The Effects of Installing Automated Ward Solutions for Medicine

A Case Study at Växjö Central Hospital

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PREFACE

The authors would like to express their gratitude to the Central Hospital of Växjö for providing us this opportunity to write a degree project; special thanks to Magnus Munge and Pia Törndahl at the Pharmaceutical Unit for their enthusiasm and guidance throughout the project. Further thank you to all the nurses and employees who participated in the interviews and observations; they were all helpful and provided valuable primary data for this degree project. It has been an enriching opportunity for the authors to gain a larger understanding of the hospital as an organisation while applying their theoretical knowledge.

The authors wish to express their gratitude to the encouraging supervisor Petra Andersson, the diligent opponents and the proficient examiner Helena Forslund for providing the authors with constructive feedback and appropriate input throughout the project’s development.

Växjö, 140528

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SUMMARY

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Title: The Effects of Installing Automated Ward Solutions for Medicine

Research Questions:

Research Question I: How does the material management process of medicine differ between a ward with, and without, an Automated Ward Solution (AWS)?

Research Question II: How do time and costs differ in the material management process of medicine between a ward with, and without, an AWS?

Research Question III: How has the instalment of a central storage affected the number of orders placed for wards?

Purpose:

The purpose is to map and compare the material management process of medicine between a ward with, and without, an AWS. Further the mapped processes will be timed, allocated costs by applying TDABC and then compared. The purpose is as well to describe how the instalment of a central storage has affected the frequency of orders placed for wards.

Methodology:

This project is a qualitative case study as the authors wished to understand the phenomena of having installed AWSs for medicine in a real context. The primary data was collected through interviews, observations and studying of documents; the secondary data was collected through scientific articles and literatures. The collected data answered the research questions with the help of process mapping and TDABC.

Conclusion:

In the created process maps it is found that the extensiveness of the different processes when compared are similar for both wards; however the allocated costs calculated through TDABC sometimes differ due to the involvement of the Pharmaceutical Unit as it carries a higher capacity cost per minute. Ward 5 can be assumed to have a higher security and accuracy due to the instalment of an AWS and by having laid more responsibility on the Pharmaceutical Unit. The AWS has however led to a larger waste for Ward 5 as it cannot return regular medicine anymore. This project could not directly connect that the instalment of a central storage with reduced order lines; however it can be assumed that it has contributed to the decreased order lines placed.
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1. INTRODUCTION

This chapter aims to introduce the reader to common problems in the health-care industry before thoroughly explaining the case by; presenting the Central Hospital of Växjö (CLV) which is the project’s object of study; briefly explaining CLV’s previous and current material management process of medicine for wards; briefly explaining the instalment of a central storage as well as including a description of Automated Ward Solutions. This is followed by discussing CLV’s perceived problems which concludes this project’s research questions and purpose. The chapter ends with an illustration of the project’s disposition.
1.1 Background

The spending on health care in the developing world accounts for a large and growing share of many countries’ gross domestic product (Cooper et al., 2011). Due to this large spending, healthcare providers become increasingly concerned with the cost-effectiveness as well as the increased information transparency in the healthcare process (Goundrey-Smith, 2013). This has caused the health care industry to search for new approaches in order to lower costs, though at the same time increase quality and value. Supply chain management has been successfully adopted by other industries to achieve this; however the healthcare industry has been slow in applying these practices. With 30-40% of hospitals’ expenses related to logistic activities and with general similarities in needs and flow-complexity of health care and industry; this suggests that an introduction of supply chain theories can be beneficial for the health care sector. (Aronsson et al., 2011)

The logistics and supply chain management represents a potential area for operation cost reduction (Christopher, 2011). The most powerful supply chain management concept is that of cost management and an organization’s costs must be understood (Anklesaria, 2008; Cousins et al. 2008). French et al. (2013) highlights the fact that healthcare is complex; and it is difficult to measure how changed processes have affected costs and time. Hospital supply chain concerns on a day-to-day basis the pharmaceutical and medical supplies. These activities are traditionally organized on separate units of the hospital. (Jacobs, 2011) Coordinating this flow of material and its related tasks is by many authors such as Arnold et al. (2008); Jonsson (2008); Park et al. (2011); Alvarado-Iniesta et al. (2013) and Chandra et al. (2013) termed as the “Material Management Process”. As according to Callender & Grasman (2011) inefficiencies in the health care sectors can be reduced by the material management process being specifically focused on “Inventory Management”, which Slack et al (2012) explains as the activity of controlling and planning the accumulation of resources as they flow through the supply network. Both terms are to be used henceforth in the project; however “material management process” will be the main term as it includes “inventory management”. The expenditure on materials is about 30-35% of most hospitals’ operating budget. Therefore the material management process is the first place to look when the aim is to reduce costs in a hospital. (Chandra et al., 2013)
The material management process can be divided into different, smaller processes according to the categories provided by the SCOR-model such as Plan, Source and Return (SCOR Supply Chain Council, 2014; Mattsson, 2012). With the guidance of these three categories, this project will divide the material management process into five different processes in order to ease the explanation, examination and analysis of the material management process.

Potential cost-binding activities in a supply chain are due to the business’ time consumption (Bregman, 2013). This aligns with Mattsson (2012) and Lumsden (2012) who both claim consideration of time is gaining a greater importance. In order to quantify costs and measure time for different activities; they need to first be identified. This can be done by having a process map made. (Lambert & Pohlen, 2011; Damelio, 2011; Bergman & Klefsjö, 2010; Anklesaria, 2008) From the different activities in a process map a Time-Driven Activity Based Costing model (TDABC) can be applied. This model entails that costs are allocated by using time as the main driver, and that an activity’s cost is calculated by the total cost for exempli gratia a department, divided by its time consumption in a given period of time in order to get a cost per time unit and then be able to apply it to each activity. (Kaplan & Andersson, 2007) This is a suitable model to use in a health-care setting as it is hard to otherwise accurately be able to quantify process improvements in terms of time, costs and employee resources (French et al., 2013)

Other potential cost-binding activities in a supply chain are due to the business’ inventory management (Abdelaziz & Mejri, 2012). To have an optimized inventory can make a positive difference for an organisation as there can be high costs related to staying either above or below the optimal level (Abdelaziz & Mejri, 2012). Jacobs (2011) explains that normally in hospitals, inventory requires the biggest working capital.

Pan & Pokharel (2007) and McClellan (1994) state that hospitals work in an environment where demand is uncertain, and Cardoso et al. (2012) explains that hospitals’ uncertainty derives from lack of available information. Uncertainties are most commonly buffered by inventory; however this is likely to lead to excess safety stock, increased costs and an inefficient resource allocation (Yu et al., 2001). Safety stock is a major difference in inventory management at a hospital compared to another business
(Jacobs, 2011); in a hospital excess safety stock is common as it is prohibited to have a shortage of medicine (Baboli et al., 2011), and calculating the cost of running out of stock is harder in a hospital as consideration for a patient’s well-being or even its life could be at stake (Jacobs, 2011). Munge (140120) concurs as he explains that a ward at CLV must always have access to a medicine either from storage in-house or from the storage held at the pharmacy.

1.2 Case Description

Landstinget Kronoberg is the Health-Sector of Kronoberg County in Sweden. It is responsible for the health care in the county and is run by elected representatives in the county council. Landstinget Kronoberg aims to give health care with respect for people’s equal worth and that this care is given with a secure and high quality. It employs over 5000 people in 2 hospitals, 33 health centres, 15 public dental health clinics as well as clinics for rehabilitation and psychiatry. (Landstinget Kronoberg, 2013a) One of these hospitals is the previously mentioned object of study for this project, CLV, which consists of 20 wards, 25 receptions and 27 clinics (Landstinget Kronoberg, 2013b).

