), the supplier essentially taking over the role of the hospitals own central store (Nathan & Trinkaus, 1996). Its conceptual “companion”, (Marino, 1998), JIT, refers to the frequency of delivery, which is responsive to orders and keeps required inventory at a minimum. In other words, JIT emphasizes the frequency or orders, when stockless, as a concept, emphasizes the point of delivery and the small quantity delivered at one time (ibid., p. 11). It is also possible to see stockless as an extension of JIT (Wagner, 1990)

The most obvious aim of stockless inventory systems is to decrease holding costs, but the method is also associated with other benefits, including reduced staff, vacated space that can be converted to other use, elimination of packing waste, and a higher (and even guaranteed) level of stock availability (Nathan & Trinkaus, 1996; Rivard-Royer, Landry, & Beaulieu, 2002). Some hospitals have embraced stockless inventory wholeheartedly, adopting the philosophy to virtually all aspects of inventory management. Cunningham and Westbrook (1992) report on three such cases, and characterize these applications of stockless as being examples of “unqualified success” (1992).

Still, not all practitioners and students of inventory managements are convinced about the actual merits of such systems. The literature warns of partnerships that have resulted in unexpected hidden costs, and increased shortages (Marino, 1998). Neither are all suppliers enthusiastic about the model, fearing that these systems are simply away of shifting holding costs onto suppliers, sometimes at the expense the efficiency of the whole supply chain (Rivard-Royer et al., 2002).

RFID

RFID is a system used for identifying and tracking objects, or even people (Hakim, Renouf, & Enderle, 2006). An RFID system is composed of tags, which are fixed onto the tracked object, and readers that are located in the area where the object is to be tracked. In addition to these components (i.e. the hardware), servers are needed to support the data flows, and software and middleware is needed to interpret the signals and transform them into relevant and valuable information (Yao, Chu, & Li, 2012).

The types of RFID systems are often classified into two categories, active and passive (e.g. S. Kumar, Livermont, & Mckewan, 2010). The distinction is important since active and passive systems are very different in functionality and in terms of costs. Passive RFID tags currently cost approximately 0.10 USD per tag, while active RFID tags cost anywhere from 5 to 50 USD (S. Kumar et al., 2010; Yao et al., 2012).

While the unit price of both tags is expected to continue to come down (S. Kumar et al., 2010), passive systems have been gained most of the interest in RFID of the healthcare industry. In terms of functionality, the range of the passive tags is limited, but they do not require a built-in power source (they receive their power from the reader), enabling them to be smaller (Hakim et al., 2006). The lack of an internal power source also eliminates the need for periodic maintenance of the tags (ibid. p. 217).

While the technology has been around since the Second World War, RFID adoption in healthcare has mostly occurred in the past decade: in August 2005, 25 percent of hospitals with over 300 hospital beds had invested in some sort of RFID based solution; by August 2008, this figure was 76 percent (S. Kumar et al., 2010). Yao et al identify 5 application areas for RFID in healthcare: tracking; identification and verification; sensing; intervention; and alerts and triggers (2012 p. 3512). In essence, RFID not only allows one to know where something is, it also helps identify the right medicine/equipment. If it is connected to a sensor, it can collect ("sense") important changes in the environment (e.g. changes in humidity) and then warn staff ("alerts"). RFID tags can also trigger the opening of doors or induce other automation that helps medical staff in performing their duties.

Thus far, the cost of the tags, as well as their handling,, have discouraged a full scale implementation of a RFID system that would track all healthcare inventory. Rather, RFID tracking has been implemented alongside existing, usually bar code-based, processes, and have focused on items that are expensive and/or prone to being stolen or misplaced (Glabman & Bruno, 2004; S. Kumar et al., 2010; Mehrjerdi, 2011; Yao et al., 2012). Still, the benefits have been estimated to be very significant (See e.g. Glabman & Bruno, 2004).

Tracking is actually much more powerful than just knowing where things are. As Kumar et al (2010) note, it is a misperception to think of RFID tags as simply "glorified bar codes". Bar codes rely heavily on the human operators of the process: the value of bar codes breaks down when someone does not scan the item, either intentionally or unintentionally. Since RFID tags do not require line-of-sight, or necessarily a specific action, in order to be identified. The difference between the functionality of bar codes and RFID tags becomes even more pronounced if the readers are numerous and well located, and if the range of the tags is significant. Active RFID is even more specifically geared towards tracking as opposed to mere identification of objects (Yao et al., 2012). The more the system enables tracking, i.e. an increased understanding of the movements of the objects that have been tagged, the more the system supports evaluation and improvement of the processes that are involved in executing these flows.

The most obvious advantage of traditional bar codes is their prevalence and cost. Bar codes are estimated to cost only 0.03 USD per unit (ibid. p. 3517), and are expected as standard on all inventory. If RFID become standard, and thus do not have to be attached separately by the end user, the equation deciding between RFID and bar codes will also change dramatically. Once questions concerning the reliability of RFID in hospital environments (ibid. p. 3519) are properly answered with improved technology, one should expect even greater enthusiasm for RFID implementation in healthcare.

2.2. Assessing logistics

The value proposition of logistics can be divided into two major components: **service quality** and **cost minimization** (Beamon, 1999; Bowersox, Closs, & Cooper, 2002, p. 23). Bowersox et al (2002) further divide the service component of this value into availability and operational performance. Availability consists of attributes of the service concerned with having inventory to meet customer requirement.

Operational performance refers to the strength and agility of the logistic chain. Bowersox et al (2002) list characteristics such as: speed and consistency of the supply chain, ability to accommodate unusual requests, probability of malfunction, and the ability to recover from malfunction. The aim of the logistical process is to achieve the above mentioned service in a cost efficient way. The costs that a supply chain faces can be divided into three main categories: carrying costs, replenishment costs and quality costs.

Carrying costs, also referred to as holding costs, are associated with keeping a product in inventory. The following cost is often listed as including the relevant holding costs. Bowersox et al also include standard ranges for these costs as a percentage of inventories:

- Capital costs: 4% - 40%

- Taxes on inventory: 0.5% - 2%
- Insurance costs 0% - 2%
- Obsolescence of inventory 0.5% - 2%
- Storage costs 0% - 4%

This creates a range for overall holding costs of 5% to 50%, for possible values. A non-industry specific rule-of-thumb that is sometimes cited is 25%, and textbooks on inventory management usually use values ranging from 20% to 30% (REM Associates). Carrying costs per unit are, on the whole rather fixed and difficult to decrease when holding the actual level of inventory constant. Some of these costs, such as insurance, tax and capital costs are correlated fairly linearly with inventory level, while storage costs (a component of which is defined in terms of the unit's share of total, fixed storage costs) are a marginally decreasing and costs of obsolescence marginally increasing with inventory level.

Replenishment costs, also referred to as order costs, are associated with the process of restocking. An individual order is associated with a number of variable costs that occur from the origination of the perceived need for new stock to its final shelving. These cost drivers include sub-processes such as order processing, tendering, transport, handling and shelving. Replenishment costs per order are subject to how efficient these processes are. A considerable share of replenishment costs are labor costs, and therefore these costs can be most dramatically affected by reducing the time, and the cost of the time, to fulfill the replenishment process.

It is important to note that because holding costs are correlated with the size of inventory, and replenishment costs are correlated with frequency of orders, they can be considered trade-offs with respect to each other.

2.3. Benefits of logistical redesign

The possible goals of supply chain integration include increasing responsiveness, reducing variance, lowering inventory levels, shipment consolidation, increasing process quality, increasing life-cycle support (Bowersox et al, 2002, p. 256). Two interesting theoretical prisms through which to see the RS process are Third-Party Logistics and Vendor-Managed Inventory.

Third-Party Logistics

The term third-party logistics, or TPL (also 3PL), refers to "the organizational practice of contracting-out part of or all logistics activities that were previously in-house" (Selviaridis & Spring, 2007). Most of TPL literature focuses on the services provided by large shipping companies that act between customers and suppliers, and focus on services such as transportation and the maintenance of external warehouses on behalf of customers (Selviaridis & Spring, 2007). Broader definitions include services such as packaging and postponement (Bask, 2001), and Berlund et al. (1999) defines of a TPL service as being, at a minimum, the management and execution of transportation, and warehousing.

Many benefits are attributed to TPL. Through specialization, logistics service providers (LSPs) are assumed to have more expertise in performing logistics function than their customers. On a system-level, TPL arrangements also allow for better utilization of capacity, (Selviaridis & Spring, 2007) since assets required for performing logistics functions, such as labor and equipment, are concentrated and used to service numerous customers with, possibly, irregular needs.

From the perspective of the customer, Daugherty (1996, in Selviaridis & Spring, 2007) reports benefits to include reductions in inventory levels, order cycle times and lead times, and improvements customers service. Outsourcing also helps to separate out logistics costs from the costs related to a company's *core* processes, helping to keep both types of cost explicit and thus measurable (Van Laarhoven, Berglund, & Peters, 2000). Many logistics-related costs have a tendency to easily remain hidden, and TPL relationships collects most of these (while certainly not all of them) into a single provider's fee, which can be put out to tender.

Bask (2001) divides TPL services into three types, characterized by their level of complexity and the depth of the relationship between the two parties. *Routine services* are simple arrangements where transportation and or warehousing is outsourced, and do not necessitate customization of the service that characterizes *standard* TPL arrangements. The most complex and close relationships are referred to by Bask (2001) as *customized TPL services*. This type of service usually necessitates high initial investments and a high level of customization (Bask, 2001, p. 476), which necessitate longer commitments and a very intimate relationship between parties.

Vendor-managed Inventory

Vendor-managed inventory (VMI) as a partnership in which the supplier is given access to the vendor's real-time inventory levels (Sari, 2007), and thus is able to take over responsibility for managing the customer's own storage locations (Claassen, Van Weele, & Van Raaij, 2008). The garment and grocery retail industries are among the most widely cited as examples of successful VMI relationships (Claassen et al., 2008; See e.g. Disney & Towill, 2003; Kaipia & Tanskanen, 2003).

VMI literature highlights the fact that removing links in the supply chain reduces delays in transfer of both materials and information the speed and quality of information (Claassen et al., 2008). Studies show, both analytically, by simulation and through case studies (Vigtil, 2007) that in doing so VMI leads to higher levels of availability, higher service levels, while lowering the costs associated with monitoring and ordering (Sari, 2007). The literature suggests that the extent to which these benefits are realized depends heavily on the customer's willingness and ability to supply demand data.

Inventory control models

There are many systems that try to optimize inventory control. These systems differ in complexity, as well as the specific circumstances for which they are designed for. One of the most basic inventory control models was designed by Ford W. Harris, in 1913 (Williams & Tokar, 2008). In this model, referred to often as the (Q,r) model, the firm orders a predetermined quantity Q when the inventory reaches a predetermined lower limit of r. Another rudimentary method is the periodic review model. Also known as the (S,T) model, inventory is reviewed with a predetermined review interval of T, when orders are placed so that inventory is brought back to a preset level of S. These models are static, in that they assume constant demand and lead time.

More complicated models often address more specific conditions set on the type of inventory in question. For instance, some take into account the time it takes for the inventory to expire, i.e. become unusable or obsolete. Some models are also dynamic, in that they introduce variance into variables such as demand, lead time and inventory costs (Aggarwal 1974).

Multilevel systems have also been modeled, the Portfolio Effect, was first introduced by Zinn and Bowersox (1988), demonstrating that the sum of aggregate safety stock in local storage facilities could be reduced by utilizing centralized storage locations: in other words, the fewer stocking locations in the system, the less inventory is held. The magnitude of the Portfolio Effect is a function of sales correlation between stocking locations, and Magnitude, which is defined as the quotient of the standard deviation of two stocking locations (i.e.$\frac{\sigma_A}{\sigma_B}$) (Zinn, Levy, & Bowersox, 1989). The effect is most pronounced when sales (or, in the case studied here, stock use) correlation between locations is small or negative and Magnitude is small. (ibid, p. 2):

$$PE = 1 - \frac{SS_a}{\sum_{i=1}^{n} SS_i}, for\ 0 \leq PE \leq 1$$

SS_a = aggregate safety stock for a given product if inventory is consolidate.

SS_i = safety stock for a given product at location *i*.

A concept that can be seen as closely connected to the Portfolio Effect is that of cross docking. Cross docking refers to a strategy where inventory is transported through distribution centers, without being stored in any noteworthy way between arrival at the receiving dock and departure at the shipping dock (Apte & Viswanathan, 2000).

2.4. Measuring quality

Quality is a broad term, often referring to a product’s or service’s capacity to meet or rise above expectations, in relation to the minimal requirements of consumers as well as competing products. However, quality also refers to the ability of a business unit, or a process, to consistently produce a product or service that conforms to standards that are predetermined as acceptable to either the client or the producer, or both (e.g. Cost of Quality literature). This second definition of quality is applied to the framework's analysis of process quality.

Service quality

Parasuraman, Zeithaml and Berry (1985) are responsible for one of the most convincing and popular conceptualizations of service quality. They signed on to the notion advanced by researchers such as Gronroos (1983) that service quality was a function of how well the consumer's perception of the service met the consumer's expectations (Parasuraman et al., 1985). Through an exploratory investigation that studied several industry sectors, they developed the Service Quality Model, in which they subdivide the gap between expectations and performance into five distinct gaps (ibid, p. 44). The original model is reprinted in Figure 1, below. What is interesting about this model in this context of supply chain integration/outsourcing is the position of the divide between consumer and the marketer. Since more of the service is outsourced, the point of contact where the process meets the customer changes.