1.2.1 Description of CLV’s Previous Material Management Process of Medicine

Granberg, Head of Department at Ward 5 (140306) explains that year 2008, the hospital introduced a new unit called the Pharmaceutical Unit due to the need for structure in wards regarding their material management process of medicine as it was “chaotic”; orders were being placed without control and much time was spent by nurses on the material management process of medicine instead of on patients. According to Pia Törndahl, Pharmacist at the Pharmaceutical Unit (140303), the Pharmaceutical Unit is responsible for the inventory of medicine and medical supply for the previously mentioned 20 wards located within the hospital compound. The Pharmaceutical Unit terms this as them providing the wards with a “pharmaceutical service”. Further, Törndahl (140404) explains that as a means of trying to control a ward’s inventory an ordering system called “Provider” was installed at CLV. It works as a support program to the already installed ordering system “E-builder”. It is the Pharmaceutical Unit’s wish that every ward would place their orders through Provider; this as it first of all shows every ward which latest ordered a certain medicine, which might lead to the ward
not having to place an order at all as they then could borrow from that ward; but it also provides statistical data for the Pharmaceutical Unit. The order is then automatically transferred and processed through E-builder by itself and from there sent to the pharmacy located within CLV.

Before December 2013; the pharmaceutical service only entailed that the Pharmaceutical Unit once a week went to the different wards’ storage facilities to control the inventory levels and determine which medicines that needed to be ordered; and then placed the order to the pharmacy. The minimum stock levels had been decided in a yearly meeting with the Pharmaceutical Unit and the specific ward; it was according to these pre-determined quantities that the inventory was controlled. The ordered medicines would arrive the next day and the Pharmaceutical Unit would then unpack and shelf them. When a ward would be out of stock of a medicine promptly needed, on any day other than when the Pharmaceutical Unit performed an inventory control, they would themselves place an order to the pharmacy located in CLV. The ward would then alone be responsible for the unpacking and shelving of the received medicines. Each ward was also alone responsible for the handling of unused narcotics, and the routines regarding this could differ from each ward; either the narcotic was discarded directly or sorted and placed back on the shelf. (Törndahl, 140303)

CLV’s material management process of medicine for wards worked as follows; the Pharmaceutical Unit had negotiated a price with the pharmaceutical industry on the medicine to be purchased. This medicine was stored by a wholesale distributor who later sold the medicine for that predetermined price to CLV’s pharmacy who stored the medicine in their storage facility. When the pharmacy received an order either from the Pharmaceutical Unit after their weekly inventory control or directly from the wards themselves; the pharmacy would pack the order and deliver it to the ward’s storage facility. Each ordered medicine is delivered at a fixed cost. This entails that it is not the quantity of items of a certain medicine being billed, but the quantity of orders of different medicines. Therefore the more sporadic orders placed a part from the weekly replenishment from the Pharmaceutical Unit’s pharmaceutical service, the higher the costs. (Munge, 140120; Törndahl, 140303) Depending on the selected order delivery time; the fixed cost per order line may vary. Below follows a table summarizing the three different types of orders that can be placed and their according fixed costs;
Table 1: Fixed Cost per Order Line of Medicine at CLV (Munge, 140428)

<table>
<thead>
<tr>
<th>Delivery time</th>
<th>Fixed Cost per Order Line charged by CLV’s Pharmacy</th>
</tr>
</thead>
<tbody>
<tr>
<td>24 hours</td>
<td>55,90 SEK</td>
</tr>
<tr>
<td>4 hours</td>
<td>76,70 SEK</td>
</tr>
<tr>
<td>Emergency</td>
<td>93,20 SEK</td>
</tr>
</tbody>
</table>

The previous material management process of medicine for wards can be illustrated as below. This model is self-made and will therefore not depict another author as reference. Henceforth, every figure, table or picture without a reference depicted is to be understood as a self-made creation by this project’s authors.

1.2.2 Description of CLV’s Central Storage

As a way of trying to reduce the number of order lines placed, it was concluded that a common storage facility, a “central storage”, would be appropriate at CLV in order to avoid the actions as illustrated below;

Figure 2: CLV’s Actions before the Instalment of a Central Storage

This central storage would act as buffer storage to which the wards would turn for medicine needed, before having to place an order at the pharmacy as previously done. The original idea developed into installing Automated Ward Solutions (AWS) to function as the central storage; this as the Pharmaceutical Unit wished have an electronic system where it is possible for the wards to see the stock levels, to have an electronic system indicating when a product needs to be replenished; an electronic system providing statistics which can function as a decision base for future stock level decisions and increase the secure handling of narcotics. (Munge, 140120) The desired function of the central storage is illustrated below;

Figure 3: CLV’s desired Actions after the Instalment of a Central Storage
During the process of exploring the possibilities of installing AWSs at CLV, the Pharmaceutical Unit found that it could be beneficial to install AWSs at a ward as well, due to the same reasons as for the central storage. From the electronic system it would then be possible for the nurses to see if the ward-AWSs had a certain medicine in case it was not available at the central storage; providing the nurses yet another option before placing an order at the pharmacy. The decision was made to install an AWS as a central storage and to conduct a trial by installing two AWSs at the medicinal Ward 5 and the surgical ward 34; these were installed in December 2013. (Munge, 140120) The central storage and Ward 5 are two out of three objects of study in this project.

1.2.3 Description of an AWS

An AWS includes dispensers, cabinets and electronic locks (Health Tech, 2010a). The dispensers (see picture 1) are suitable for one-dose pharmaceuticals, and other small products for which the hospital requires high security and 100 % traceability of extractions. In order to get the medicine or supply, the nurse must first log in and thereafter choose the patient, product and amount; thereafter only the exact amount requested will be available for extraction. (Munge, 140120; Health Tech, 2010a)

![Picture 1: Automated Ward Dispenser (Health-tech, 2010b)](image)

The cabinets (picture 2) can store larger volumes than the dispensers. The medicines are here placed in electronically locked cabinet drawers in which each drawer consists of multi sized sections. These sections are either closed (picture 3) or open (picture 4). When the cabinet is closed the nurse can, after entering the same information as for the dispenser, open the cabinet drawer and see a light lit up on the cover of one of these
sections (picture 3). The nurse will then only be able to open this now unlocked section in the drawer and extract the amount of medicine needed. These sections are used for medicine from opened packages. (Munge, 140120; Health Tech, 2010) In an open drawer, the nurse can access any section. The medicine is here stored in sealed packages, in no alphabetical order and not grouped according to type of medicine; this to minimize the risk of a nurse extracting the wrong medication. (Munge, 140219)

The electronic lock (see picture 5) can be placed on any door and is connected to the AWS computer system. When extracting, the electronic lock will detach allowing for the door to be opened. CLV uses this lock on refrigerators. (Munge, 140219)
1.2.4 Description of CLV’s Current Material Management Process of Medicine and the Project’s Focus Area

For the remaining wards without an AWS installed, their storage facility layout has not changed. One of these wards is the medicinal Ward 3, which will be an object of study in this project. Here, the storage facility’s walls are lined with shelves, with a working area underneath. The shelves provide storage space for medicine and equipment which does not need to be refrigerated; for those which do, there is a refrigerator next to the shelves. The shelves are marked with stickers with barcodes; indicating where each medicine is to be placed. (Törndahl, 140303)

![Storage at Ward 3](image)

After the installation of AWSs, the pharmaceutical service given by the Pharmaceutical Unit has developed and now entails more tasks than previously. Activities that still are the same regardless of an AWS installed or not are that the stock levels are still determined by yearly meetings, the lead time for receiving the medicines is still the day after the order is placed and a ward can still place orders directly to the pharmacy. For a ward without an AWS, the routines and the pharmaceutical service provided are still the same, with the exception that the nurses now go to the central storage or a ward-AWS prior to placing an order to the pharmacy.

For the wards with an AWS the pharmaceutical service looks a bit different; the Pharmaceutical Unit does its inventory control twice a week here and is also responsible for the reverse logistics of unused narcotics. Furthermore, the Pharmaceutical Unit is now also responsible for the stock keeping and replenishment of the central storage; it
places orders to the pharmacy and unpacks and distributes the medicines into the central storage’s AWS and handle possible narcotics to be returned. (Törndahl, 140303)

The current material management process of medicine for CLV’s wards looks different compared to that in figure 1. The first three steps are the same; the Pharmaceutical Unit still negotiates a price with the pharmaceutical industry, the wholesale distributor still keeps it and sells it to the pharmacy and the pharmacy still holds the inventory and handles orders received at a fixed cost. The change is however that the orders can now be delivered to either a ward without an AWS, a ward with an AWS or to the central storage. From either place, the medicine is then distributed to the patient. (Munge, 140120)

This project will not examine the steps from the pharmaceutical industry to the pharmacy’s storage of medicine; nor the distribution from CLV’s pharmacy to a specific storage facility or the distribution of medicine from a nurse to the patient. This project’s focus will solely be on the storage facilities with or without an AWS as well as the central storage with an AWS; including the possibility that wards may interact with each other and the central storage in terms of the material management process of medicine. The table below depicts the project’s objects of study;

<table>
<thead>
<tr>
<th>The Project’s Objects of Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Ward 3 without an AWS</td>
</tr>
<tr>
<td>• Ward 5 with an AWS</td>
</tr>
<tr>
<td>• The Central Storage with an AWS</td>
</tr>
</tbody>
</table>

Table 2: The Project’s Objects of Study

Figure 4 below illustrates the current material management process of medicine for CLV’s wards and the circled area below illustrates this project’s focus. Henceforth, it is only the circled area which is addressed whenever the term “material management process of medicine” is used in the empirical.

Figure 4: CLV’s Current Material Management Process of Medicine with the Project’s Focus Area
1.3 Research Discussion

1.3.1 Research Discussion for Research Question I

“How does the material management process of medicine differ between a ward with, and without, an Automated Ward Solution (AWS)?”

According to Jonsson & Mattsson (2011) an AWS is a type of Paternoster storage as it is automated and suitable for picking stock and smaller objects from opened packages. Jacobs (2011) further explains how automated storages are used to control the dispensed medications and medical supplies in such a way that inventory management becomes automated and traceable; the system generates reports to be used when managing costs and optimizing medicine and supply utilization. Munge (140219) explains that those attributes, together with the impressions from their visits and the stories they heard from other counties laid as decision base for the investment in AWSs. The mentioned visits were made in order to see and learn more about the AWSs at Karolinska University Hospital, Skaraborg Hospital Skövde, Hallands Hospital Halmstad and Hallands Hospital Varberg.

Munge (140219) says that it wasn’t the original idea to have AWSs placed in wards, but it was understood that this ought to be a good idea and that the decision was based more on a “gut feeling” rather than hard data. These AWSs were installed hoping that they would reduce orders placed by wards, increase secure narcotics handling, decrease the risk for taking or returning the wrong medicine, free up time for nurses to place on patients and to have an electronic system which would provide statistics, stock information and alert when it is time to replenish. Further, the AWSs were also installed hoping that they would be beneficial on intangible aspects such as the nurses’ perceived sense of secure handling of medicine. Munge (140120) has expressed the wish of evaluating how the AWS has affected the material management process of medicine for a ward with an AWS. In order to make the evaluation the authors find that it will be necessary to make a comparison of the “current situation” (at a ward with an AWS) to the “past situation” (at a ward without an AWS).
This calls for a mapping of different processes concerning the material management of medicine to be made; as a process map is useful to understand how material moves and where inventory is kept (Jacobs, 2011). By creating a process map the work becomes more visible which improves understanding; and interpreting a process map will answer questions of how the different processes are used. (Damelio, 2011) In accordance with Bergman & Klefsjö (2010), Damelio (2011) and Heinrich et al. (2009), the authors need to get a systematic presentation of the current situation at CLV in order to gain an understanding of the material management process of medicine for a ward. This aligns with Granberg (140306) who states that it is important to have mapped processes in order to understand the impact the AWS’s have on the Pharmaceutical Unit, as well as the wards.

In order to ease the comparison between the past and current situation, the authors find that they will need to break down the material management process of medicine based on the categories Plan, Source and Return provided by SCOR (SCOR Supply Chain Council, 2014). These processes will be; replenishment of medicine, stock inventory of medicine, extraction of medicine for trolley, extraction of medicine for patient and reverse logistics of medicine as these align with the explanations given by Mattsson (2012) and Lumsden (2012) of what the categories entail.

1.3.2 Research Discussion for Research Question II

“How do time and costs differ in the material management process of medicine between a ward with, and without, an AWS?”

Many different costs can be identified in a supply chain and they often represent a big proportion of a company’s total cost and these can be hidden within the material and information flow from procurement to distribution (Christopher, 2011). This is true for CLV as Munge (140219) says that they have good information regarding the purchasing cost of medicine but a problem is that they have little knowledge of the costs around the material management process of medicine.

As Munge (140120) has expressed, CLV is primarily interested in knowing if the investment in AWSs was a good decision, and how it has affected the material management process of medicine for a ward where it has been installed. As according to
Kaplan & Andersson (2007) costs in a process’ activities can be driven from time through a TDABC model. Other authors seem to align with this as Mattsson (2012) stresses the importance of reducing time in a material management process and as Bregman (2013) states, a business’ time consumption affects its costs. Harrison & van Hoek (2011) state that to have measured time helps identifying and improving the activities consuming the most time and creating inefficiencies, and that the major advantage of measuring time is the ease with which it is understood as a measurement since it is not as subjective or open for interpretation. Lambert & Pohlen (2011) further explains that metrics and measurements give management means of assessing whether performances have improved or not; this could be applied to a comparison between a ward with, and without, an AWS; as an evaluation of an AWS and if it has led to an improvement or not is desired by CLV as according to Munge (140120). French et al. (2013) validates the use of TDABC in a health-care setting as they explain that it is a suitable model to use in such a complex environment as that of a health-care institution.

Kaplan & Andersson (2007) as well as French et al. (2013) explain that in order to be able to apply TDABC it is necessary to first create a process map from which then time can be measured and later costs can be applied to each process or activity. The authors find that they need to use the process maps created in Research Question 1 in order to know which activities to time and later allocate costs through TDABC. Further the authors find that they need to compare the measured time and allocated costs between a ward with, and without, an AWS in order to see if there are any differences due to having an AWS installed.

1.3.3 Research Discussion for Research Question III

“How has the instalment of a central storage affected the number of orders placed for wards?”

A centralised inventory approach entails according to Abdelaziz & Mejri (2012), that the inventory is perceived as a shared pool of goods across multiple units. This lessens the burden on each unit of having to manage storage space and safety stock levels for each item and reduces the behaviour of a decentralised system where each unit tries to reach its own objectives and goals without consideration of the other units. By having a centralised inventory, Shahabi et al. (2013) state that costs and waste can be reduced and efficiency can be increased.
Munge (140120) explains that the Pharmaceutical Unit recognized a problem in that the wards would rather place orders at the pharmacy before verifying if the medicine was already available in-house at other wards; this as it is a time consuming process to have to call other wards and ask if they have the medicine in question. This led to excessive order placement as well as medicine becoming obsolete and as a means of decreasing this; the decision was taken to have a central storage implemented. Jonsson & Mattsson (2011) adds that a shared inventory leads to larger quantities being stocked together which can open up for investments in automated solutions. Precisely such an investment was made at CLV as it was decided to have an AWS to function as the central storage. The reasons explained by Munge (140120) for why an AWS was installed to function as the central storage aligns with Jacobs’ (2011) previous explanation of an automated storage’s attributes; it controls dispensed medicine in an automated and traceable way.

By having centralized information each participant knows more about the others and treats them as strategic partners, which eases the inventory replenishment (Yu et al., 2001; Marklund, 2002). Storing and handling all this information requires a well-developed information technology (IT) system from which real-time stock level information can be acquired (Marklund, 2002; Seo et al., 2000). Jacobs (2011) adds that an automated storage generates reports to be used when managing costs and optimizing medicine utilisation. It was the Pharmaceutical Unit’s wish according to Munge (140120) that such a centralised information system would be available at CLV, which was another reason for having an AWS function as a central storage. From the AWS statistics on which wards using the central storage can be extracted, the replenishment metrics can be electronically monitored and real-time stock levels can be acquired by nurses searching for a medicine.

The authors find that it is necessary to investigate the numbers of orders placed for wards before and after the instalment of a central storage as well as gain an understanding from different nurses at different wards; this in order to see if the central storage achieved what it aimed to in terms of reducing excessive order placement by wards and if the wards use the central storage as a safety stock.
1.4 Research Questions

*Research Question I:* How does the material management process of medicine differ between a ward with, and without, an Automated Ward Solution (AWS)?