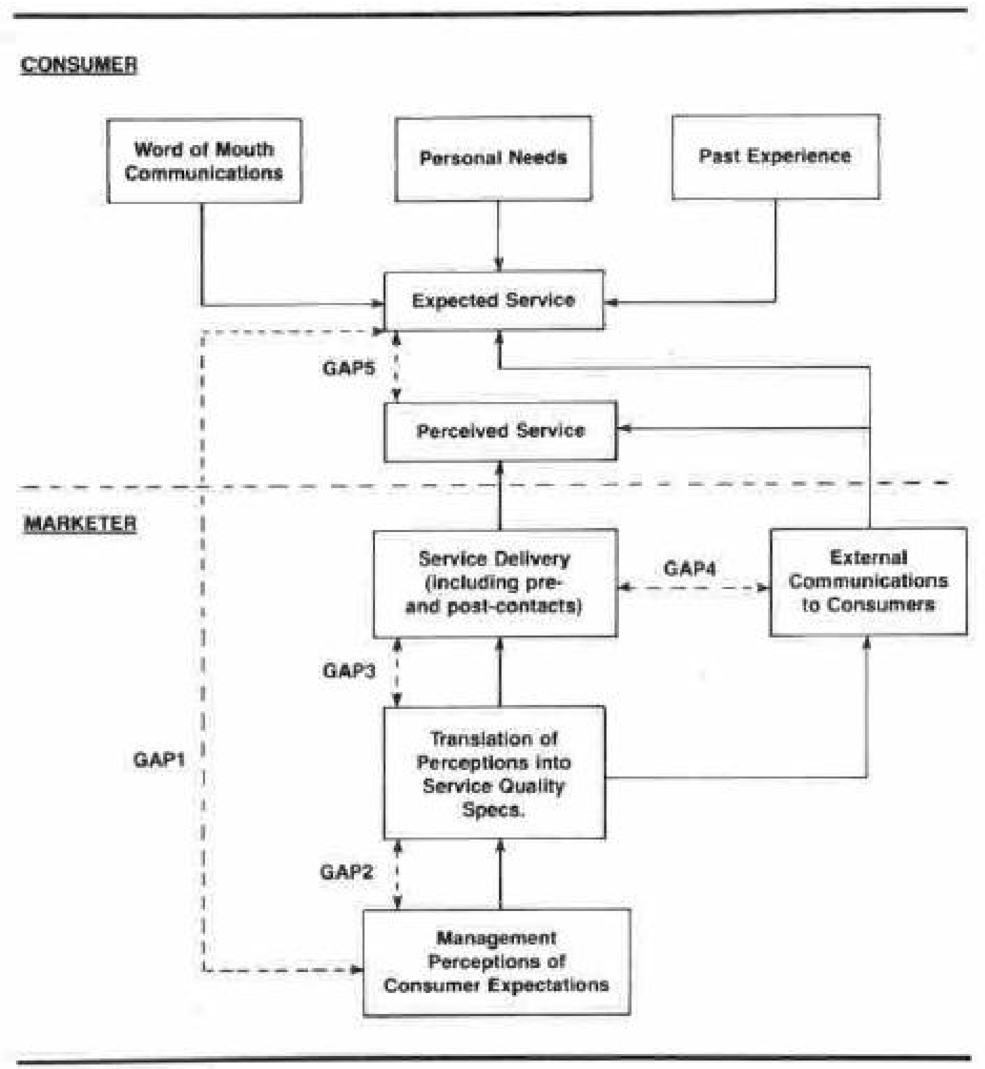


Figure 1: Service Quality Model (Parasuraman et al., 1985)

Cost of Quality (CoQ)

There are many ways of conceptualizing the *cost of quality* (CoQ). The prevalent, underlying idea is that the total cost of quality is the sum of conformance costs and non-conformance costs (Schiffauerova & Thomson, 2006). That is, good quality requires resources to achieve and maintained, but bad quality also results in costs. However, authors differ on the makeup of these two categories, and in how cost and quality interact. Burgess (1996) divides these interactions into three types of interactions:

- Type 1: at a certain point (an optimum), the cost of additional quality is higher than the available gains

- Type 2: to achieve increasing quality, appraisal costs will first need to increase, followed by increased prevention costs. At a certain stage, it becomes possible to decrease the resources committed to prevention. There is therefore no optimum level of defects.
- Type 3: quality is plotted against *quality awareness* (time) instead of resources. After initial increased resourcing of appraisal and prevention, both can be allowed to decrease while still making gains in improved quality.

Schiffauerova and Thomson (2006) on the other hand identify four types of cost of quality model based on the way these models attribute and divide costs to quality: prevention-appraisal-failure (P-A-F), opportunity cost, process cost and ABC models.

The P-A-F model (Prevention, Appraisal, Failure), which is also known as the Crosby model, and its variants, dominate CoQ literature (Burgess, 1996; Schiffauerova, Thomson, 2006). Prevention costs are costs that are associated with the design, implementation and maintenance of the total quality management system. Prevention costs are planned and are incurred before actual operation. Appraisal costs are associated with the supplier's and customer's evaluation of purchased materials, processes, intermediates, products and services to assure conformance with the specified requirements. Internal failure costs occur when the results of work fail to reach designed quality standards and are detected before transfer to customer takes place. Finally, external failure costs are costs that occur when products or services fail to reach design quality standards but are not detected until after transfer to the customer. (Oakland, 1993; Tsai, 1998)

From the perspective of Burgess's typology, above, Crosby's conception of CoQ was of the first type: as Crosby famously stated, "quality is free" (also the title of one of his most famous works). This is certainly not true of all P-A-F models, many of which assume a trade-off between conformance (P, A) and non-conformance (F) costs (i.e. Type 3). Plunkett and Dale (1987) represent those who, after an extensive review of models from both sides of the argument, are unconvinced by the notion of an optimum level of defects. In addition to the typology above, Burgess (1996) contributes to this debate by suggesting that the CoQ optimum may exist in the short-run, but not in the long-run.

This thesis subscribes to the process cost conceptualization of cost of quality. In this case, the cost of non-conformance is defined as the failure costs associated with the process not being executed to the required standard.

2.5. Evaluating processes

The literature review has so far focused on understanding inventory management and its goals. It is now time shift the attention of this section to the concepts and tools used to evaluate inventory management as a process.

2.5.1. **Business Process Modeling**

Business process modeling is a tool for conceptualizing – often visualizing – business processes, with the intent of gaining a better understanding what the inputs and outputs actually are, and how inputs are transformed (ibid, p.28). The analysis (both quantitative and qualitative) that the model enables can, for instance, result in the identification of bottleneck, or the realization that the process could be greatly simplified (Becker, Rosemann, & von Uthmann, 2000; Darnton & Darnton, 1997). It is important to be mindful of the fact that processes can be modeled at different degrees of detail, according to the goal of the modeling exercise.

There are many ways of modeling processes. Techniques include the flow chart, data flow diagram, action diagram, role activity diagram, role interaction diagram, Gant chart, and several types of IDEF techniques (Aguilar-Saven, 2004). According to Macintosh (1993, in Aguilar-Saven, 2004), the method selected should be based on the maturity of the process. Taking this into account, for the purposes of this thesis, flow chart is the most relevant for further review.

The flow chart technique represents a process as a sequence of actions. Actions are characterized by what is being done and by whom. The flow chart technique is very flexible and easy to used, but this is also its weakness, as it is easy to make a flow chart cluttered and complicated (Darnton, Darnton, p. 16).

2.5.2. Evaluating logistical processes

As this thesis aims to construct a framework for evaluating a replenishment process based on readily available raw data, there is a heavy emphasis on quantitative data. Logistics literature contains many useful metrics that have been developed for quantifying the performance of logistical processes. For example *avalability*, discussed above as one of the two components of logistical service quality can be reflected by indicators such as stock out frequency and fill rate. The other component, *operational performance*, is reflected in, for instance, order cycle consistency.

There are many ways to group measures; these groups often also overlap, depending how they are defined. These include Cost/Quality/Time/Efficiency (Kallio, Saarinen, Tinnilä, & Vepsäläinen, 2000), Customer Service/Quality/Asset Management (Bowersox et al., 2002). The apparent disagreement on how to categorize certain measures stems from the dynamic nature of the problem. For example, lead times decrease the need for inventory but also decrease the time it takes to respond to a customer's needs. A decrease in lead times could thus be considered to fall in categories including: Cost, Asset Management, Time or even Customer Service. It all depends on how these categories are defined and separated.

Robb and Silver (1998) assessed the economic impact of switching from one inventory control model to another by comparing what they termed Total Relevant Costs, the sum of inventory holding costs and shortage costs. Expected Percentage Cost Reduction was calculated as (Robb, Silver, 1998, p. 1089):

$$EPCR = \frac{ETRC_{K_1} - ETRC_{K_2}}{ETRC_{K_1}} \times 100\%.$$

It is worth noting that this calculation ignores cost reductions/increases related to controlling and ordering. However, in many cases, these are either small (especially in highly automated processes) or fairly constant (i.e. do not change with control or ordering frequency).

Categorizing metrics by what they reflect is far from straight-forward. Table 2 turns the question around and lists common metrics from a less equivocal but equally relevant perspective: the source of the data behind each metric.

Table 2: Common metrics by source of data

Data source:	Error reports	Inventory flow	Inventory levels	Cost items	Response Times	Feedback
Metrics:	Shipping errors	Delivery consistency	Stock outs	Work-in-progress	On-time delivery	Customer complaints
	Order entry accuracy	Cycle time	Inventory levels	Fixed Costs	Punctuality	
	Picking accuracy	Inventory turns			Lead-time	
	Complete orders	Fills rate			Backorders	
	Response accuracy					

The common metrics listed above reflect the problem that the framework created in this thesis seeks to solve: all of these are of course relevant, but many are correlated, either negatively or positively.

3. FRAMEWORK: EFFICACY, QUALITY, STRENGTH

Building on the theoretical foundations constructed in the previous section, this section will aim to form a coherent methodology for evaluating the inventory management processes. The framework will aim to be as quantitative as possible, so that it can be easily applied not only to the data being analyzed in this case, but hopefully to other cases as well.

The service-cost dichotomy in Section 2.2 contained elements of quality in both. Quality affects both service level and cost level, and is the only element where the two are not necessarily in conflict with each other – *quality is free*, as Crosby proclaimed. Therefore it is better to delineate process quality as its own category. The resulting framework splits the evaluation into three perspectives on goodness of inventory replenishment:

3.1. Process Efficacy

In this text, process efficacy will refer to the efficiency with which resources are used to execute inventory replenishment. At a given level of efficacy, granting more resources to inventory management will increase service quality and inventory efficiency.

Resources can be quantified monetarily, and are a factor of time used and cost of time. Time used will refer here to the total time taken to complete one replenishment cycle. Net salary costs are equal to the hourly labor costs for the employer of the individuals performing the tasks:

$$Resources = time\ used \times net\ cost\ of\ labor\ per\ minute$$

3.2. Process Quality

Process Quality in this essay refers, in accordance with cost of quality literature, to the degree to which a process is performed without error. As discussed in the literary review, the cost of non-conformance comes in the form of internal and external failure costs. In the inventory management process, the most significant error is the failure to receive what was intended to be ordered; and in this setting, the most common cost derived from the realization of this risk is not reputational, or that of lost demand, but of the resources used for error correction.

3.3. Inventory Control Strength

Inventory Control Strength refers to the rigor with which the process is taking care of inventory management. In other words, it measures the results of the process. Two important inventory management objectives relate to carrying: availability and minimization of carrying costs. A strong process, as defined here, simultaneously maximizes **availability** and **inventory efficiency**, and the extent to which these are achieved in unison is down to what this thesis defines as inventory control strength.

3.3.1. **Availability**

Availability essentially boils down to having the stock on hand to meet prevailing demand. Stock outs are usually associated with costs. As discussed in the literature review, extra costs can be conceptually divided into two categories cost: costs of not unfulfilled demand and cost of express delivery.

Normally, the former cost component leads to reputational costs as well as foregone sales. In a healthcare setting, the costs of not being able to fulfill demand can be extremely high, even life threatening. On the other hand, the price of express delivery is usually very low compared to the overall cost of the service being offered to the patient. For these reasons, unfulfilled demand effectively does not exist in this setting, and stock out costs can be approximated being equal to the cost of expediting deliveries.

3.3.2. **Inventory efficiency**

As indicated before, process strength is not just about the degree to which the process is avoiding stock outs, but also the degree to which the process is controlling (keeping down) stock levels. A well maintained inventory system is optimized for order frequency, buffer level and order size.

Over-ordering can be revealed in ordering patterns. A long gap between two orders of the same item indicates that the quantity ordered in the former was unduly large. In an optimized system, ordering is frequent and order frequency is fairly steady, as the quantity ordered is optimized to last until the next order. However, in a situation where inventory is managed in a suboptimal way (either due to poor resourcing or poor execution), this pattern is bound to be less uniform. In practice, one would expect to see more variance in peaks and the frequency of order. Therefore, conclusions on inventory efficiency can be made based on ordering behavior.

Over-ordering (referred to in Disney and Towill, 2003, as *rogue ordering*) is in itself reflective of two factors: the abilities of the actor in charge of the process and interest divergence between this actor and the organization more broadly.

3.4. Integrating the elements into a single framework

This framework is argued to provide a comprehensive picture of the merits of the inventory management process in question, on its own merits and when compared with the former service it is in the process of replacing.

As noted in the literary review, the value proposition of a logistical process consists of two elements: service and cost. This thesis does not dispute this, but proposes a different division. This division is not in conflict with the service/cost split.

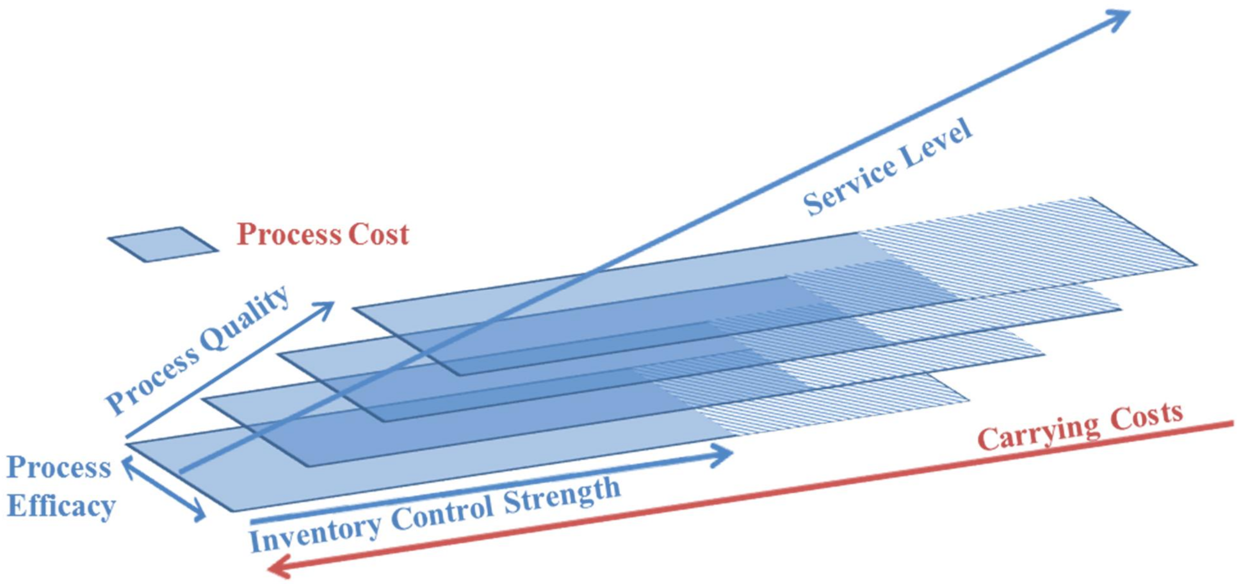


Figure 2: The dynamics between Quality, Efficacy, Strength, costs and service level

Figure 2 shows the relationship between the three attributes used in this thesis to evaluate inventory management processes. For a given level of Efficacy, increasing Strength will increase the cost of maintaining the process. More Strength will, however, increase cycle times, thus decreasing carrying costs. Service level increases with both process quality and process intensity. Increasing quality allows the process to jump diagonally onto a new Strength/Efficacy plane without any trade-off.

4. HUS AND HUS-LOGISTICS

This study now turns its attention to the case study. The following explains the context in which the two processes are being performed, by giving brief descriptions of HUS (Section 3.1) and of HUS Logistics (Section 3.2). The next sections introduce the two inventory management processes compared in this study, NRS (Section 3.3) and the more integrated RS (Section 3.4). Section 3.5 conceptualizes HUS Logistics and the RS process through the prism of logistics theory, and the final section (Section 3.6) gives some perspective on current adoption rates of RS.

4.1. HUS

HUS, the Hospital District of Helsinki and Uusimaa (*Helsingin ja Uudenmaan sairaanhoitopiiri*), is a joint municipal authority (also *joint authority*).

In Finland, a joint authority is an organizational organ that brings together municipalities to provide services. Funding is provided by member municipalities, who exercise decision making power through a general assembly (Suomi.fi, 2012).

HUS is formed by 24 municipalities, which on 31.12.2012 represents a population of over 1 562 000 (31.12.2012 figure). HUS has hospitals in 8 different locations, which in 2012 offered 233 755 inpatient days and had operating costs of €1 668.9 million. (HUS 2012)

Figure 3: HUS Area

Finances

HUS's cost structure is represented in figure 2 (below, from *HUS logistics financial statement.*2012). Personnel costs are clearly the largest contributor to costs, and have continued their rise during the past years. Subsidies and grants have risen the most over the period, but represent only 0,05% of the budget. Personnel costs are predictably the largest cost driver for HUS.