*Research Question II:* How do time and costs differ in the material management process of medicine between a ward with, and without, an AWS?

*Research Question III:* How has the instalment of a central storage affected the number of orders placed for wards?

1.5 Purpose

The purpose is to map and compare the material management process of medicine between a ward with, and without, an AWS. Further the mapped processes will be timed, allocated costs by applying TDABC and then compared. The purpose is as well to describe how the instalment of a central storage has affected the frequency of orders placed for wards.
1. Introduction

2. Methodology

3. Research Question I
   3.1 Theory
   - The Material management process
   - Process mapping

   3.2 Empirical
   - Current state description of Ward 3 without an AWS
   - Current state description of Ward 5 with an AWS

   3.3 Analysis
   - Creation of process maps for Ward 3 with, and Ward 5 without, an AWS
   - Comparison of process maps for Ward 3 with, and Ward 5 without, an AWS

4. Research Question II
   4.1 Theory
   - Time-Driven Activity-Based Costing

   4.2 Empirical
   - Data on costs and time in the processes for Ward 3 without an AWS
   - Data on costs and time in the processes for Ward 5 with an AWS

   4.3 Analysis
   - Capacity cost per minute for Ward 3 without, and Ward 5 with, an AWS
   - Time equations for Ward 3 without, and Ward 5 with, an AWS
   - Calculated scenarios for Ward 3 without, and Ward 5 with, an AWS
   - Sensitivity Analysis for Ward 3 without, and Ward 5 with, an AWS

5. Research Question III
   5.1 Theory
   - Centralized Inventory in Material Management of Medicine

   5.2 Empirical
   - Qualitative Data

   5.3 Analysis
   - Define the impact on order lines from installing a centralised storage

6. Conclusion and Recommendation

7. Reflection and Self-Criticism

8. Further Research

9. The Project’s Contribution

Figure 5: The Project’s Disposition
2. METHODOLOGY

This chapter aims to justify the authors’ chosen methods for this project; including a description of its primary and secondary sources. Each section presents the method(s) and thereafter justifies this project’s method(s). The chapter ends with a summary model of the chosen methods.
2.1 Research Strategy

A case study is an empirical investigation of a contemporary phenomenon (the case) in depth in its real-world context, the boundaries between the case and the context may be unclear (Yin, 2014). The basic case study requires an intensive and detailed analysis of a single case. It is concerned with the particular nature and complexity of the specific case in question. It can for example be done on a single organization, a single location, a person or a single event. (Bryman & Bell, 2013) According to Yin (2014) it is suitable to do a case study when the aim is to understand the real-world case and to do so, important contextual conditions tends to be involved. In order to eliminate a large reliance on one single approach, it favours a combination of qualitative methods, such as observation and unstructured interviews; as those are methods which generate intensive, detailed data for the examination of the case. (Bryman & Bell, 2013) The findings of case studies are not statistically generalizable as they will be too small of a sample to represent a larger population; they are rather analytically generalizable, meaning that the generalization goes beyond the case’s setting (Yin, 2014). Bell (2007) suggests that a case study is suitable for researchers working on their own as they offer an opportunity to study a delimited aspect of a problem during a limited amount of time.

*The Project’s Research Strategy:*

The aim is to study the effects of installing the AWSs in the real context at CLV. The research questions aim to see how the costs and structure of the material management process of medicine was impacted by the AWSs. The authors need to gain an understanding of the process of material management process of medicine at wards in terms of costs allocated through time; this in order to be able to see the impact (if any) of the AWSs. The authors therefore found it suitable to perform a case study to get to study these questions in depth. A case study is flexible and allows for a combination of methods of collection of data which will help the authors in gathering an understanding of the problem. As this is a case study, it will be analytically generalizable in terms of the results being able to go beyond the setting of CLV. The study can be helpful for other studies in terms of how the authors conducted their process mapping and quantification. The results could also serve as a part of another health-care institution’s decision base for weather or not to implement a central storage and/or invest in AWSs. A further evaluation of the project’s generalizability is depicted in chapter 7.
2.2 Epistemology & Ontology

The epistemology consists of two contrasting doctrines and according to Bryman & Bell (2013) these are difficult to pin down and are described slightly differently by different authors. One is positivism which is the epistemological position that supports the application of methods of natural sciences to study the social reality. It says that the purpose of theory is to produce hypotheses that can be tested and can then allow explanations of laws to be assessed. Further knowledge is acquired by gathering facts that provide basis for laws. It presumes that science can and must be conducted in an objective value-free way. It is common for case studies to follow the positivistic doctrine. The other doctrine is interpretivism which advocates a view that the social sciences, such as people and institutions, are fundamentally different from the natural sciences. This entails that the social world requires a different logic in the procedure of research. This is a doctrine which has its heritage in the theology’s hermeneutics which, when incorporated into social sciences, tries to interpret human action. (Bryman & Bell, 2013)

Ontology is the science of “being” and is used when discussing the social entities’ art or nature. In objective ontology there are categories of facts that cannot be affected, for example an organization which is a concrete object which has its own rules. Here strategies and procedures are developed to get things to run smooth. Constructive ontology on the other hand questions that the categories do have already pre-established rules that cannot be questioned nor changed. This can be described as a culture in which there is a constant process of construction and reconstruction. (Bryman & Bell, 2013)

The Project’s Epistemology and Ontology:

This project followed a positivistic doctrine as the authors wished to be objective, and explain the collected empirical data and theory, rather than interpreting it. The authors treated CLV as a concrete object which has set rules and procedures and therefore ontological objectivism was followed. During interviews and observations the authors accepted the results in an objective way; the same was done in the studying of the documents provided by CLV. By following the positivistic doctrine, the authors could gain an insight in CLV’s material management process of medicine in order to contribute to the empirical data in an objective way.
2.3 Scientific Approach

The most common relationship between theory and research is represented by deductive theory. Here a hypothesis (or hypotheses) is composed based on what is known theory to that domain by the researcher. This hypothesis is then subjected into empirical scrutiny and translated into researchable entities. The researcher must specify how data can be collected in relation to the concepts that make up the hypothesis. This is a logical and linear way of research where from theory a hypothesis is deduced and this drives a process of data collection. (Bryman & Bell, 2013)

The method that works the other way, or involves induction, is inductive theory. Here the researcher starts in the empirical and then feeds it back into the theory and research findings associated with a certain domain. The method includes amongst others grounded theory which is a process where reflection on theoretical data has been carried out. The researcher goes back to collect further data in order to establish conditions in which the theory will or will not hold. Such a theory is often called iterative and involves a lot of weaving back and forth between theory and data. (Bryman & Bell, 2013)

It is not always clear if a researcher use only deductive theory as the publication of new theoretical data may be published during their research, or the relevance of a data to a certain theory becomes clear only after the data is collected (Bryman & Bell, 2013). One approach that includes this uncertainty is called abduction and is a mix of qualitative and quantitative, approaches and concepts and is an approach commonly used in case studies (Alvesson & Sköldberg, 2008; Johnson & Onwuegbuzie, 2004). Abduction is a more logical and practical alternative which is the uncovering of the best set of explanations for understanding one’s results (Johnson & Onwuegbuzie, 2004). This can be done through interpretation of a comprehensive hypothetical pattern; that if real, would explain the case in question. This interpretation shall then be attested by new observations. Abduction therefore has some traits of both induction and deduction but it is important to note that it is not a simple “mix” of the two as it adds new steps. The empirical is developed throughout the process and theory is refined and adjusted along the way as well. Abduction also differs from the other two approaches in the sense that it aims to bring understanding. (Alvesson & Sköldberg, 2008)
Yin (2014) explains how it is common for case studies to make the mistake to assume that the case’s qualitative nature calls for an inductive approach, when in fact a case study requires to first gain an understanding of the phenomena through theory; which according to the paragraphs above calls for either an approach of deduction or abduction.

**The Project’s Scientific Approach:**

The authors found the approach of abduction was the most appropriate for this project. This as they conducted a case study where the logical and practical approach offered by abduction was suitable. The authors moved between empirical and theoretical data throughout the process. They started with an empirical problem and then turned to theory to gain a better understanding of models and previous research done in similar context. Thereafter more empirical was gathered. When needed more theory was gathered as it became relevant; it was adjusted and refined along the whole process to stay relevant for the case. As abduction is an approach that brings forward understanding it was more relevant than the deductive objective or inductive interpreting approach.

**2.4 Research Method**

Quantitative and Qualitative research methods are two ways to distinguish methodological issues. Quantitative research is a strategy that emphasizes the quantification when gathering and analysing data. It tends to entail a deductive approach between research and theory where the intonation is put on the testing of theory. It incorporates positivism in the sense of practices and norms of the natural scientific model. It views the social reality in an external and objective reality. By contrast the qualitative research is a strategy that emphasizes words rather than quantities when collecting and analysing data. In the relationship between theory and research it tends to follow the inductive approach with an intonation on the generation of theory. It rejects the positivistic norms and practices and prefers the ways in which individuals interpret their social world. It views the social reality as constantly shifting due to individuals’ creation. (Bryman & Bell, 2013) Yin (2014) explains how in a case study it is common to deliberately use both qualitative and quantitative data, but still have the case stay true to its qualitative approach; this because the case’s research questions have been at a higher level, whereas the quantitative data was collected for an embedded unit. This
shows that there are no fixed boundaries between the two methods, as according to Creswell (p. 3, 2014); “a study tends to be more towards qualitative than quantitative or vice versa”.

**The Project’s Research Method:**

The purpose of this project is to map the material management process of medicine for a ward with and a ward without an AWS; as well as concluding the impact of installing an AWS as a central storage. This was made by conducting interviews, observations and having studied documents at CLV which called for a qualitative research method. The importance laid in the whole picture where CLV is considered a higher level; not just a specific activity or an embedded unit such as the nurses of CLV. Also, as the authors wished to conduct a deep and thorough empirical investigation, it was more desirable to conduct interviews over surveys making a quantitative research method less appropriate. Observations gathered quantifiable empirical data which was used in the TDABC-model and the studying of documents also provided quantitative data; however this quantifiable data was collected with the purpose that its results would be specific for certain activities and not the whole picture. The collection of data continued until deemed fulfilled, which was possible with a qualitative research method and a case study; and enhanced the depth of this project’s research. As previously mentioned, different research methods have different connections to epistemology; the authors however stayed true to this project’s positivistic nature in both the qualitative and quantitative data.

**2.5 Sample Selection**

Probability sample is selected randomly and each unit in the population has a known chance to be selected; this will then mathematically represent a subgroup of some larger population (Berg, 2009; Bryman & Bell, 2013). Non-probability sample is not selected using a random selection method which implies that some units in a population are more likely to be selected than others; this is not a representative sample and is therefore harder to generalize. Convenience sample is a type of non-probability sample where the sample is simply available to the researcher. Snowball sampling is in a sense a form of convenience sampling where the researcher start by contacting a group of people who are relevant to the research and then uses their contacts with others to collect further data. (Bryman & Bell, 2013)
This Project's Sample Selection:

As this project was handed to the authors by Magnus Munge, Department Manager at the Pharmaceutical Unit, it was natural that he was the first source, making him a convenience sample.

Research Question I & II

As it became more clear how the authors wanted to conduct this project and which processes it was that they wished to map Munge directed them, in a snowball-sampling fashion, to other viable sources. These sources were other employees within Pharmaceutical Unit which he saw fit to best answer the authors’ questions and participate in their observations as well as the Head of Department for wards 3 and 5. These were chosen as they both represent a so called “Medicinal Ward” in which Ward 3 does not have an AWS installed but Ward 5 does. As they are both the same type of wards, but with different inventory systems it was decided that they could most clearly show distinct differences (if any) between a ward with, and a ward without, an AWS installed. The head of departments in turn directed the authors to different nurses who they saw fit to answer their questions and to participate in their observations.

Figure 6: The Sample Selection for Research Question I & II
For Research Question III the authors relied on a non-probability convenience sample as they went to each ward and asked if there was a nurse who had time to answer a couple of questions. Further the nurses answering in these interviews had varying years of experience; although the authors made sure they had at least one year of experience, which ensured that they had been there before the central storage was installed. Some nurses had more knowledge about the ordering process of medicine as they were one of the few with the authority to place orders of medicine for wards.

2.6 Data Collection

When data which has not been available before is collected, for example through interviews or observations, this is called primary data (Dahmström, 2011). Interviews are one of the most important sources of information in a case study (Yin, 2014). There are three categories of interviews; structured, semi-structured and unstructured interviews. Structured interviews are often done in connection with quantitative research; as this type of interview promotes a standardization of both asking questions and recording answers. Semi-structured is more flexible and usually has a list of questions on a topic that is to be covered; this is often referred to as the interview guide. Here the interviewee has more freedom in formulating their response. In unstructured interviews the researcher has barely prepared some prompts on a certain range of topics. (Berg, 2009; Bryman & Bell, 2013)

Observations are according to Yin (2014) another suitable source of evidence for a case study as the aim is to study a case in the real-world setting. Observations can add new depths to the researchers’ understanding of the context. Observations are made on the field and can be done by side walking an activity or participating in meetings, with the purpose of finding behaviours during a certain period of time. Bryman and Bell (2011)
concluded that observations compared with interviews can help provide more accurate information about events. The reliability of the observation can be increased by having more than one single observer making the observation (Yin, 2014). Validity in observation usually relates to if it measures what it is supposed to measured (Bryman & Bell, 2013). Bryman & Bell (2013) suggest that observations works best when it is used together with other methods; this as it does not provide reason for the observed pattern of behaviour.

Studying documents can help verifying other data already collected and help as the researcher might be able to ask new questions after having read a document (Yin, 2014). These documents provided by an organization are also considered primary data. This includes for example protocols, brochures, reports, letters, meeting notes, decisions, and financial documents. They came from practical use and have not been “organized” in the sense to be a base for scientific research. The researcher has to be critic when analysing documents to avoid bias. (Bell, 2007)

When using data that has already been collected, this is called secondary data (Dahmström, 2011). This includes interpreting data found in literature, articles and databases (Bell, 2007). Secondary data is usually a faster process than collecting primary data, but can also require that time is spent in order to understand the complexity of data collected by another researcher (Dahmström, 2011).

The Project’s’ Data Collection:

The primary data for this project has been collected through interviews, observations and the studying of internal documents. The initial interviews with Munge were unstructured; as the authors did not yet have an understanding of the phenomena they did not want to lead the discussion in any certain way but let it up to Munge to freely express the phenomena. The authors then gathered secondary data in terms of scientific articles and literatures in order to gain a deeper understanding and to know how to conduct their project. After gaining an understanding, the projects disposition was planned, the research questions were formulated and the specific data to be collected for each question was decided and will be explained in the subsections below. All interviews, observations and internal documents used for all research questions are depicted in the tables below;
<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Date</th>
<th>RQ I</th>
<th>RQ II</th>
<th>RQ III</th>
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Table 3: The Project’s Data Collection through Interviews
### Observations

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<th>RQ III</th>
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Table 4: The Project’s Data Collection through Observations

### Internal Documents

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Table 5: The Project’s Data Collection through Internal Documents

**Data Collection for Research Question I:**

The scientific articles were found through the databases ScienceDirect, EBSCO, Springer Link, Wiley Online Library, Google Scholar, Business Source Premier and Emerald by using search terms such as; “material management process hospital”, “process mapping”, “flowcharting symbols” and “data collection process mapping”. The literatures were chosen based on their relevance regarding material management process and process mapping. Literatures weigh heavier in the sections because the authors found that they provided a more in-depth description of material management process and process mapping compared to the articles they found.

The primary data for Research Question I was collected through semi-structured interviews with Magnus Munge, employees at the Pharmaceutical Unit, the Head of Department at wards 3 and 5 as well as nurses on each of those wards. As the authors
found the need to map different processes in order to gain an understanding on a wards material management process of medicine, the people mentioned above participated in different process maps depending on their relevance.

Once the process maps had been drawn according to the interview responses, these were, along with the written empirical data, confirmed by the interviewees to ensure the authors had understood the process correctly. The authors then made observations to see if the process when executed in real life accorded to the map that was drawn; this also offered the opportunity to change their process maps in case an activity was made which had not been mentioned in the interviews. The observations were made simultaneously by both authors in order to increase the observations’ reliability.