Still, material and material management-related costs (*materials, supplies and goods*) represent a very significant part of HUS's overall running costs: 19% of the total in 2012. It is worth noting that these are only costs direct attributable to logistics. This percentage does not include the hidden costs related to material management, such as the work done by healthcare staff and secretaries to management inventory. While significant strides have been made in controlling these costs, as evidenced by the low rate of growth of these costs compared to other cost categories, savings achieved at HUS-Logistics (and in the greater supply chain process) have the potential to have a sizeable impact on the bottom line of the entire hospital district.

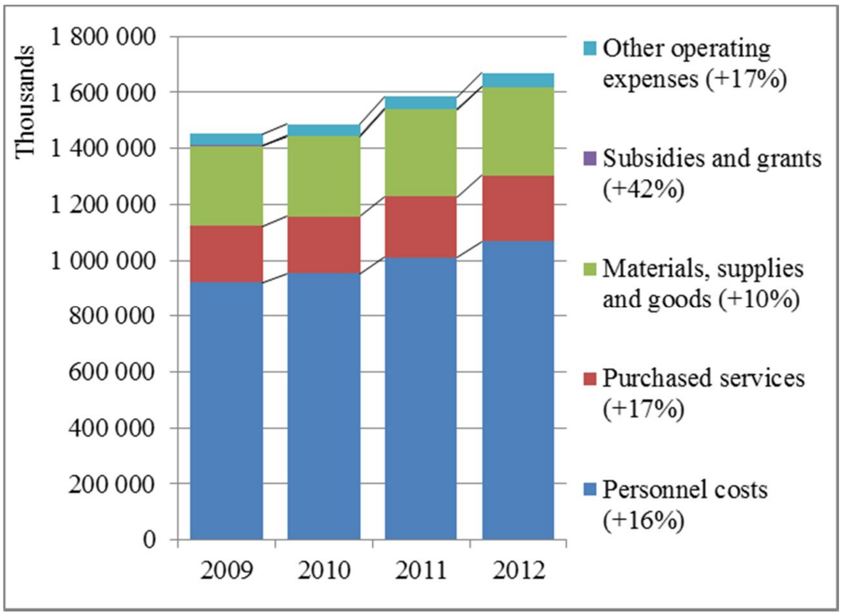


Figure 4: Cost structure of HUS (%-change since 2009)

4.2. HUS Logistics

HUS Logistics is a municipal enterprise owned by HUS. Municipal enterprises have a relatively independent budgetary status, when compared with other municipal functional units (Statistics Finland, 2013). Of HUS's 24 member municipalities, 18 are currently clients of HUS Logistics. As a municipal enterprise, HUS-Logistics' goal is not to make a profit, but to provide the service level demanded by HUS as efficiently as possible.

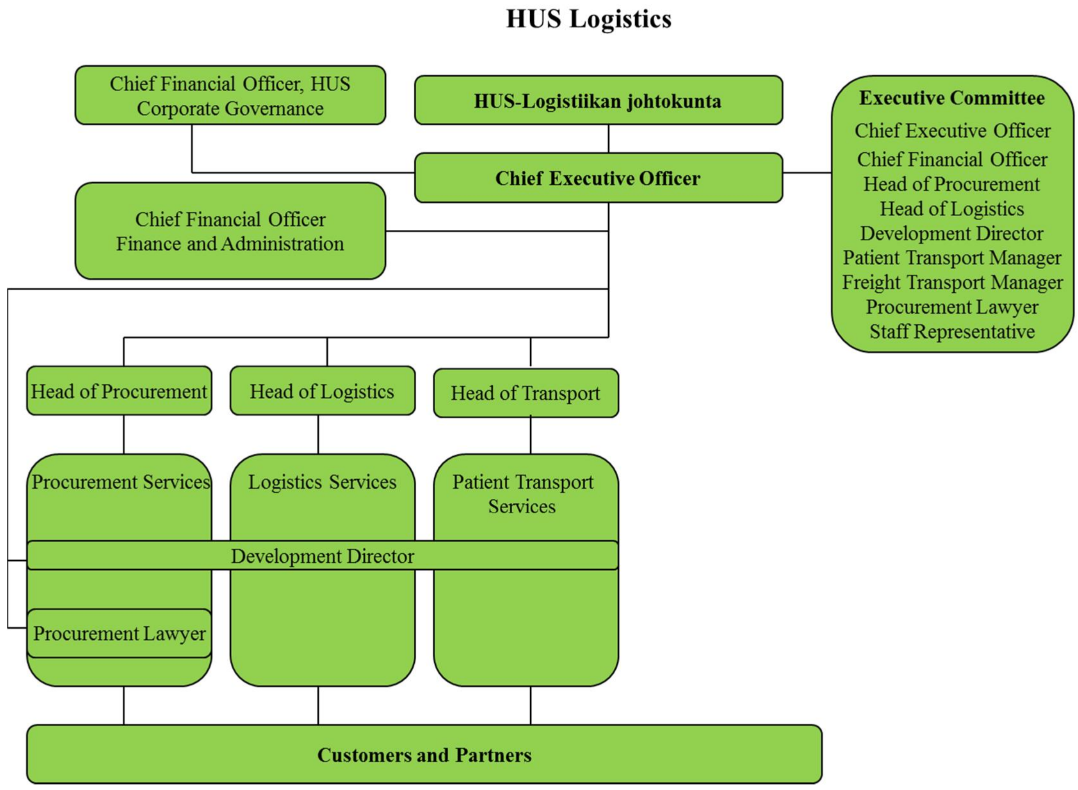


Figure 5: Organizational chart (adapted, HUS Logistics' Strategy 2012-2016-presentation)

In essence, HUS Logistics was established as a way to outsource and concentrate most of HUS's supply chain for hospital equipment and supplies. HUS Logistics takes over the process from the moment a need is declared. HUS Logistics is in charge of purchasing, supplier management, processing of incoming inventory and final delivery. It is also responsible for the tendering process, when the volumes for a specific item are expected to be significant; reclamation, in the case of delivery mistakes; and legal services, that enforce agreements and review contracts. In addition to increasing efficiency by concentrating administrative resources in a single place, concentration of inventory storage and management allows HUS to lower overall inventory levels by allowing for cross-docking.

HUS Logistics is divided into 3 functional departments, all offering services to HUS: Procurement, Logistics and Transport Services (see Figure 5). In addition to its classic logistics function, Transport Services is also in charge of non-urgent patient transport. Inventory replenishment is performed by the Logistics Services division, and orders are processed and executed by Procurement Services.

Not all supplies entering HUS are managed by HUS Logistics (only 40% of total): control of the various supply chains has been divided by type. In monetary terms, the pharmaceutical supply chain is almost as large, and is controlled by HUS Pharmacy, also a municipal. Laundry and nutrition are also managed by their own enterprises, Uudenmaan Sairaalapesula Oy and Ravioli, respectively. Plans to increase high-level coordination between these parallel supply chains will be implemented during the coming years. This further coordination will no-doubt bring with it exciting possibilities for synergies.

Finances

In 2012, HUS Logistics employed over 283 people (HUS Logistics Financial Statement, 2012), with had a total revenue of €145,7 million, an increase of 4% on the previous year. It made a profit of €0.9 million, but this was returned to customers. (Ibid., p. 399)

Its cost structure is illustrated in Figure 6 (below). Materials, supplies and goods represent an overwhelming proportion of HUS Logistics' cost structure, and has also risen significantly, which is mostly reflective of the enterprise's expansion. This also explains why personnel costs have risen more than in its parent company.

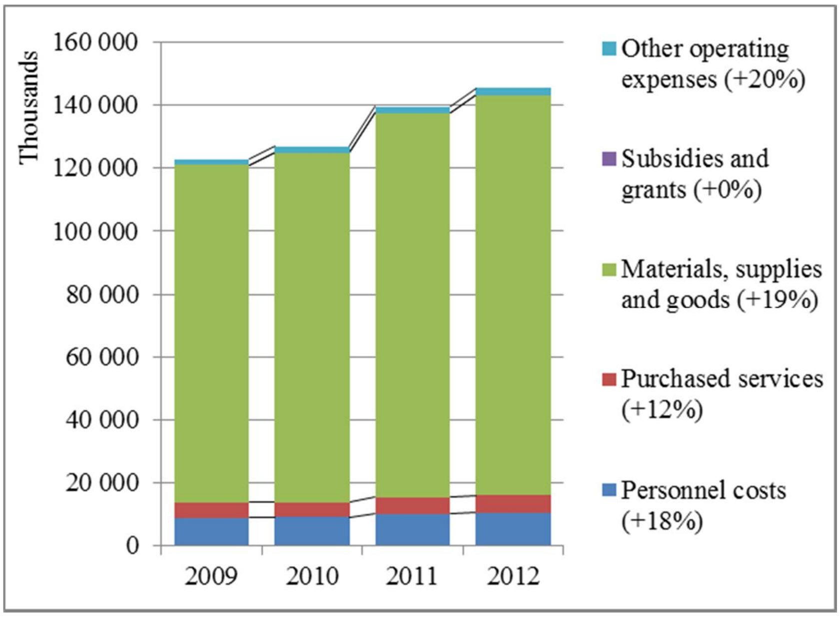


Figure 6: Cost structure of HUS Logistics (%-change since 2009)

Even if the pricing of inventory follows a cost-plus system, and is thus directly carried over to the customer, the onus remains on HUS Logistics to do its upmost to control this significant cost item on behalf of its parent company. This category of costs can be, and has been, controlled with various efforts related to purchasing, such as improved category management and more effective tendering.

Personnel costs represent about 7% of HUS Logistics' overall running costs. As the organization expands to fulfill a larger mandate, there is an opportunity to constrain the rise in personnel costs by increasing the efficiency of processes. The most labor intensive processes in the organization relate to order handling and material management.

4.3. Conventional Process (NRS)

HUS Logistics offers two models for inventory management. The more established, and less comprehensive, NRS is described first. Figure 7 depicts the default replenishment process for all units at HUS. A member of the medical staff from the unit, usually a nurse or a secretary, checks storage rooms on a regular basis. If he feels that something is running low, he will write this down. Some units have a check list, others do not. In some units this is done at a predetermined time, and this responsibility is either assigned to one individual or rotated among several. In other units, checks are fairly unstructured, usually meaning that one or more individuals check the storage whenever they have time.

Depending on the unit, the same employee or a secretary will then place an order for the required items in the ordering system. The order is then processed by HUS Logistics' Procurement Services. If the ordered units have been identified with the appropriate reference codes, the processing and acceptance of orders happens very quickly. When reference numbers are incorrect or the item does not exist in the system, this step becomes time consuming. Once an order has been processed and accepted it is relayed to the appropriate supplier. It is then received at the warehouse, processed and shelved.

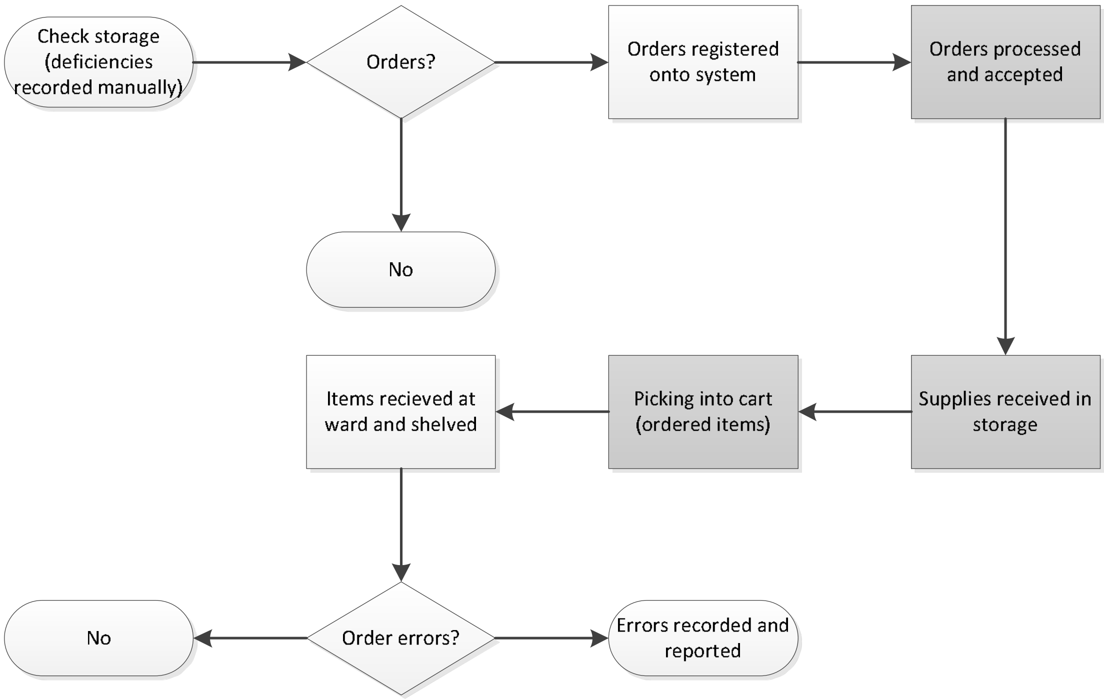


Figure 7: Flow Chart model of NRS Process

When Logistics Services is scheduled to deliver supplies to the unit in question (1-5 times a week), all ordered and received supplies are picked into a cart and transported to the unit. Someone from the unit's staff will then shelve the contents of the cart and make sure that the items ordered match the items received. If a mistake made in the order is perceived at this point, it is recorded and reported to HUS Logistics. Errors occasionally relate to quantities, as these are sometimes misinterpreted at the ordering stage. In practice, a nurse might need five pens, but orders five boxes of 100 pens. When errors are reported, they are processed by HUS Logistics, and retrieved by Logistics Services. If the value and quantity of the mistakenly ordered material is significant, a request to return the goods is frequently made to the supplier.

The NRS process is characterized by a large number of process owners, with process ownership often *ad hoc* and sometimes poorly defined. Some units have started trials with using the same bar code readers as are used by Logistics personnel in the RS process. The significance of this development as an alternative for RS is addressed in Section 6.

4.4. Replenishment Service (RS)

HUS Logistics' Replenishment Service (RS) was established in 2008. The idea of the service is to take the service traditionally offered by HUS Logistics (described above) one step further, by taking even more control of the HUS's logistics. More precisely, units that opt for RS hand over control of local storage facilities to HUS Logistics. HUS Logistics is then in charge of:

- deciding on targeted inventory levels in consultation with the unit's staff
- checking inventory levels regularly
- ordering inventory from central storage units when stocks are low
- shelving ordered stock
- general maintenance of the storage rooms

It should be noted that even if a unit has opted for RS, there are still orders that are not handled by the service. The service only applies to items that are in sufficiently regular demand, and are thus kept in stock. One-off or otherwise rare needs are still ordered outside the service. The share of one-off orders becomes apparent in the inventory control strength section of the analysis.

Currently, the service is completely optional and the decision to opt in is made by the head of the unit in question. RS costs 300 euros per month. RS has been implemented in over 90 units. So far, the attitude of unit heads to the proposed service has varied. Many see RS as very welcome indeed. Others have been put off by the monthly fee, and doubt that the service would actually save money.