*Data Collection for Research Question II:*

The scientific articles were collected from the databases ScienceDirect, Google Scholar, Business Source Premier and Emerald by using search terms such as “measurement tools”, “metrics”, “supply chain measures”, “cost in material management process” and “time-driven activity-based costing”. The scientific articles were based on Kaplan & Andersson (2007), which is the literature that weighs the heaviest in this part. The articles were chosen as the authors wanted to see how TDABC could be applied in a health-care setting. The authors find that the literature’s large weight is validated as it was Kaplan & Andersson who invented the concept of TDABC.

The primary data for Research Question II was collected through observations which took place according to the process map produced in Research Question I. The aim of the observations was to gather data on consumed time for selected activities. The observations were made simultaneously by both authors in order to increase the observations’ reliability. In order to gather data on costs, interviews were performed with Magnus Munge and the head of departments for Ward 3 and Ward 5.

*Data Collection for Research Question III:*

The scientific articles were collected from the databases Science Direct, EBSCO, Springer Link and Emerald by using the search terms such as “in house central storage hospitals” and “safety stock”. The literatures were chosen based on their relevance to central storage, orders and safety stock.
The primary data was collected through semi-structured interviews with employees at the Pharmaceutical Unit to gain an understanding in the impact of the installation of an AWS as a central storage and by semi-structured interviews with nurses at different wards in order to gain an understanding of their perception of the central storage as well as through the studying of internal documents.

2.7 Analysis Method

The aim of a case analysis is to produce empirically based findings by examining, categorizing or otherwise recombining evidence that has been collected during the study. To define the priorities of the study it is important to get started on the analysis. To attend to all the evidence collected, displayed and presented during the study is necessary in order to create a high-quality analysis. A strategy to work by is through following the theory which helped shape the prerequisites for empirical collection, this as the theory often provides analytical qualities. The theory can then be compared against the empirical findings through a “pattern matching”. (Yin, 2014)

The Project’s Analysis:

Research Question I:

The analysis for Research Question 1 was performed by dividing the chapter into two different parts. The first part put theory against empirical in analytical discussions through a pattern matching, which generated in process maps for both Ward 3 and Ward 5. These process maps enabled the second part where each process map for Ward 3 was compared to its equivalent for Ward 5. This showed similarities and differences, which generated a basis for conclusion to be used later when answering Research Question I. Below is an illustration of the analysis’ disposition:
Research Question II:

The analysis for Research Question II was divided into three different parts. The first part determined the capacity cost per minute for Ward 3, Ward 5 and the Pharmaceutical Unit through an analytical discussion and pattern matching of theory and empirical. The second part generated time-equations for Ward 3 and Ward 5 through an analytic discussion and pattern matching of theory and empirical. The third part generated in calculated scenarios for Ward 3 and 5 through an analytic discussion and pattern matching between theory and the outcomes of the previous parts. This was done by applying the capacity cost per minute from part I into the different time-equations from part II. This resulted in a proposed process cost according to pre-determined assumptions for the calculated scenarios. To enable a comparison of wards, each process was given a calculated average cost by dividing all possible cost outcomes with the amount of calculated scenarios for a process. In order to cover possible deviations which the observations might not have covered; a sensitivity analysis was performed and included in the process average costs. The different costs for Ward 3 and Ward 5 were then compared to each other to give a basis for conclusion in order to be able to answer Research Question II. Below follows an illustration of the analysis’ disposition:
Figure 9: Analysis’ Disposition for Research Question II
Research Question III:

The analysis for Research Question III has been performed by putting the theory against the empirical findings through a pattern matching. The analysis sometimes mentions references which are not depicted in the empirical chapter for Research Question III; this is because it has already been depicted earlier in the project and the authors felt it would be redundant to write the same data twice. This sub section ends with a table showing the basis for conclusion in order to answer Research Question III. This table will provide different statements as according to what CLV has expressed they wished the central storage would achieve and based on the findings from the analytical discussion, the statements will either hold true or not as shown in the table. Below follows an illustration of the analysis’ disposition:

Analysis Model for Research Question III

2.8 Ethics

Researchers in case studies ought to aim for the highest possible ethical standard, including for example; not plagiarising or falsifying data; breaching copyright or intellectual property laws; avoiding dishonesty; accepting responsibility for the work conducted as well as having a professional competence by staying up to date on related theory (Yin, 2014; Bryman & Bell, 2013). As case studies often investigate in the lives of other human beings there is a great ethical obligation; therefore the researcher has to ensure the rights and welfare of those people or organisations that form the focus of the study (Berg, 2009; Yin, 2014). Ethics in case studies involving human beings revolve mainly around the following four issues; whether there is harm to the participants, lack of informed consent, invasion of privacy, or if there is deception involved. Each of these issues will be further explained below. (Yin, 2014; Bryman & Bell, 2013)
Research that might cause harm to the participants is regarded by most as unacceptable. But what is understood to be harm? It can come in the form of physical harm, or psychological harm which includes but is not limited to stress and negative impact on development or self-esteem which can harm the participant’s future career opportunities. (Bryman & Bell, 2013; Yin, 2014)

Invasion of privacy is another important issue and to infringe on the right of privacy in research is regarded as unacceptable. Information from a respondent that might be sensitive shall not be available to unauthorized audience; and if the respondents request anonymity this shall be granted. (Bryman & Bell, 2013; Yin, 2014)

Lack of consent is the most debated area of ethics in business. It tends to focus on what is variously known as disguised or covert observation. This concern letting the prospective research participants receive as much information as needed to make an informed decision in whether to participate or not. This also includes that the respondents should be told if recording- or observation techniques are to be used during an interview. (Bryman & Bell, 2013; Yin, 2014)

Deception occurs when the research is represented as something other than what it really is by the researcher. This might be condoned to a certain extent because the researcher aims to receive a more natural response from the participants by limiting their understanding of what the research is about. (Bryman & Bell, 2013; Yin, 2014)

The Project’s’ Ethical Standpoint:

As this project is a case study involving human beings, the authors evaluated the ethics according to the four main issues presented above. There was no harm to the participants as data was only collected from documents, interviews and observations. Landstinget Kronoberg, where the study was conducted, had a good understanding of the aim of the research; therefore no lack of informed consent was present. When the authors conducted observations at CLV everyone involved was informed on what methods to be used. When the authors chose to use a recorder during interviews the respondent(s) was informed beforehand. The authors do not see that this study transgressed on anyone’s privacy; those asked to participate in interviews could choose to not answer and those who participated in the observations agreed beforehand. The authors have not presented their research with intended deception as the aim of the research will not alter the outcome of the interviews nor observations.
Yin (2014) suggests four tests of quality measurements which are suitable for case studies; these are construct validity, internal validity, external validity and reliability. Validity is considered by many to be the most important quality criteria in research. This is concerned with the integrity of the conclusions drawn from the research. (Bryman & Bell, 2013)

Construct validity concerns if the study actually investigates what it claims to study and if this then leads to accurate observations of reality (Gibbert et al., 2008). Constructive validity can be achieved by using multiple sources of evidence in the collection of data and have key informants review the report (Yin, 2014).

Internal validity is concerned with if a conclusion which incorporates a causal relationship of more than a single variable actually makes sense (Bryman & Bell, 2013). Internal validity can be strengthened by using logic models to show the relationship (Yin, 2014).

External validity reflects if a result of a study holds true also to generalize outside of this specific research context (Bryman & Bell, 2013). Many case studies fail to achieve statistical generalization as the sample and case is too small to reflect a larger population; it may however be achieved by analytical generalisation in which the case’s results can go beyond the case’s environment (Yin, 2014).

Reliability is concerned with if the results of the research are repeatable. One prerequisite for this is the need to document the procedures to allow for another investigator to repeat the case. (Yin, 2014; Bryman & Bell, 2013) This term is commonly used in relation to if the measurements are consistent. Reliability tends to be more of an issue in quantitative research, as this research is concerned with if a measure is stable and can be considered reliable, or not. (Bryman & Bell, 2013)

The Project’s Measurement of Quality

To strengthen the reliability of the research the authors documented the whole process; from the selection of theory and how this led to certain empirical data collection; how this empirical was collected through different samples and sampling techniques and how the analysis method was conducted. In order to achieve construct validity the authors let key informants confirm that the information was correct. The authors further
used a wide range of scientific articles and literature in order to ensure constructive validity. Internal validity is showed by the authors through the models of the relationship following throughout the project. The project’s external validity comes from its analytical generalizability. This project will serve as help and guidance for other health-care institutions thinking of installing a central storage or AWSs; as well as helping other researchers in how to apply process mapping and TDABC in a real context. A deeper explanation on the project’s validity and reliability is presented in chapter 7.

2.10 Method Summary

<table>
<thead>
<tr>
<th>Method</th>
<th>Selection</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Epistemology &amp; Ontology</strong></td>
<td>Positivistic &amp; Objective</td>
</tr>
<tr>
<td><strong>Scientific Approach</strong></td>
<td>Abductive</td>
</tr>
<tr>
<td><strong>Research Method</strong></td>
<td>Qualitative</td>
</tr>
<tr>
<td><strong>Research Strategy</strong></td>
<td>Case Study</td>
</tr>
<tr>
<td><strong>Sample Selection</strong></td>
<td>Non-Probability, Judgemental &amp; Snowball</td>
</tr>
<tr>
<td><strong>Data Collection</strong></td>
<td>Primary data through 26 interviews, 10 observations and 1 internal document; Secondary data through literature and scientific articles.</td>
</tr>
<tr>
<td><strong>Ethics</strong></td>
<td>No harm to participants; informed participants; no invasion of privacy; no deception</td>
</tr>
<tr>
<td><strong>Analysis Method</strong></td>
<td>Pattern Matching</td>
</tr>
<tr>
<td><strong>Quality Criteria</strong></td>
<td>Constructive, Internal &amp; External Validity and Reliability</td>
</tr>
</tbody>
</table>

Table 6: Summary of the Project’s Methodology
3. RESEARCH QUESTION I

“How does the material management process of medicine differ between a ward with, and without, an Automated Ward Solution (AWS)?”

This chapter aims to present the theory and empirical related to research question I. The empirical will separately treat Ward 3 without an AWS from Ward 5 with an AWS. The analysis will be performed in two steps, which will result in a basis for conclusion.

Figure 11: Overview of Chapter Three’s Disposition
3.1 Theory of the Material Management Process and Process Mapping

3.1.1 The Material Management Process

Mattsson (2012) presents the material flow and information flow as examples of flows on which focus is laid when managing a supply chain. These are commonly seen as one-way flows going from a distributor to a customer, however, consideration needs to be taken to the reverse logistics of misplaced or defect products. These two flows are indirectly connected to each other; information can lead to a material flow when for example an order is placed and a material flow can lead to an information flow in for example reverse logistics. (Mattsson, 2012) This project’s focus is as previously established on the material management process and consequently on the material flow. The information flow will therefore not be treated separately under its own sections; but will be seen as a complement to the material flow and material management process.

The material management process coordinates, executes and supervises tasks related to the flow of material (Chandra et al., 2013); which includes materials that flow from suppliers into the organisation, flows of material within the organisation and flow of material from the organisation to the final user. (Jonsson, 2008; Park et al., 2011; Alvarado-Iniesta et al., 2013; Arnold et al., 2008) Many health care organisations have recognized the need and importance of implementing supply chain management tools. Supply chain management within health care organisations includes for example the material flow of pharmaceuticals and medical supply. By improving the material management process in hospitals, internal performance will improve significantly and costs can be reduced. (de Vries & Huijsman, 2011)

A flow of material is triggered by a demand which is for example stock replenishment or an order having been placed. The desired quantity is determined and handed over to a purchasing function which then places an order at a supplier. If the demand is for a product in stock, the order is handled by a function which plans in- and outbound deliveries which then picks, packs and delivers the order. (Mattsson, 2012) A flow of material is rarely continuous nor is the rate of supply the same as the rate of consumption (Jonsson, 2008); inefficiencies in health care sectors can therefore be reduced by the material management process being focused on inventory management (Callender & Grasman, 2010).
A way to divide a material management process is by the categories provided by the SCOR model. SCOR divides it into for example; Plan, Source, and Return. Each of these different steps can be found in the supply chain’s different links, and can be broken down to different levels with different amount of detail and measurements. (Mattsson, 2012) This project will use the categories provided by SCOR, but not the model itself.

**Plan:** This step entails planning demand and supply in order to create a balance between resources and requirement as well as determining communication along the supply chain. The step includes as well the determination of business rules to improve and measure such as inventory. (Mattsson, 2012) In order to keep a balance, the resources will need to be replenished. Determining the inventory levels can be made by a replenishment point system. This is made by comparing the available quantity in stock to a predefined quantity, usually termed as a replenishment point. When the stock level has gone below this point, an order needs to be placed which will satisfy the desired stock level quantity. This quantity considers as well the lead time for replenishment and a safety stock level. (Mattsson, 2012; Lumsden, 2012)

When an order has been placed, the products will eventually be delivered. When the products arrive at a storage facility they need to be inspected; either on quality, quantity or both. Verifying the quantity is made by simply cross-referencing the delivered quantity against the quantity stated in the order and packing list. The quality can be verified before delivery by the supplier or by making a sample or total control of the delivery. After a delivery has been controlled and approved, the products will need to be put into the storage facility. Depending on the method of stock-keeping there are different rules for how the placement ought to be performed. With a fixed placement; every product shall be placed at the same location every time whereas with a flexible placement an empty space can be used for any product. When the product has been replenished, the stock level status shall be updated. (Lumsden, 2012)

Making sure that the stock levels are up to date is made by inventorying where the actual stock level is verified against the records. If any deviation is found it needs to be investigated and the records adjusted to the correct stock level. (Lumsden, 2012) The stock levels are most commonly controlled on a regular basis; be it per day, week or
month and this control can be made in different ways, the most efficient being the automatized ways. For example, the most common way for identifying objects and related information is by barcodes. The barcodes are printed on stickers, and read by laser scanners. Another way is by a completely automated information handling, where the computer system updates by itself the new stock levels, alerts when a replenishment point is reached, compiles statistics over consumption, creates forecasts as well as calculates optimal ordering quantities and safety stock levels. (Mattsson, 2012)

Source: This step includes the processes for satisfying a demand by acquiring material. These processes are for example; acquisition, receiving of goods, transports and handling of material. (Mattsson, 2012) Acquiring material can be done from an inventory, which can be kept in a physical storage facility. This facility should be designed so that maintenance and handling costs are minimized; this can be done by having a high filling rate and low operating costs. (Jonsson, 2008) The inventory is taken from the facility to its destination by different means; either by different vehicles or by a physical person (Jonsson & Mattsson, 2011; Lumsden, 2012)

In order to be able to take a product, information is needed on what product that needs to be extracted as well as its thought out destination; and this information is mediated through a picking order (Jonsson & Mattsson, 2011; Grosse & Glock, 2013). The information can be sent in different ways; man to man, man to information system, information system to man or information system to information system. The first entails that a person communicates directly with another person without the information being stored or processed through an information system. The second involves that a person initiates the communication of information, and stores and processes it through an information system. The third entails that the information system initiates the communication of information and delivers it to a person and the last involves that information systems communicates with each other without a physical person being involved. (Mattsson, 2012)

When the destination is a specific client, the exact amount depicted in the order is always extracted. The extraction can be made in different ways; one of them is the so called man-to-material method. This method entails that the person physically goes to the storage and extracts the product directly from the storage. It is common to bundle many picking orders into one in order to reduce time that is consumed when acquiring
the different products, this as order picking is recognized to be a time-consuming process. (Jonsson & Mattsson, 2011; Grosse & Glock, 2013)

Return: This step includes the processes involved in the reverse logistics of products (Mattsson, 2012). Reverse logistics can be defined as “the role of logistics in product returns, source reduction, recycling, materials substitution, reuse of materials, waste disposal and refurbishing, repair and re-manufacturing” (Mattsson p. 398, 2000); where focus is laid on the material flow from point of consumption back to point of origin (Arnold et al., 2008; Rogers & Tibben-Lemke, 2001). It is performed worldwide by various industry sectors, as its importance has been increasingly acknowledged; especially by the statement given by the Reverse Logistics Executive Council claiming that firms in US have lost billions of dollars due to bad reverse flow management (de Brito & Dekker, 2004).