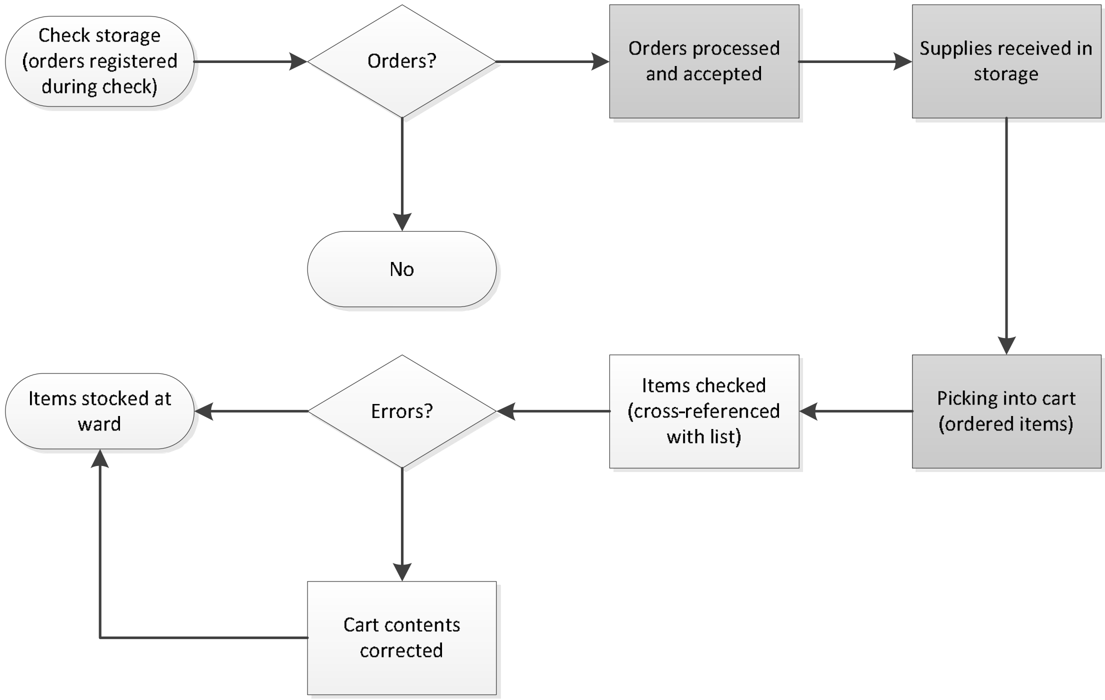


Figure 8: Flow Chart model of RS Process

The RS process is illustrated in Figure 8. When comparing the two processes, the first thing to note is that there are elements that are exactly identical. The three tasks found in both NRS (Figure 7) and RS (Figure 8) are shaded in gray. These tasks are executed by the warehouse staff irrespective of who is in charge of the rest of the process.

The RS utilizes a bar code scanner (slightly larger than a television remote), to read the bar codes of stock items that are deemed by the logistics worker to need replenishment. The bar codes are attached to the shelf, where the item is stocked. The bar code is associated with a predetermined order quantity. The result is that it is extremely difficult to make a significant ordering error in this process.

4.5. HUS Logistics, RS Process and Logistics literature

4.5.1. The HUS-HUS Logistics relationship

The relationship between HUS and HUS-Logistics is neither TPL nor VMI in their purest forms, for several reasons. The following goes through how these differences affect the expected outcomes of the relationship.

HUS-Logistics is fully owned by HUS, which significantly decreases interest asymmetries between the two organizations. These would normally be expected in a relationship between two companies, where each is trying to maximize its share of the value being created from the relationship. While HUS Logistics enjoys significant independence from its owner with regards to its day-to-day operations, the head of HUS Logistics remains directly answerable to HUS's CFO, and its board. All net profits earned by HUS Logistics operations are also returned to its HUS clients. Therefore, even if HUS Logistics aims at efficiency and even profitability, this profitability is not at the expense of its clients, but to their benefit. Thus, while one might expect margins to increase as a result of handing over increased control of the logistics process in normal conditions, in the case of HUS Logistics, this is both less likely and less problematic. While HUS Logistics certainly has an institutional interest in increasing its role and significance, increasing this role is not in itself associated with the risks alluded to in the literature, where authors stress the need for monitoring, balance of power and water-tight contracts to make sure that the co-operation is successful.

On the other hand, HUS's relative size as HUS Logistics' client takes away from the economy of scale and scope gains predicted by both TPL and VMI literature. Even if HUS Logistics has other clients (e.g. the Finnish Army), HUS is party to a very important proportion of HUS Logistics activities. This is important, since one of the often mentioned benefits of TPL is the spread of logistics costs more widely than if each client organized its own supply chains. On the other hand, there is a great deal of diversity within HUS. Units have different demand patterns and their demand patterns are, at least to some extent, uncorrelated.

The concept of VMI is often, though not always, limited to a situation in which the vendor owns the inventory until it is bought by the end customer (Disney & Towill, 2003; but not

Kaipia & Tanskanen, 2003). In the case of this relationship the inventory is, however, owned by the ordering unit, and inventory risk is thus not shifted from HUS to HUS Logistics in either of the two services. VMI also usually refers to a relationship where a specialized vendor supplies a specific product to a customer with less expertise in the particular class of products and is thus in a better position to predict demand and optimize inventory levels (Claassen et al., 2008). In the relationship studied here the clients remain more knowledgeable about the products being used, and are also more aware of changes in demand for certain products, resulting from e.g. technological advances or changes in procedures.

Still, many similarities remain. Even if the units are more intimately familiar with the products, HUS Logistics represents a concentration of expertise in inventory optimization, and is in a position to aggregate knowledge about historic changes in demand both at a certain location as well as for the system as a whole. Creating a strong organizational divide and thus isolating the logistical operations from HUS's core functions also helps to uncover, and control, the real costs associated with the organization's supply chain. Concentrating inventory management into a separate entity also allows for high levels of specialization and process standardization.

The similarities and differences of HUS Logistics and the RS process to the models outlined in VMI and TPL literature leave this thesis to hypothesize that relinquishing additional control of HUS's logistics operations to HUS Logistics should result in significant system-wide savings, most of which will ultimately be to the benefit of the units themselves.

4.5.2. **The RS as a service and as an inventory control system**

From the perspective of the Bask (2001) classification, the RS process could be considered as a customized TPL service, especially if one accepts a fairly inclusive definition of the TPL model. The initial investment, including modifications to the storage room and assessment of inventory quantities, can be considered considerable. In accordance with Bask's model and its implications, these changes require a longer term commitment by the ordering unit to the system and the benefits are primarily those of scope (Bask, 2001). As inventory management is fully surrendered by units to a central logistics center, general processes can be developed and improved upon. This paper also highlights the importance of information-sharing, joint planning and investments in IT services when this level of cooperation is concerned (ibid.)

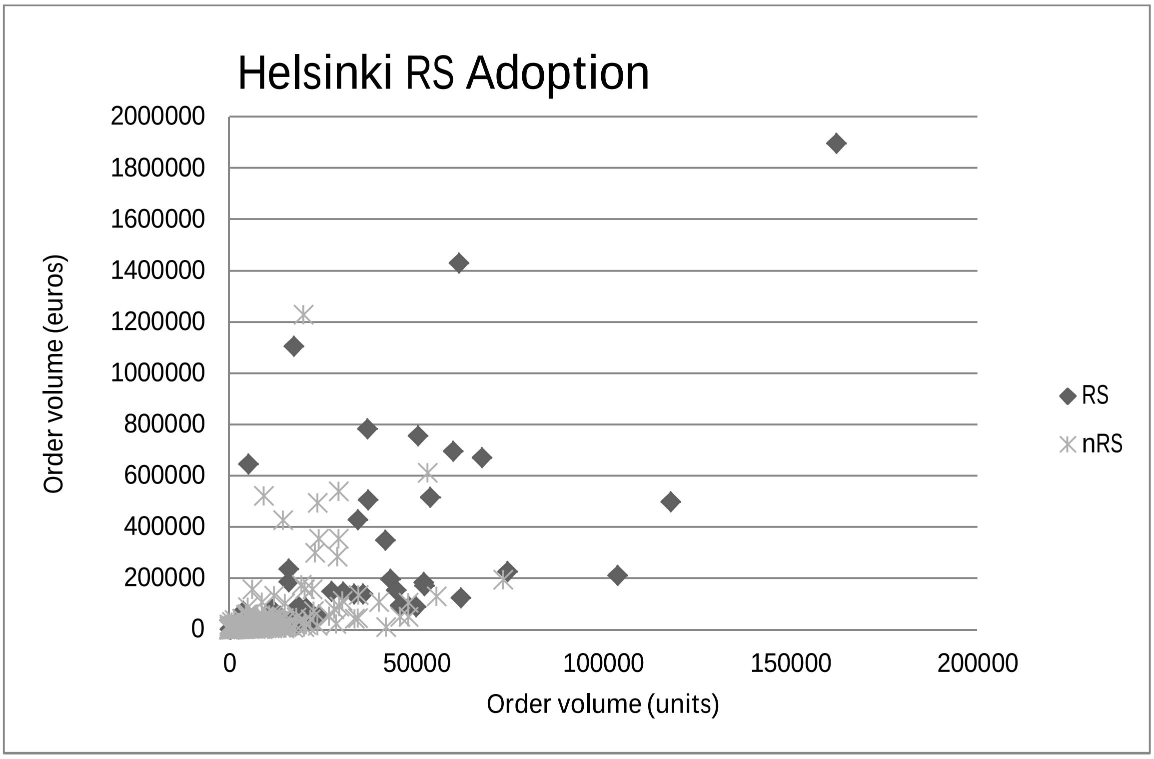
In practice, the RS system is a hybrid inventory control model. It has a fixed review period: RS-operators assess storage levels at a frequency that has been agreed to between HUS Logistics and the unit. However, inventory is not replenished to a specified level; instead, the system also has a fixed order quantity, with predetermined lower limits which act as a trigger for reordering. The predetermined order quantities are also often constrained by the size of packages. As a matter of practicality, efficiency is usually derived from ordering, transporting and stocking whole packages, instead of splitting them into more specific quantities at the central storage facility. The control system used by NRS units, while often not as systematic or even explicitly designed effectively resembles the same sort control system in practice.

In such a system, inventory levels are optimized, i.e. safely minimized, by ordering just enough to suffice until the next step, in addition to maintaining a small buffer. In practice this optimization is constrained by several factors: order quantities are not fully divisible and usually come in boxes of several (1-100) units), demand is stochastic. Still, poor inventory management is not only reflected in stock not lasting until the next check (stock outs, discussed above) but also in over-ordering.

Adoption of the service

Figure 9 shows the adoption of RS by units in Espoo and Helsinki, in terms of size of the units' order volumes (in units and monetary terms). Several conclusions can be made from these diagrams. RS has been primarily offered to, and adopted by, units that deal with relatively large material flows. Units that deal with greater inventory flows will likely have the most to gain from adopting RS, regardless of how they perceive their own performance. These diagrams also bring attention to the fact that RS is perhaps not suited to all units, as a large proportion of units handle very small volumes of inventory. Many of these units are supporting units (receptions, administration, etc.). Since RS is only applicable to units that display certain characteristics, this should be taken into account in the comparative analysis regarding the two processes.

Furthermore, with regards to the practicalities of performing the study at hand, since RS has initially been adopted by a relatively homogenous group of units in terms of order volume, it will be important to avoid making false conclusions that are in reality a result of selection bias.



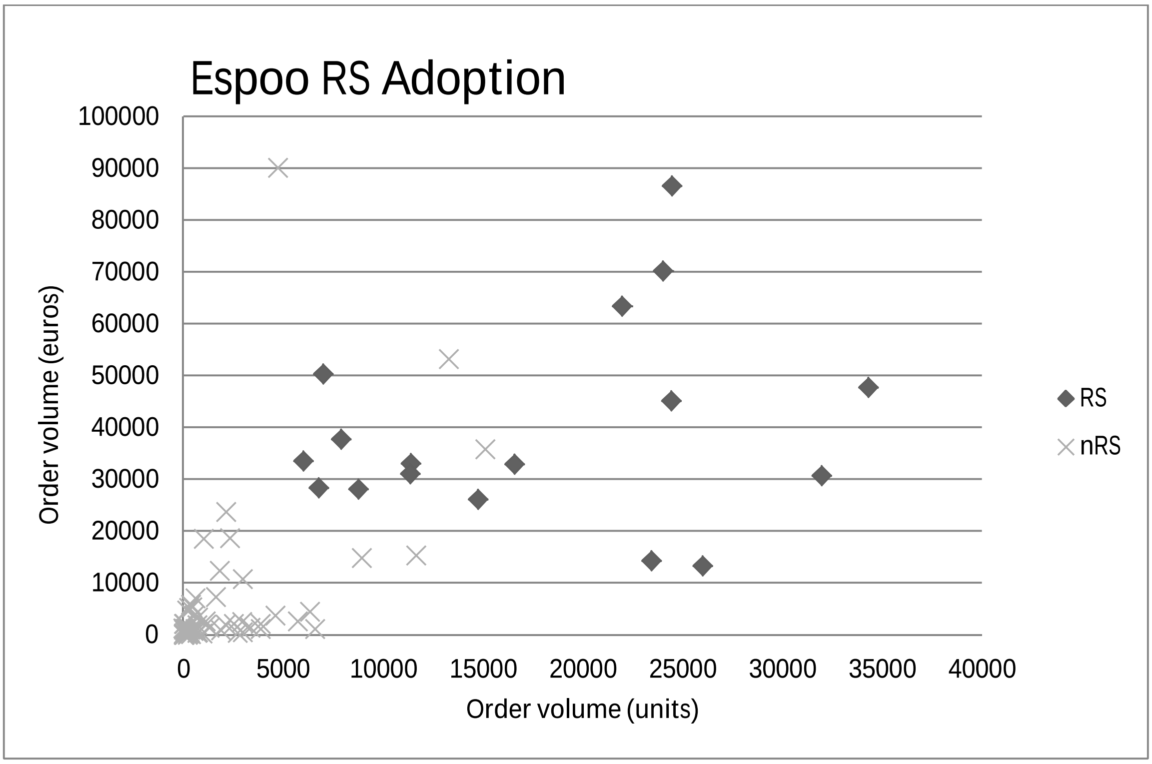


Figure 9: Adoption of RS at in Espoo and Helsinki

5. METHOD

This section will test the framework outlined in Section 3 by applying it in a case study. Applying the framework to a real life setting will help to identify issues with the framework, as well as interesting opportunities for further improvement. The case study will also serve as a way to illustrate how the framework is intended to be used in practice.

Figure 10 illustrates how Process Efficacy, Process Quality and Inventory Control Strength, were tackled in practice. It depicts these three components of the inventory management process from the perspective of inventory management through time. **Strength** allows for a decrease in inventory (area) and the risk of stock outs (red line) that result express orders (green line) with more frequent (distance between checks) and more effective inventory management (better optimized size of order, height). **Quality** decreases the occurrence of errors (red area) that are ordered and subsequently returned (yellow). **Efficiency** reduces the amount of money spent during time, T.

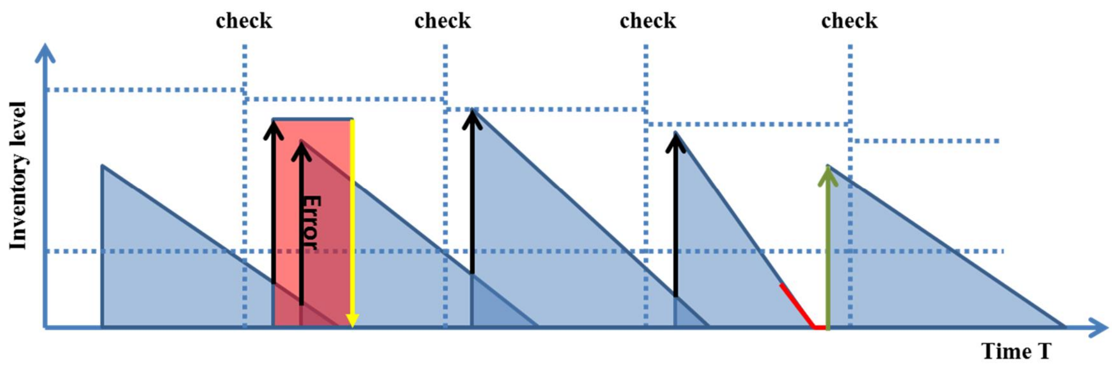


Figure 10: Inventory replenishment process

5.1. Data

The section will first describe the sources of the data on which the analysis is based. Out of the hospital district's 8 main sites, the analysis will be limited to sites in Helsinki and Espoo. The two will be treated separately, with Espoo's Jorvi hospital site acting as a control for location-based differences. The table at the end of the section shows how the different elements of the analysis utilized this data.

5.1.1. **Process times**

Data on processes times of RS was gathered at the Jorvi site, as it was deemed most representative of what the RS process looks like when fully implemented. The largest site, the Meilahti hospital area in Helsinki, site is currently not an ideal source RS process times. It is currently undergoing a great deal of restructuring (units are being moved, some in temporary locations) and construction (e.g. the site's large tower building, *Tornisairaala*). Espoo's RS process is also well established and operational in 23 of Espoo's units. NRS was studied in both Helsinki and Espoo.

The process times in this thesis were collected by observing the processes in practice. This method was chosen in favor of less work intensive solutions such as requesting self-assessments of time use, in the interest of accuracy. This study wished to avoid the risk of rounding down that could have resulted from the self-reporting of time use. This was seen as an even bigger risk given that some of these tasks are split up and spread over a period as long as a week.

Upon meeting the performer of a task, he (or she) was briefed on why his work was being timed. Care was taken to make the situation as relaxed as possible, and it was emphasized that the situation did not represent a test or a "race". It was hoped that a relaxed environment would minimize the effect of the timing on the process times themselves, making the results as representative as possible of the swiftness with which actions were performed in normal circumstances.

Times to complete the three tasks in question, checking storage, ordering, and shelving were recorded, along with other information (see Table 3). Extraordinary incidents that inhibited the normal completion of a task (e.g. a shelf collapsing during shelving) were also recorded.

Table 3: Inputs in process analysis

Task identifier	**Actor**	**Location**	**Task characteristics**
Number	Job title	Unit name	Task type
	Labor costs (€/hour)	Unit code	Units delivered/ordered
		Room code	Total time (hours)
		Orders/week	Abnormal events affecting process

5.1.2. Labor costs

Labor costs are made up of several components. In Finland, these consist of (gross) salary, employee benefits, employer's social security payment, employer's contribution to employee pension and employment insurance and insurance payments.

In order to calculate the cost of time spent on the inventory process, data on the average salaries was collected from HUS's databases. There are two relevant ways to compare wage costs: wages without extras such as overtime, weekend and evening pay; and net wages, including extras.

There is is a good case to be made for not including extras. RS operators work fairly regular hours, and do not perform inventory management during weekend or evenings. There is also no necessity for this task to be performed during out-of-office hours. Therefore, the unit cost of time without extras could be argued to provide a fairer, and a more conservative, point of comparison between the two processes.

On the other hand, there are also good arguments for including these extras. First, in practice inventory management by care giving staff is often managed outside standard office hours, where extras apply. It could also be argued that time managing inventory, even if performed during office hours, shifts other tasks to other times, making the timing of inventory management itself irrelevant.

Therefore, for the sake of transparency and clarity, both unit costs (net and gross of extras) will be included in the analysis. The average percentage of extras for each relevant employee category was calculated from aggregated extras and aggregate gross wages from an eight-month period (1.1.2013-30.8.13).

In the case of the RS, the inventory management process is managed by a logistics operator, in the role of RS-operative. In the case of the competing self-managed NRS process, storage facilities are generally tended to by secretaries, midwifes and sterile supply technicians (*välinehuoltaja*). Table 4 shows the average costs of time by employee type.

Table 4: Average cost of time by employee type

Role	Average cost of min.	Average cost of min. (with extras)
RS-operative	0,199 €	0,203 €
Secretary	0,220 €	0,238 €
Nurse	0,224 €	0,270 €
Midwife	0,254 €	0,319 €
Sterile supply technician	0,194 €	0,209 €

5.1.3. **Items in storage**

The number of different stock-keeping units (SKUs) held at a particular storage room was estimated from the rows of ordered items that had been saved into the ordering system used by HUS units. Each page of the item list contained 11 SKUs and this figure was approximated from the number of pages. The last page was assumed to be half full, i.e. 5 rows full.

5.1.4. **Order data**

Data on all orders registered between 1.10.12-30.4.13 was retrieved from HUS Logistsics ordering system. Each row of each order is registered separately, and are identified with numerous identifiers along with the following, which are relevant to our analysis: item code, item description, unit price, customer code, date of occurrence.

A separate database was used to connect the units with which service they were using. The order data was also used to calculate the overall order volume that each unit handled during the period. The number of individual orders was also calculated for each unit.

Order rows were identified with whether or not the item was reordered during the review period, and with the number of days until the next order. If the number of days between two orders of the same item at the same unit was under 8, the item was identified as frequently ordered. If the quantity ordered was above one, the order was identified as being an order of several units. If the order was order was made after 26.1.13, it was identified as occurring too late in the review period to be considered in some calculations.

Figure 11 describes the available order rows, i.e. the size of the sample, and the size of the individual segments. Much of the analysis concentrates on a subset of this sample.

	RS	nRS	Total
Helsinki	113311	111058	224369
Espoo	24640	22409	47049
Total	137951	133467	271418

Figure 11: Order rows by service and location

5.1.5. **Return request data**

This data on requested returns was retrievable by specified period and by product category. It is reasonable to assume that all of these returns were carried out. Since returns are not a frequent occurrence, a weekly sum of returned items by product category and by returning unit will be approximated as resulting from one error.

The returns registered between 1.10.12-30.4.13 at the Jorvi and Helsinki site were transferred to excel. Orders registered during the same period were also retrieved. The location of the returning unit, as well as the service (RS or NRS) it was using was identified. The total errors for the period was calculated for each unit being considered, and the units were again identified by service and total ordering volume.

Figure 12 shows the total return requests retrieved, by location and by service.

	RS	nRS	
Helsinki	94	147	241
Jorvi	70	73	143
Total	164	220	384

Figure 12: Errors by service and location

5.1.6. Requests for express delivery

Data on all express deliveries between 1.11.12-30.4.13 at the Jorvi site and the sites in Helsinki was retrieved. The data was in the same format as data on regular orders, identifying individual express order rows by date, customer, item, quantity, etc. Assuming rows from the same date to be part of the same order, the number of different dates on which express orders were registered was used to calculate the number of express orders for each unit.

Figure 13 shows the total express deliveries retrieved, by location and by service.

	RS	nRS	Total
Helsinki	1976	2110	4086
Jorvi	685	574	1259
Total	2661	2684	5345

Figure 13: Express orders by service and location

Table 5: How data was utilized, by section

Section	***Data utilized***
Efficacy	Process times, labor costs, items in storage
Quality	Order data, return request data
Availability	Order data, express order data
Efficiency	Order data

5.2. Segmentation of units

For the conducted comparative evaluation of processes to be informative, it is important that the processes and the settings in which the process is conducted are comparable. Volume of inventory, in monetary terms, ordered during the period was selected as the most adequate indicator of unit characteristics, and will be used as the main segmentation criteria in the analysis of Quality and Inventory Control Strength. There are two main reasons for using monetary volume instead of unitary volume. First, medical supplies are usually more expensive than other supplies, making monetary value more accurate in separating supporting units, which may order large quantities of inexpensive office supplies, from care-giving units in the data. Second, the importance of inventory management is in many ways correlated with the monetary value of the inventory in question.

Having identified monetary ordering volume as the key characteristic for the type of unit in question, the total ordering volume for each unit was calculated from the order data. The decision was then made to limit the analysis to a specific volume range. This is important for several reasons. First, not all units are eligible for RS. Some units are too small for RS to be a viable and efficient option. Units with an order volume of less than 10 000 euros during the 6 month period will thus not be considered. Some ordering "units" found in the data are cost centers used for accounting purposes instead of actual hospital units. For instance the data consists of data ordered by HUS Logistics itself, or the other municipal enterprises, such as HUS Pharmacy. Thus, the decision was made to separate out ordering units with ordering volumes above 1 000 000 euros from the analysis.

The data attributable to units in the remaining range, 10 000 – 1 000 000 euros, was then segmented based on volume. Segmentation is also essential, in making the processes more comparable between units, since the inherent quality of the process is not adequately tested in units where the ordering process is conducted in conditions very different to those faced by an average care-providing unit. The data contains so much variance in terms of the type of unit being considered that segmentation is absolutely essential. Not only are care giving units of different sizes and faced with different needs for inventory, the data also contains administrative units and other supporting units. Figure 14 shows the quantity of units in each segment.

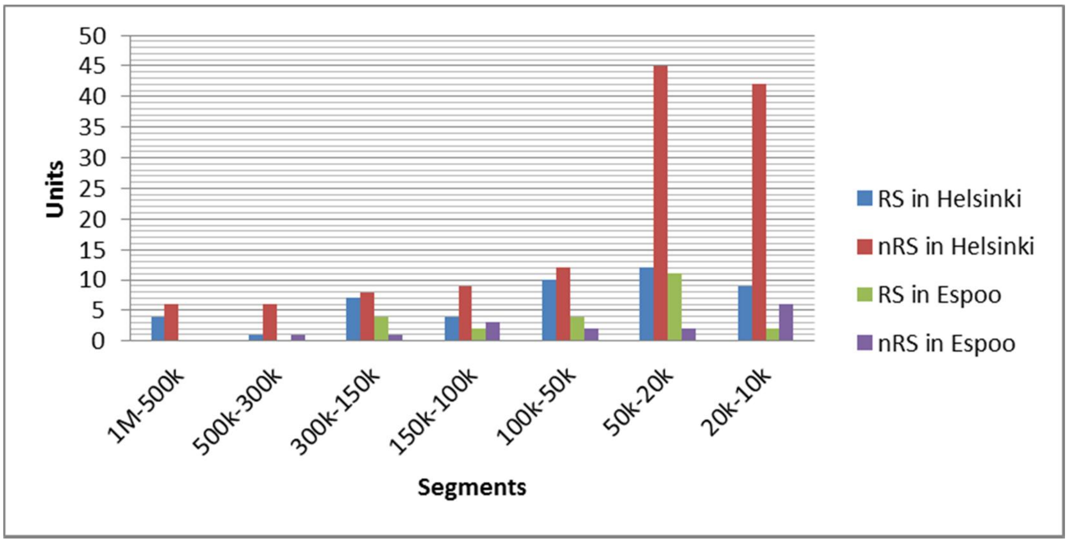


Figure 14: Units by segment

5.3. Process Efficacy

Total labor costs for maintaining the inventory management process are a function of the time expended and the cost of this time to the employer. The hypothesis of this section considers both of these elements.

Hypothesis: At a given level of quality and inventory control, RS uses less resources than NRS to manage inventory.

To gain an understanding of the time needed to manage inventory by the two services, the various tasks were observed and timed. A fairly accurate picture of the time demands of RS were acquired at Jorvi. The process worked very smoothly. The operators have become very familiar with the storage facilities they managed, and seem to know the shelves, their contents by heart. They also knew which units needed to be checked at every visit, and had an idea about which items were close to re-order levels even from a distance.

The times for NRS process were less easily quantified. Since the tasks, especially that of checking inventory levels, is often performed bit-by-bit whenever there is time, it proved very difficult to gain an accurate assessment of how much time is expensed to inventory management on average. Still, the observations that were acquired shed some light on the differences between the two processes. With the exception of very experienced hospital staff, the checking and ordering tasks in NRS were less efficient and structured. Inventory checks were often protracted by issues with remembering ordering numbers, for instance.

Table 6 seeks to give an understanding of the time taken by the two processes to manage the relevant tasks of the inventory process. As mentioned before, the first thing to note is that this is not an all-inclusive list of the tasks involved in the process but, as was illustrated in the process maps of the two processes, these are the only three tasks that differ between the two process. The rest of the tasks, such as picking, for instance, are performed in exactly the same way regardless of process. The RS results are based on seven observations of checking and ten observations of shelving, and can be regarded as giving a reasonably accurate picture of the time taken to perform these tasks. The NRS results are only based on eight in total, and should be regarded as purely illustrative. Even though it was not possible to get a larger sample for these measures, the general magnitude of the times was corroborated by discussions with staff. The estimates given are conservative, i.e. rounded down. Depending on the inventory needs of the units, ordering and shelving is performed 1-5 times a week. Even if the results are not statistically accurate in their entirety, it can be concluded that the tasks of the RS process take significantly less time to complete.

Table 6: Time needed by process

Role	Checking (min)	Ordering (min)	Shelving (min)	Total time
RS	4.3	-	4.7	9
NRS*	Over 20	Over 10	Over 10	Over 40

Based on the observations gathered, the RS service is much faster at performing both *checking* and *ordering*. Even though it was difficult to quantify how much time was actually spent on checking inventory levels in NRS units, the difference is significant, even if this time is ignored altogether. RS-operator spent an average of 25 seconds per executed delivery while performing their *checking* task, in which orders are made during the check. NRS staff, who either order based on a list they have compiled themselves or by a colleague, or based on a list combined collectively by the whole unit, spend an average of 90 seconds per executed delivery. While the samples were small, this clear difference in times gives an indication of the size of the difference, especially as all the time spent by staff checking inventory levels is excluded from this value.

In a separate study (HUS Logistics Report on the Establishment of a Logistics Center and the Replenishment Service Process), the average unit was estimated to spend 12 hours per month on ordering. Assuming these estimates, Table 7 shows the cost of inventory management by job category.

Table 7: Costs of performing inventory management

Role	Monthly Cost	Monthly Cost with Extras
Secretary	158,57 €	171,53 €
Nurse	161,58 €	194,37 €
Midwife	182,87 €	229,76 €
Sterile supply technician	139,77 €	150,75 €

5.4. Process Quality

When an ordering error is detected, and deemed to be significant, it is returned. While errors are not tracked directly, requests for the return of items are, and this data will be used as a proxy for ordering errors when comparing the RS and NRS process.

It should be stressed that while the over-whelming majority of ordering is internalized in the RS process, one-off orders for items that are not stocked (e.g. new computers and other electronic equipment) are still ordered by the unit itself. The data will therefore not necessarily reveal mistakes made by HUS-Logistics, but if this process is less prone to mistakes, as is the hypothesis, this should be reflected in the data as a statistically significant decline in returns.

Data directly measuring ordering errors does not exist. However, this essay will assume that an overwhelming majority of errors are returned to the central storage facility. This analysis will thus use data on requests to return items as a proxy for the errors themselves. Quality is often defined in terms of errors per chances to make a error (usually 1000 chances). Here, every order row is considered as one chance to make a mistake. Since every row of an order is registered separately by the ordering individual, each represents a chance to make an error. The errors are also segmented by order volume. Figure 15 shows where the errors are originating from.

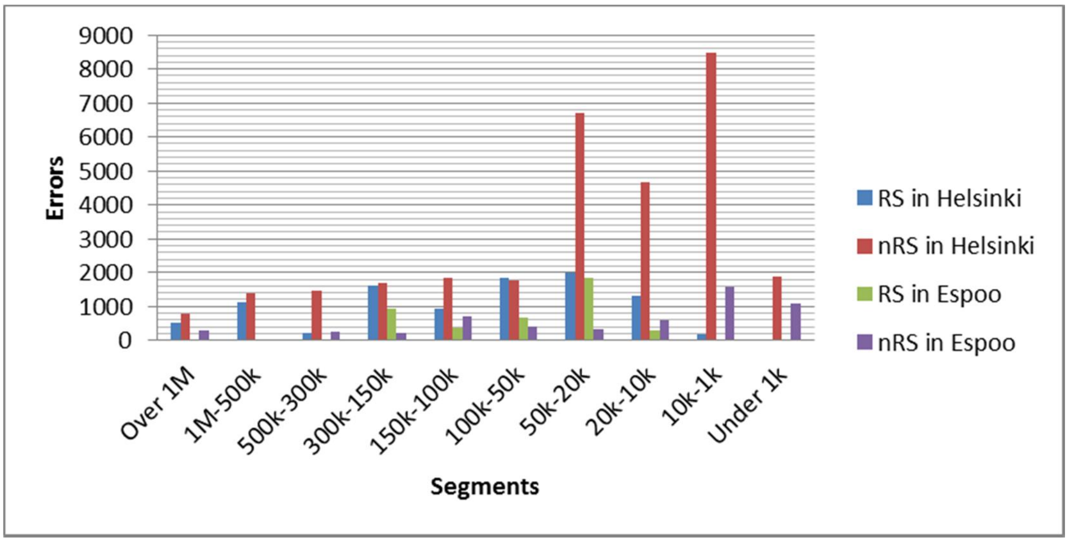


Figure 15: Errors segmented by order volume of unit

The next step is to relate the number of errors to the number of chances for error. As per the discussion above, units with volumes below 10 000 euros and above 1 000 000 euros during the period are left out of the analysis. Figure 16 represents all errors stemming from all orders in units, *i*, by volume, i.e.,

$$\sum_{0}^{i} \frac{{errors_i}/{chances_i} * 1000}{i}$$

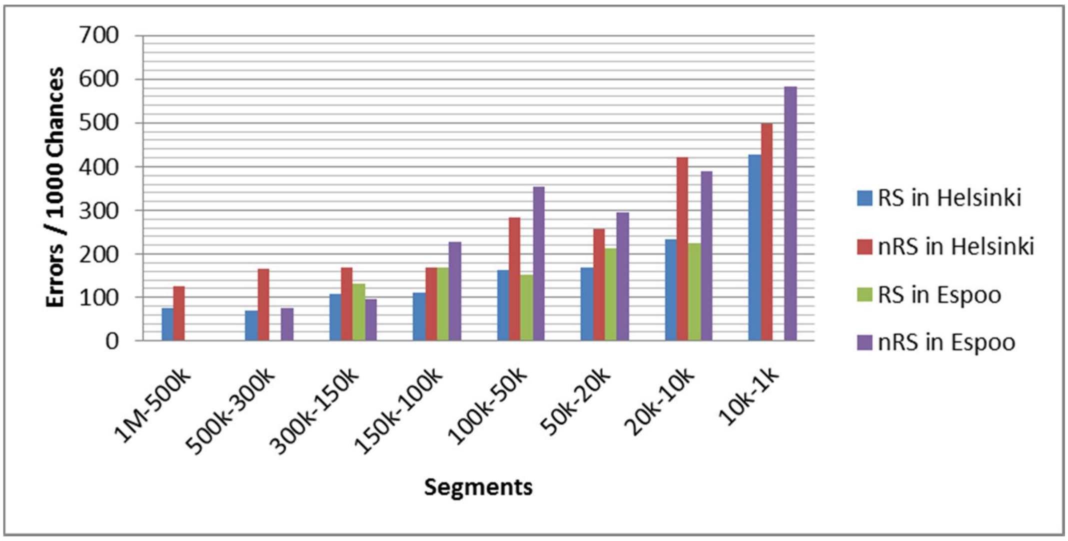


Figure 16: Average errors per 1000 chances in unit, segmented by total order volume and location

SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0,676							
R Square	0,457							
Adjusted R Square	0,447							
Standard Error	117,871							
Observations	213,000							
ANOVA								
	df	*SS*	*MS*	*F*	*ignificance F*			
Regression	4,000	2434763,030	608690,758	43,811	0,000			
Residual	208,000	2889871,097	13893,611					
Total	212,000	5324634,127						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*.ower 95,0%*	*Jpper 95,0%*
Intercept	370,666	22,668	16,352	0,000	325,978	415,354	325,978	415,354
Order rows	-0,111	0,013	-8,349	0,000	-0,137	-0,085	-0,137	-0,085
Order Volume (euros)	0,000	0,000	1,262	0,208	0,000	0,000	0,000	0,000
RS=1	-58,723	19,412	-3,025	0,003	-96,991	-20,454	-96,991	-20,454
Hki=1	5,887	22,073	0,267	0,790	-37,629	49,403	-37,629	49,403

Figure 17: Errors/1000 chances regressed by location, service, order rows and order volume

The summary output of the regression (Figure 17) suggests that the use of RS is indeed associated with a drop in errors per 1000 chances. Having RS is associated with almost 59 less errors per thousand order rows. Neither location nor order volume can be said to play a significant role in predicting error frequency, due to the high P-value. These are of course result based on the whole sample. From Figure 16 we see that there are in fact notable difference between segments, even if the change is not uniformly in one direction, when moving from bigger to smaller ordering units. The RS process performs at its best in very large units. This can partly be explained by the fact that the proportion of the inventory ordered by HUS-Logistics is likely to be at its greatest in these units.

5.5. Inventory Control Strength 1: Availability

As stated earlier, the analysis of inventory control strength will be subdivided into an analysis inventory availability (viewed through shortages) and an analysis of inventory control efficiency (viewed through ordering behavior).

Information on shortages is not available as such, but the following analysis will use data on requested express orders, which are orders that HUS-Logistics fast tracks, currently guaranteeing a wait of less than 12 hours.

Admittedly, not all expedition requests reflect a stock out. Sometimes units request expedition of one-off items that are not stocked at the unit in question, but are held at the central storage facility. Even so, a drop in stock out occurrences would still be reflected in a drop in express deliveries, *ceteris paribus*. Expedited orders also use more resources than orders made through the normal process. Thus, even if no stock out has actually occurred, they still reflect a cost that is hidden, especially from the units' decision makers.

The following shows how the orders are divided into the different services, locations, and units sizes. The rest of the analysis will focus on the categories in the middle that were deemed earlier to be the main focus of this thesis.

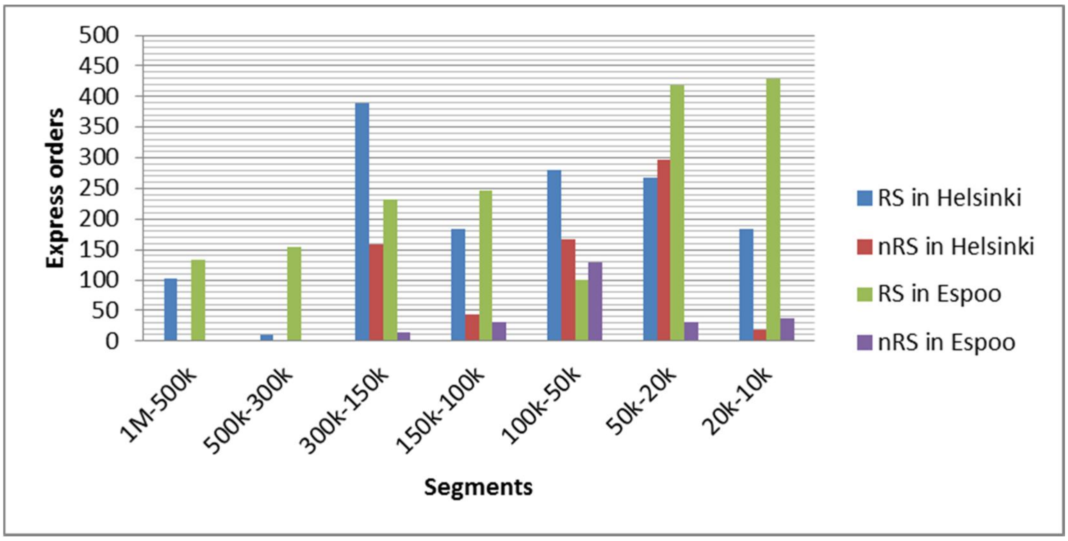


Figure 18: Express orders segmented by location, service and order volume

A regression analysis of the ratio between express orders and normal orders and order volume, service (RS or NRS) and location (Helsinki or Espoo) was then performed on the orders and express orders of the units that fit the inventory volume criteria (10 000-500 000 euros during 6 months). Figure 19 describes the results of this regression. According to the results, none of these three factors is a very significant predictor of the units use of express orders.

SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0,155							
R Square	0,024							
Adjusted R Square	0,010							
Standard Error	0,095							
Observations	219,000							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	3,000	0,048	0,016	1,767	0,154			
Residual	215,000	1,957	0,009					
Total	218,000	2,005						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95,0%*	*Upper 95,0%*
Intercept	0,094	0,018	5,368	0,000	0,060	0,129	0,060	0,129
Order Volume (euros)	-2,17E-08	0,000	-1,014	0,312	0,000	0,000	0,000	0,000
RS=1	0,023	0,014	1,652	0,100	-0,005	0,051	-0,005	0,051
Hki=1	-0,013	0,017	-0,746	0,456	-0,047	0,021	-0,047	0,021

Figure 19: Summary output of express order regression analysis

Figure 20 describes the same information by segment. It becomes clear that express orders are all too common in some segments, notably the segment of RS units in Helsinki that ordered between 100 000 and 150 000 euros of inventory during the period. Indeed, NRS outperforms RS in about half the segments (i.e. smaller ratio of express orders to normal orders).

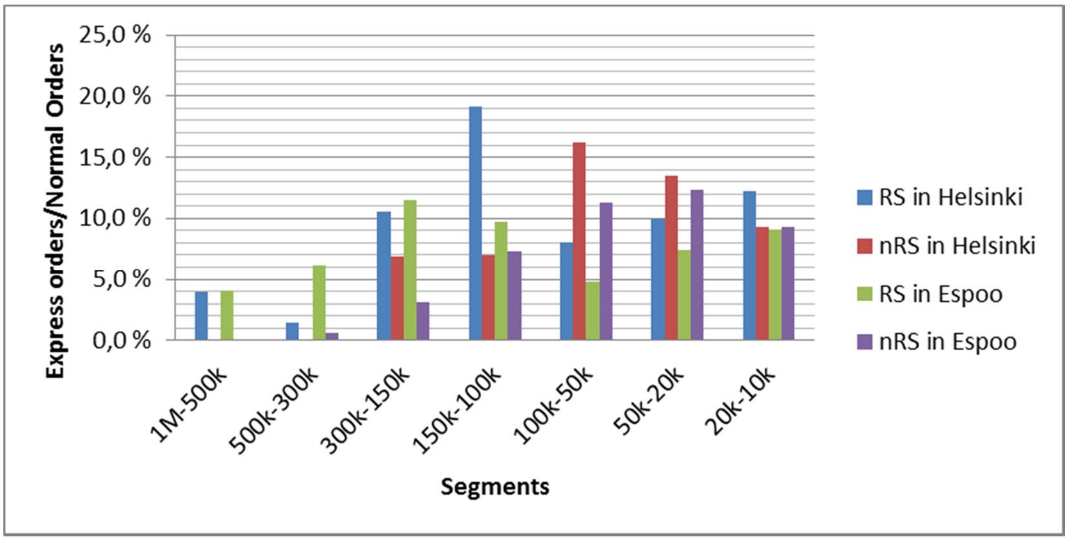


Figure 20: Average ratio of express orders by segment

5.6. Inventory Control Strength 2: Efficiency

Hypothesis: the ordering behavior in units with RS is more efficient than ordering behavior in units with NRS.

Since the analysis in this section deals with the time it takes for a unit to re-order the same unit, a cut off within the data set was needed: it is natural that the closer the order is to the end of the period, the more likely it is that the reorder is not captured in the data. Therefore, the date 26.1.2013, roughly in the middle of the time series, was chosen as a cut-off, and the analysis limits itself to time periods starting before this date were considered.

	RS	nRS	
Helsinki	52756	51773	104529
Jorvi	11306	10567	21873
Total	64062	62340	126402

Figure 21: Order rows before 26.1.2013

The rest of the order rows were segmented in terms of how the reflect order behavior.

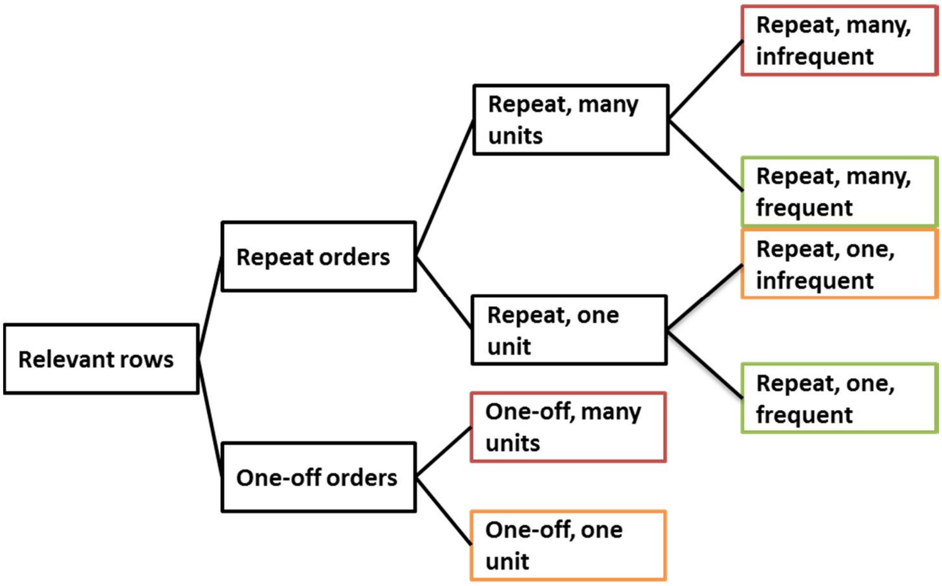


Figure 22: Segmentation of orders rows

Figure 22 illustrates the segmentation of the order rows deemed relevant for further analysis, i.e. those of Figure 21. The orange segments, “repeat, one unit” and “one-off, one unit” are inherently optimal, and thus do not reveal anything about the ordering unit’s behavior. Orders in the “one-off, many units” are ambiguous cases because orders in this segment have either optimally addressed a one-off need, or indicate a sub-optimally large order where stock from a single order has lasted through the entire period under review (i.e. at least 117 days). Still, one would expect inefficient inventory management to result in a lower proportion of orders being in this category.

The green categories, “repeat, many, frequent” and “repeat, one, frequent” reflects fairly efficient ordering behavior. Here, the ordering period has been under two weeks. The ordering period for “repeat, one, frequent” is roughly as short as it can be; in this sense, the fact that there is variance in the reorder periods in this segment is also a reflection of the demand of the product in question. One would still expect more products to be ordered in this "fully optimal" manner in an efficient process.

The ordering period for "repeat, many, frequent" is perhaps not minimal (i.e. there is still room to divide the order quantities into smaller batches) but is reasonably close. Within this segment, it is possible to look at how far the order costs are from the nearly stockless benchmark.

The red segment "repeat, many, infrequent" is the clearest indicator of inefficient inventory management. These could be ordered more frequently. Both "repeat, many, frequent" and "repeat, many, infrequent" can be further segmented by unit characteristics.

Table 8: Summary of above discussion

Optimized	***Optimizable***	***Not optimizable***	***Unclear***
Repeat, one, frequent *Repeat, many, frequent*	*Repeat, many, infrequent*	*One-off, one unit* *Repeat, one, infrequent*	*One-off, many units*

The quantitative analysis of the differences between these two services will follow the general principles of the methodology outlined by Robb and Silver (1998). The expected percentage cost reduction (EPCR) in holding costs will thus be based on the difference between achieved holding costs, give the performance of each service in optimizing its inventory control.

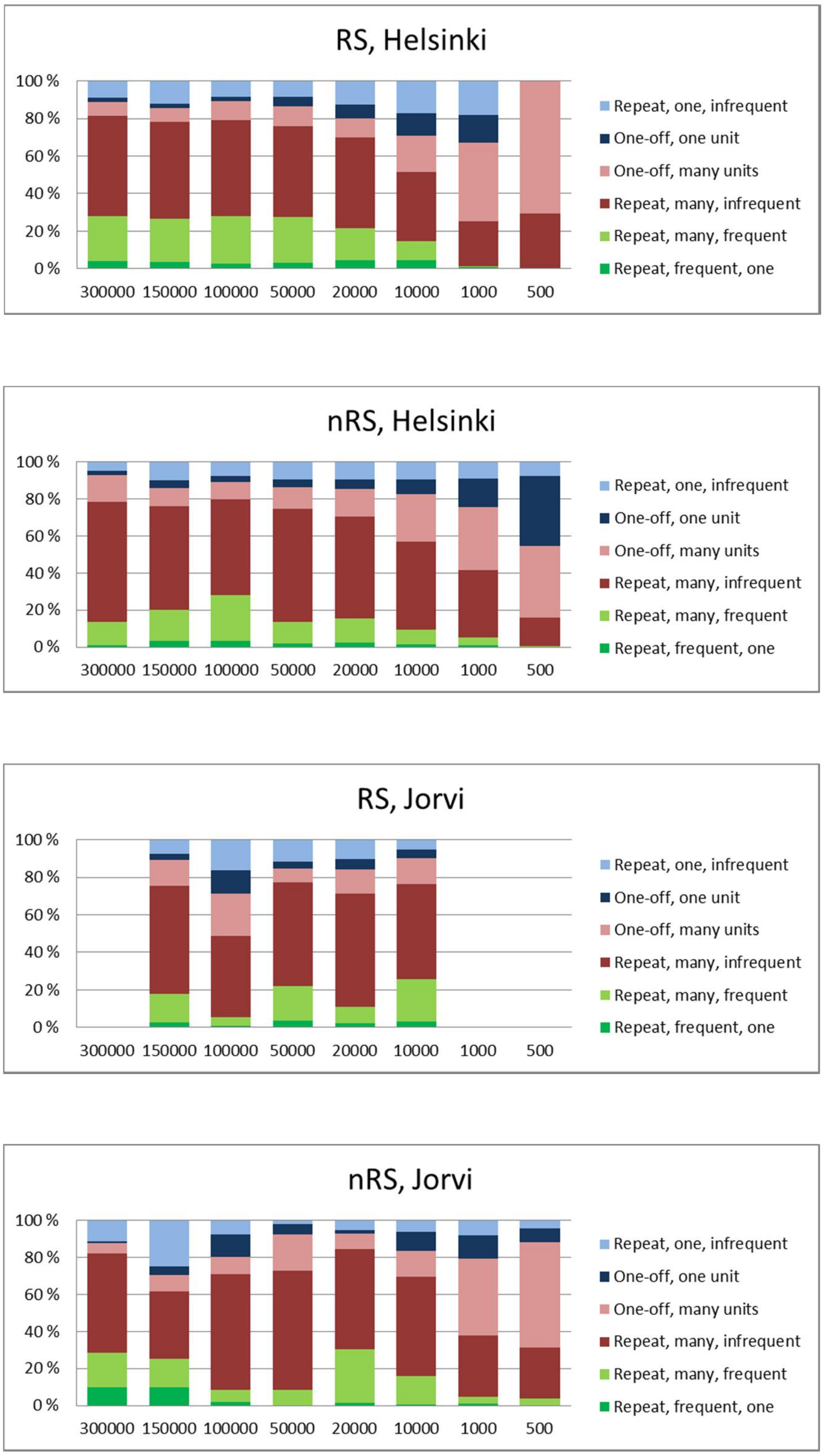


Figure 23: Inventory volumes by ordering behavior

A carrying cost was calculated for each of the items. This calculation assumed overall carrying costs to be 30% of inventory value, annually. It is also assumed that a reorder marks the time at which the ordered quantity has run out (the buffer is assumed to remain constant). Thus inventory costs are calculated as 30% of half of the ordered quantity times days held in proportion to a full calendar year (here, 360 days) (Bowersox, 2011):

$$Carrying\ costs = 30\% \times \frac{value}{2} \times \frac{days\ until\ reorder}{360}$$

For the hypothesis to prove positive, it should be shown that units currently under NRS manage stock more efficiently, i.e. have lower holding costs, if they were under RS.

We have now seen that the different segments of the data are able to manage stock efficiently to different degrees. The hypothesis should thus be tested by seeing what the holding costs would be if the inventory of NRS units had been managed in the same way as it was in RS units of the same size.

In this case, we will assume that *repeat, many, infrequent* (R,M,I), *repeat, many, frequent* (R, M, and *repeat one, frequent* are alternatives to each other. In other words, items in one category could have fallen in another, if the process had been performed more efficiently or less efficiently. Borrowing from the methodology adopted by Robb and Silver (1998), the analysis will compare the holding costs of NRS units, $ETRC_{nRS}$, with recalculated holding costs assuming the units had ordered as efficiently as RS units from the same location, $ETRC_{RS}^{*}$. As stated earlier, this improvement can be stated as:

$$EPCR = \frac{ETRC_{nRS} - ETRC_{RS}^{*}}{ETRC_{nRS}} \times 100\%$$

Stock efficiency is increased if EPCR is positive.

The first step was to calculate the **proportions** of the three ordering behaviors with respect to each other. Next **average holding costs per euro of inventory** were calculated for each segment, by ordering behavior (e.g. average holding cost of stock ordered frequently but with quantity>1 at Jorvi units with ordering volumes 1000€-10000€). The **overall inventory attributable** to these three ordering behaviors was also calculated.

Now, the holding costs attributable to these three categories can be recalculated as

$$ETRC_{nRS} = \sum(proportion_i^{nRS} \times inv_i^{nRS} \times avg\ holding\ costs\ per\ € \ of\ inv_i^{nRS}).$$

$ETRC_{RS}^{*}$ will be calculated by recalculating the original $ETRC$ with the proportions from units with RS from the same segment, i.e.:

$$ETRC_{RS}^{*} = \sum(proportion_i^{RS} \times inv_i^{nRS} \times avg\ holding\ costs\ per\ € \ of\ inv_i^{nRS}).$$

Figure 24 summarizes the results of the calculations. The results do not unequivocally support the hypothesis that RS is more efficient with keeping down holding costs. The improvement seems more apparent for units in Helsinki than in Jorvi.

At the Jorvi site, two segments show a significant drop in efficiency when moving from NRS to RS.

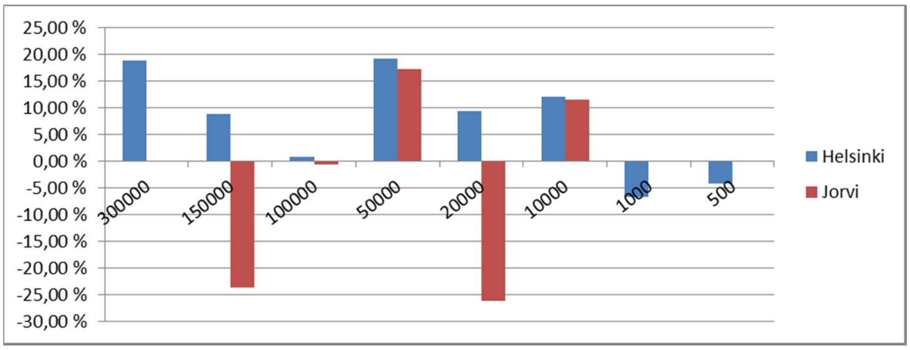


Figure 24: EPCR of Holding Costs by Location and Unit Size (NRS → RS)

6. FINDINGS AND IMPLICATIONS

This section deals with the implications of the results in the previous section and suggests key factors to explain these results. Finally, the focus is turned towards the future, as RS expands to a much greater number of units.

Table 9: Brief summary of results

Section	**Is RS better than NRS?**
Efficacy	Yes
Quality	Yes
Strength	Ambiguous

6.1. Analysis of case results

The RS process is less labor intensive

While the results on time use were not statistically conclusive, the observations strongly suggest that the hospitals own staff tends to use significantly more time to perform the three main relevant tasks of inventory management, considered in this thesis as checking, ordering and shelving inventory.

One major difference is that the separate task of ordering is eliminated in the RS process. Since inventory is checked and ordered simultaneously, a separate and time-consuming task of ordering items where stock has been perceived as low becomes redundant. The other tasks are also faster in the RS process, where they are characterized by deliberateness and structure. Checking is quick, particularly since the task is not interrupted by manual logging of deficiencies. The bar code reader used by RS enables the task to flow smoothly. Since the same individual has checked the order in the storage facility, items are recognized quicker at the destination unit, during shelving.

In contrast, the NRS process is, on average, plagued by stoppages. During inventory checking, shortages are logged manually. In some units, checklists have been devised to bring some efficiency to this task, but in others, items that need to be ordered are written in free form in e.g. notebooks. As an anecdotal example of the informality of this process in some units, in one unit, a piece of cardboard ripped from the side of a box was used to note down order quantities. Even if processes can achieve the required results without formal guidelines, the inherent quality of the process (i.e. how resistant it is to error) and the speed at which it is conducted on average can both be assumed to suffer from lack of formalized processes.

Caregiving labor resources are not only expensive but also unduly diverted from the important core responsibilities of hospital units, namely caring for patients. At the unit level, this means less time can be afforded to simple human interaction. More personal care is associated with greater patient satisfaction (Cleary & McNeil, 1988).In some units, the unit secretaries have relieved nursing staff from all inventory related responsibilities, but even in this case, this process cannot be considered as matching their level of education, skill set or interests.

At a macroeconomic level, the time of health care professionals is becoming scarcer: demand for care is increasing at the same time as a combination of demographic shifts and attitudes towards nursing as a profession has resulted in an increasing shortage caregiving staff. This phenomenon has already resulted in programs aimed at recruiting nurses from abroad, e.g. the Philippines (Vanhala-Harmanen, 5.12.2011). Not only are healthcare professionals a scarcity, HUS Logistics predicts that the market for potential logistics professionals is also becoming more limited (HUS-Logistics Strategy 2010-2015, slide 11), due to an aging population. These trends increase the importance of efficiency on the part of both HUS and HUS Logistics.

RS process is less prone to errors

The results of the analysis suggest that the RS process does in fact reduce ordering errors significantly. In fact, there was only one segment in which NRS seemed to outperform RS: 150 000 – 300 000 euros ordered during the period, in Espoo. This anomaly in the results should not be dismissed off-hand, but could certainly be a result of sample bias in this segment.

In light of the results and observations, RS process seems very robust. As was explained in the Background-section, bar codes linked to specific items are situated right underneath the item's shelf position, and the bar codes are associated with preset ordering quantities. The only real chance for error is during picking, but these errors are usually identified before shelving, since the contents of carts are checked in the storage facility.

A fair number of returns were still requested at RS units. It was not possible in this analysis to identify which of these returns resulted from items ordered by the RS operator, and which resulted from ordering executed by the unit's own staff. Still, because of the inherent robustness of the process, discussed above, it is not unreasonable to assume that even in the case of RS units, most of the errors are made by the unit's own staff when ordering inventory that is not kept in stock. Since RS only replaces ordering of items that are kept in stock, it is natural that the change in process quality can only be detected in this portion of orders.

One of the most common explanations for ordering errors is a misinterpretation of order quantities. To illustrate, during one order, two secretaries struggled for seven minutes as they tried to decide whether to insert a 1 or a 70 into the "Order Quantity"-field. The item came in boxes of 70, but there was no indication of how the quantity should be interpreted in this particular case. Not only did this take time (a typical example of a stoppage referred to above), but it is very likely that the interpretation decided upon by the secretaries was in the end the wrong one. It should be said that the author of this thesis was just as perplexed as the secretaries.

Errors are costly in several ways. First, reporting them is a process that takes up time in the unit. The report must then be reviewed by HUS Logistics. The item must be retrieved and logged. If the item is commonly used it can be reacquired by HUS Logistics, but if it is not, a request needs to be made to the supplier, to see if they will take it back. The supplier may refuse to accept the item(s), in which case the unit bares their cost. If the request is accepted, returning the item to the supplier takes up resources in itself.

A troubling amount of errors are made in the smaller NRS units, in both Helsinki and Espoo; errors in themselves are a strong argument for bringing them into the RS system. If units, especially those with high ordering frequencies, continue to remain outside the service, other ways of curbing the amount of errors should be considered. Material to support ordering could be made available. In practice this could be something as small as providing a template checklist for all units. Training material could be made available to help unit staff streamline their inventory management process. This material could provide tips and examples of current best practice. Much could also be done to make the ordering software more user-friendly. Pictures and less ambiguous quantity options could go a long way decreasing errors.

RS reduces express orders but more can be done

Inventory Control Strength is the area in which the effects of RS are most ambiguous. In the case of availability, the data seems to suggest that RS prevents stock outs in larger units but fails to do so in smaller ones. In fact, RS units perform worse than NRS units in segments 50 000-100 000 euros and 20 000 – 50 000 euros, in both locations.

Express orders, just like errors, result in additional costs, and add strain to the inventory management process. Express orders require separate handling and, often, separate delivery arrangements. These tasks are hard to structure or optimize, and also disrupt routines associated with the regular processes.

As has been noted already, it is clear that not all express orders result from of stock outs. Orders are sometimes expedited because of a need that has arisen unexpectedly of an item that is not stocked regularly. The unexpected and urgent need of certain unstocked supplies is unavoidable. In many cases, it may even be more efficient to not carry these supplies on hand, but expect them to arrive quickly once a need arises. However, in addition to these optimal express orders, observations and anecdotal evidence suggests that sometimes orders are expedited simply out of convenience. Unnecessary express orders can, and should, be decreased. This could be achieved by increasing awareness about the hidden costs of express orders in the ordering units.

Currently, HUS Logistics does not charge units for express orders. Making a portion of these costs explicit by sharing them with the customer could be one way of increasing awareness about costs that are currently completely hidden from the customer. This increased awareness, and the associated monetary disincentive, could potentially decrease the portion of unnecessary express orders. This might not be a practical solution however, and might lead to unfair treatment between units, some of which are bound to have a higher proportion of completely justified express orders.

Potential for improvement in inventory efficiency

With regards to inventory efficiency, the method of comparison used in this study, which focused on ordering patterns, did not reveal major differences between the two processes. It is important to remember that this method tries to reflect inventory efficiency, but is not a perfect proxy for the underlying indicator of efficiency: average inventory levels.

However, it seems that the RS process orders a larger proportion of its stock efficiently, as a larger percentage of volume is ordered frequently. Here, one should be cautious in making strong conclusions, as the ability to order efficiently varies between units. This ability is influenced by various factors, including the unit's size, its ability to predict demand and the types of items that the unit stocks. Some items come in very large, indivisible quantities. Stocking of these items is difficult to optimize in smaller units. Some of the distorting effect of these constraints is thankfully removed from the analysis as a result of the segmentation of units by ordering volume.

Even when taking into account the balance that has to be made between ordering costs and holding costs, it seems that there is still room for optimization in the RS process. In practice, the upper limits are not always followed religiously, and the RS-operators still sometimes rely on their own judgment in placing orders. This behavior is somewhat self-enforcing, since non-reliance on predetermined boundary levels removes a need to adjust them. Inventory level optimization is a complicated equation, the results of which need to be followed quite religiously for it to bear fruit.

In the units that are not part of the RS service, inventory levels are not formally optimized at all. Unit staff that are in charge of ordering base order quantities on requests by other staff and on their own perceptions of past demand. Not only are quantities not formally optimized, but there is a risk that the optimization that is being conducted informally is actually doing so based on the wrong incentives. "Well lets order a bit more, so it doesn't run out right away" and variations of this remark were heard a few times while observing inventory management in NRS units. Implicitly, the optimization at work behind such a comment minimizes ordering, not overall inventory management costs.

This behavior is completely understandable. The individuals in charge of inventory management in units, especially when they are caregivers, are likely to not consider inventory optimization as a primary goal in their work – for many, it is not likely to count as a secondary goal either. This leads not just to a lack of incentives to do the task optimally, but even to reverse incentives: the more is ordered, the less often this secondary task needs to be performed. When this dynamic is combined with a lack of training in inventory management, no formal tools for inventory optimization, no explicit targets or controls for minimization of holding costs, it is clear that inventory efficiency in NRS units is unable to compete with that of RS units.

6.2. Key ingredients of RS success

When comparing the two processes and their performance, some differences stand out as being key in explaining why RS performs better. The most important of these success factors are outlined here as the use of bar code readers, process structure and process ownership.

The effect of bar code readers on performance

The use of bar code readers, one of the major technological advantages distinguishing the RS-process, gives the process a clear edge over its competitor, in several ways. First, the readers significantly reduce the time needed to perform the process. The bar code reader significantly quickens the logging of depleted stock during the checking process itself, eliminating the need to write out items or find them in a checklist (depending on the unit). The required accuracy slows and burdens the process. The system is also preprogrammed with quantities for each stock, eliminating the need to decide these with every order. Most significantly, the bar code ordering system eliminates separate inputting of order details, i.e. the whole task referred to in this thesis as *ordering*.

Second, the use of readers virtually eliminates the chance for error in the checking and ordering stages of the process. Quantities are not inputted manually, and orders are made by physically pointing to the spot on the shelf where a type of item is running low on stock.

Some units are experimenting with bar code readers of their own. While this decreases the chance of error, this improvement in the NRS process does not necessarily have the same potential for time saving as does switching to the RS process. This depends on how aware the staff in charge of ordering are of inventory demands. In some units, ordering is performed by secretaries that rely on medical staff to report supplies that need to be ordered. In these units, there are no plans to teach all staff how to operate the bar code readers, nor would this likely work in practice (due, for instance, to the risk of double-ordering). Therefore, even bar code readers are adopted, it is likely that required items will still be reported manually, and the savings brought on by the bar code reader will be limited to increasing the speed with which needed items are identified and ordered.

Importance of structure and process ownership

In some NRS units, staff members describe how neither the checking nor stocking processes are usually performed as deliberate, identifiable task. Rather, a few minutes here and there are afforded to each, whenever time permits. This is very likely to result in inefficiency, as the task is started, stopped and restarted several times. Especially in the case of checking, an incremental and unstructured approach is very likely to lead to either too little checking, possibly leading shortages; or too much checking, resulting in unnecessary expenditure of time and energy.

In contrast, RS-operators execute inventory checks and replenishments according to a pre-determined schedule. Checks are often performed in clusters, creating a Fordist structure to the process: RS-operatives move from storage facility to storage facility, from unit to unit, with no other activities to distract from this task. The risk of the process being under or over performed is much lower. Since the frequency of the cycle is determined in conjunction with the wishes of the unit, it can also be adjusted if the cycle turns out to be sub-optimal in practice. A well-structured process thus increases both the efficacy and the strength of inventory management.

Another observation that bears noting is the speed that is developed, by RS-operatives, through the repetition of this well-structured process. As literature on the effect of experience suggests, people become faster at performing tasks for a number of reasons. The inverse relationship between experience and process costs, referred to sometimes as the learning curve phenomenon (also, progress curve, improvement curve), was first reported in 1936 (Yelle, 1979) has been proven empirically (e.g. Hax & Majluf, 1982), and has been explained by a combination of several factors. Most relevant to the argument for structure and ownership is the idea that repetition builds dexterity in the task in question, which increases the speed at which it can be performed (ibid. p. 53).

In this case, repetition of storage checking allows the RS-operator to build a memory for the require storage levels of items in a store room. Ideally, an RS-operator has full ownership of the entire inventory management process for a specific set of storage rooms, holidays and sick leave being the only instances when management is handled by others. Repetition drastically decreases the time required to locate items in the different facilities, and also increases the ease with which the operator identifies SKUs that are running low. An awareness of which items need constant attention also develops with time. This is already the reality at Jorvi Hospital, for instance. The same phenomenon also applies, to an extent, to medical staff, provided that responsibility for checking storage rooms is not divided between too many members of staff. However, as this is not considered a core task, in some units, these tasks are circulated for reasons of fairness.

Ownership also strengthens the process in more subtle ways. Having accountability for the management of a specific storage facility allows for faster detection of problems in e.g. cycle speeds, storage layout. Ownership also seems to increase job satisfaction among the RS-operators: increased ownership is a point of pride, and also allows for increased independence in the timing of processes. In Espoo, at the Jorvi site, where RS has been most fully implemented, there are currently two workers charged with executing the service.

6.3. Towards expansion of RS

RS is expected to expand to a much larger proportion of units, and there is even a debate about whether it should be mandated as compulsory for all units that fit a certain profile. Expansion will certainly both enable and necessitate change. This will not only mean an increase in resources, but this thesis argues that an expansion in RS should lead to structural changes in the make-up of HUS Logistics workforce. Expansion also brings possibilities for increased process optimization.

RS expansion will require a larger number of RS-operators. Currently, at the Jorvi hospital site where the RS process is well established, two operators each manage roughly half of the 23 units that are part of the service. Ten units per operator can be used as an initial estimate for the required workforce as the process expands. On the one hand, these operators are very experienced and acquainted with the storages they manage; and one should estimate capacity per operator conservatively, because the demands of units vary significantly from one another. On the other hand, if recruitment succeeds in selecting individuals that are as motivated and as capable as the operators in Jorvi, it should not take more than a month or two to reach their level of efficiency.

On top of the efficiency gained from experience ("dexterity"), expansion will also enable increased optimization of the process. As more units subscribe to the service, units can be divided amongst operators more efficiently, in terms of the makeup of the portfolios of RS-operators, in terms of number of units and the routes (from unit to unit) that they enable in practice.

Expansion also provides the opportunity to fine tune the process itself with the goal of increase efficiency. Once the number of fully staffed RS-operatives that operated from a specific terminal reaches critical mass, it might be possible to hand over some of their administrative responsibilities, for instance, to support staff. With the work more geared towards visiting units, and time spent working at the terminal is minimized, the number of units in each operative can manage can be increased.

Technology can also increase the mobility of RS-operatives and their ability to perform tasks away from the warehouse. The operator is able to build and develop a relationship with the staffs of the units he services, thus becoming the main contact between the unit and HUS Logistics. This increases the flow of information, increases mutual understanding and perceived service quality. One key to increased efficiency lies in increasing the number of tasks carried out during each route. Returning to the terminal represents a stoppage and down-time from the core tasks performed by RS-operatives: time on paperwork should be decreased to a minimum, in favor of more time for checking and shelving.

As RS becomes a more established service, and HUS Logistics gains even more experience about the required service levels of different sized units, clearer guidelines can be set on the service offered. Currently, the frequency of the inventory management process is negotiated with the unit's head. More frequent replenishment cycles are sometimes offered ease the transition to RS. Less room for negotiation would help to make sure that units are not being promised an unnecessarily high service rate, which put unnecessary strain on the resources of RS operatives.

The expansion of the service has the potential decrease the need for inventory at the HUS level. Because of the Portfolio Effect (outlined in the literature review, above) effective inventory management that lowers inventory levels in local storage, will lower the need for inventory in the whole system. This is essentially because having stock at centralized storage facilitywill make it available for the all storage units, while unnecessarily having extra stock in local storage makes this stock unavailable to demand in the rest of the system. The importance of the Portfolio Effect on overall inventory needs will only increase once HUS Logistics consolidates all of its larger storage facilities into one, central facility, due to be ready in 2015. Efficient cross docking becomes an important concept as RS expands, since as HUS moves to a single centralized storage facility, minimizing disruptions in the regular supply chain (e.g. minimizing express orders) becomes even more important.

Restructuring and increased efficiency will enable RS to expand at a faster rate than the number of operatives needed. Importantly, expansion of RS will alleviate some of the pressure on other functions performed by Logistics. This thesis has shown that the process quality of RS is significantly better than that of NRS, and RS expansion is thus expected to decrease returns at HUS significantly. As explained above, this reverse logistics process ties up a significant amount of resources in the reclaiming unit, who detect and report the error; of Procurement Services, which handle relations with suppliers in cases when the items are returned to them; and of logistics operators, who transport and log the items from unit to terminal, and from terminal to supplier.

RS expansion is also predicted to decrease shortages, and thus expedited orders. Express orders mainly strain Logistics Services, for whom an express order requires separate handling and transport. Also, RS expansion will decrease the portion of orders that require assistance from Helpdesk staff, who assist units in making orders.

If the positive effects of expansion are reinforced by measures that decrease errors made by staff ordering non-stocked items (e.g. education, user-friendliness of ordering platform), and measures that decrease avoidable express orders (e.g. awareness, clearer guidelines), some of the additional resources required by RS can be found within the organization. At the same time, the expansion of HUS Logistics client-base will probably mean that any decreases in resources in any of HUS Logistics' divisions are relative instead of absolute.

It is hoped that the framework established in this thesis will also frame how RS is evaluated and developed in the future. This study intends to draw attention to the importance of considering the merits of processes holistically. It is, after all, very difficult to maximize a supply chain's potential without a well-developed set of performance measures and metrics geared towards effectiveness and efficiency (Gunasekaran et al., 2004).

This means considering direct costs as well as more indirect, hidden costs associated with a certain solution. The study also attempts to give a system-level perspective to a question that has until now been considered, and decided upon, at the unit level. A narrow unit-level perspective, combined with a focus on explicit costs has, in some units that have considered the service, resulted in the overemphasis of the 300 euro per month subscription fee. A system-level perspective that remembers to take into account the less obvious benefits of RS and its potential when fully implemented is needed, and from this perspective the RS process clearly represents superior model for inventory management. It is a process that strains the supply chain less by decreasing express delivery and reverse logistics; it is a process that cheaper to maintain, while freeing more time and energy of caregiving staff to do the work they value most and were trained for.

7. THEORETICAL IMPLICATIONS

Trichotomizing the value proposition of inventory management

This study proposed a new way of conceptualizing the different dynamics at play when assessing inventory management. The strengths of this conceptualization are that its elements are precisely defined and fully quantifiable (*contra* loose or qualitative). There are many qualitative features of inventory management that are certainly interesting and important, *especially* when inventory management is being offered as a service. Still, the starting point, and in some ways the challenge undertaken by this study, was to create a framework for assessing inventory management that was as quantifiable and objective as possible.

Even more importantly, this conceptualization aims to be as *MECE* (mutually exclusive and collectively exhaustive) as possible. This was the main motivation for creating a new framework. Reviewing the literature on inventory management, and logistics more generally, lists of potential aims are plentiful (lower inventory, higher service level, lower cost, shorter lead times, predictability, responsiveness, etc.), but there was not a framework available that adequately integrated these aims in a way that dealt with their conceptual overlaps and conflicts. As an example, shorter lead times and increase costs or decrease costs, and has an impact no service levels in a number of ways. A smorgasbord of interconnected and sometimes inadequately defined positive and negative consequences of inventory management was an excellent starting point, but also highlighted the need for a well-defined set of qualities, and a framework in which the dynamics between them were explicit.

Ordering behavior as a way to measure inventory efficiency

This case study applied a fairly rare method in its analysis of inventory efficiency. Actually, in reviewing relevant literature, concentrating on ordering behavior rather than the resulting average inventory levels has been done before (e.g. Disney & Towill, 2003), but usually in the context of simulation. This thesis takes this concept, and applies it to the analysis of actual ordering data.

This study highlights the need for a comprehensive segmentation of the data before any conclusions can be made when using this method. The ordering bodies should be segmented by size, as unit size will inherently allow for more efficient ordering. Unit size affects, for instance, the magnitude of inventory flows and the amount of available storage space. Importantly, this study finds that it is equally important to dissect the types of orders from each other when preparing the data. The ability to optimize ordering behavior differs and is heavily dependent on the characteristics of the item (divisibility, cost, size), and the type of demand for the item witnessed by a specific orderer.

8. LIMITATIONS AND FURTHER RESEARCH

This study aimed to compare the two processes, RS and NRS, in a holistic and objective manner. With additional resources some of the suggested methods could have been taken a step further to increase the accuracy and confidence of the results. The study also uncovers some interesting further strands of analysis.

With more time and resources, the analysis on process times would ideally have contained more measurements. At the moment, the process times cannot be considered accurate reflections of the entire unit population, but rather give a general understanding of the magnitudes in question. In order to gain a more detailed understanding, these times could then be scaled by an adequate indicator of the requirements set by that particular environment. Units are different and this needs to be taken into account.

The number of products kept in storage is the best available indicator with which to scale the resources committed to the inventory management process. Having more product categories makes the task of manually monitoring stock levels more strenuous, simply because there are more things to track. In the ordering phase, the complexity of an order lies not in the volumes but in how many separate items need to be ordered. In the stocking phase, volumes do admittedly play a role in the magnitude of the task at hand. Still, a larger and more complex storage room does make it somewhat harder to determine the appropriate location of an incoming product.

The study on shortages could be developed upon by looking at the type of items requested for express delivery. If a proper inventory of stocked items was conducted, this would help to distinguish items that are stocked regularly and items that are not and/or should not be held before a need arises. An analysis could then study the reasons for these express order requests in more detail, shedding light on which express orders are optimal and justified (items that are needed quickly but should not be stocked), which orders reflect bad inventory management (i.e. shortages), and which are otherwise unnecessary (expedited out of convenience).

In order to gain a more accurate understanding of ordering behavior (*Inventory Control Strength 2*), a more meticulous study should seek to delimit the pool of items studied only to those that are required regularly. This would even out the playing field and take away some of the inherent differences in care providing units that result from the type of care and the type of supplies they require.

There are also many interesting questions that merit further study. One could seek to calculate the costs related to the reverse logistics process associated with ordering errorsthe cost associated with express orders could also be estimated, which would help in determining more accurate criteria for whether or not to have buffer stocks of a specific item in local storage. One could also seek to quantify the learning curve and capacity to take on units of an average RS-operator. Since RS is projected to expand significantly in the medium term, optimal use of each RS-operators resource will be very important, in terms of operating costs, and in terms of job quality and retention rates.

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