3.1.2 Process Mapping

3.1.2.1 Purpose of Process Mapping

A process consists of many resources which turn input to output, where output should have a higher value than the input, in order to satisfy internal and/or external customers (Slack et al. 2012; Jacobs, 2011). By having a process map, the work becomes more visible. This visibility improves understanding and communication (Damelio, 2011; Soliman, 1998; Bergman & Klefsjö, 2010); and allows for a systematic presentation of a division’s processes and the activities, people and data which creates an output (Heinrich et al., 2009; Biazzo, 2002). It also helps provide a common reference for all involved (Anklesaria, 2008; Recker et al., 2010).

These maps are often used to show the current work in an organization and can be referred to as a “snapshot” in time; showing all steps, functions, outputs and inputs (Harrison & van Hoek, 2011; Recker et al., 2010); and how accurately these are depicted affects the process map’s quality (Recker et al., 2010). Analysing the processes shown in the map will help the organization identify key performance indicators and actions in order to reduce costs, cycle-times and defects as well as establish, strengthen and evaluate process performance measures (French et al., 2013; Damelio, 2011; Haponava & Al-Jibouri, 2010; Singprasong & Eldabi, 2011). It can show what is causing logistical costs, where the largest cost binding activities take place and which
products, suppliers and customers that have the most significant effect on the logistical efficiency and profitability. (Jonsson & Mattsson, 2011)

A process map can also be used in order to show how an organisation wishes to work by examining a map of the current situation and then changing it to align with the organisations goals and wishes. Therefore, process maps are a prerequisite for creating successful designs of an organisation, for reengineering processes and for benchmarking projects. (Damelio, 2011)

3.1.2.2 Creating the Process Map

The first thing to do according to Damelio (2011) is to choose which process to be mapped. This should be chosen in regard to one or more criterion of the following; cost reduction, impact on customer-perceived value, cycle time reduction, defect reduction, bottleneck elimination or obsolete technology. Melan (1992) continues with explaining that after a process has been chosen, a start and finish needs to be established and that within these boundaries, activities will be identified. According to Mattsson (2012) a process begins with a demand and finishes with the demand being satisfied; either at a customer or leading to another process.

Mattsson (2012) explains the importance of the activities having a clear beginning and end in order to be properly measured, and not just the process itself; the activities needs to also have a logical relation to each other. If a group of activities are always performed before another group of activities; these should be considered as a prerequisite and they should all be included in the same process. If not, the different groups of activities should be treated as separate processes.

Soliman (1998) and Melan (1992) explains that the activities will first be defined on a macro level; meaning that the activities are presented in groups and allowing for a framework to be used when defining activities on a micro level; it is these activities which will be depicted later in the process map. Damelio (2011) and Yin (2014) explains how collecting the necessary information in order to create the map can be done in different manners; such as one-on-one interviews, group interviews, observations or the reviewing of documents (Damelio, 2011; Yin, 2014). When creating a process map in a hospital, Singprasong & Eldabi (2011) suggests data collection through one or more meetings with the staff.
The most popular method of process mapping and also the most detailed is the flowchart. A flowchart gives a simplified view and shows all tasks that make up a process, the sequence of these tasks, the relationship between the tasks as well as the input/output for a specific work progress. (Damelio, 2011; Meyer et al., 2007) A flowchart is used to answer the question of how the work is essentially done (Damelio, 2011). When drawing a flowchart, outputs must be defined, the work that provides that output as well as the input necessary to create the output. A flowchart can be drawn both vertically and horizontally. (Melan, 1992) The more symbols used in a flowchart, the bigger will its usefulness become (Damelio, 2011). Below is a description of the different symbols to be used in a flowchart;

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boundary</td>
<td>Indicates the start or finish of a process</td>
</tr>
<tr>
<td>Operation</td>
<td>Indicates an activity that changes an input</td>
</tr>
<tr>
<td>Movement</td>
<td>Shows the moving of output between locations</td>
</tr>
<tr>
<td>Inspection</td>
<td>Shows that the flow has paused so the output can be evaluated and receive approval for continuing.</td>
</tr>
<tr>
<td>Delay</td>
<td>Indicates when something is put in a temporary storage or just simply has to wait.</td>
</tr>
<tr>
<td>Storage</td>
<td>Indicates when an output is put in storage and needs authorization to be retrieved.</td>
</tr>
<tr>
<td>Decision</td>
<td>Identifies a point of decision in the process. The decision should be written inside and each path emerging from it should be labelled with for example yes/no or complete/incomplete.</td>
</tr>
<tr>
<td>Document</td>
<td>This identifies when an output becomes recorded on paper.</td>
</tr>
<tr>
<td>Database</td>
<td>This identifies when an output has become electronically stored.</td>
</tr>
<tr>
<td>Arrows</td>
<td>Arrows show the flow within the process.</td>
</tr>
<tr>
<td>Demarcation line</td>
<td>Indicates when the work flow crosses organizational interfaces</td>
</tr>
<tr>
<td>Display</td>
<td>Indicates when something is shown on a computer screen</td>
</tr>
<tr>
<td>Loop limit</td>
<td>Indicates start and finish of a loop.</td>
</tr>
</tbody>
</table>

Table 7: Flowcharting Symbols (Damelio, 1996; Meyer et al., 2007; Melan, 1992; Karan et al., 2003)
Below is an example of a traditionally used flowchart. This depicts the step of “order taken” within an order fulfilment process. It uses seven different symbols of those shown above in order to illustrate how these can be used. (Damelio, 1996)

![Flowchart](image)

Figure 12: Order Fulfilment Process “Order Taken” Step – Flowchart view (Damelio, 1996)

When a process is more complex, Jonsson & Mattsson (2011) suggest the design of a cross-functional map. Damelio (2011) explains that it shows different functions, steps, order of steps, input/output for a specific work process as well as who is responsible for each task. It includes processes between and within functions and is sometimes also known as a swim lane diagram due to its resemblance to a pool’s lanes. The term swim lane diagram is used by for example Singprason & Eldabi (2011) as they explain it to be a common method for mapping a hospital’s functions and processes in order to understand the personnel’s workflow.

Mattsson (2012) explains that an organisation’s functions in its material management process are those which together are involved in the activities related to value adding and the movement of material along the material flow. Jonsson & Mattsson (2011) and Gadde et al. (2012) identifies some functions, not limited to hospitals, to be as follows; forecasting, customer order treatment, material and production control, transport planning, purchasing, material handling, production, storage and external transport of goods. A cross-functional map can help in the discovery of how and where to work quicker, more efficiently and with less resources. Damelio (2011) explains that these opportunities can become visible from having clarified the input/output requirements; and the more they cross function-barriers the more opportunities for improvement there will be. By simplifying the processes and not including unnecessary steps, it will be easier to discover more opportunities for improvement. Below is an example of a cross-functional map, showing the order fulfilment process.
Damelio (2011) warns for common mistakes when creating a process map and these are for example when some areas are too detailed and others too vague; when steps are missing; when the map becomes too clustered or when the terminology is not clear and creates misunderstandings for those involved.

### 3.1.2.4 Analysing a Process Map

Analysing a process is done in order to understand the process (Karan et al., 2003; Damelio, 2011). The first step is to interpret the completed process map. Interpreting a process map will answer questions of how the different processes are used. When interpreting, questions should be asked such as; which steps that require a certain output? What is the order of the different steps? Who is responsible for each step? What are the interfaces between functions? What is the input and output for each step? (Damelio, 2011) Singprasong and Eldabi (2011) also emphasize asking “why” throughout the analysis.

### 3.2 Empirical Data on the Material Management Process of Medicine

#### 3.2.1 The Material Management Process of Medicine for Ward 3 without an AWS

3.2.1.1 Replenishment of Medicine

The replenishment of medicine at Ward 3’s storage facility is controlled and performed by the Pharmaceutical Unit through their pharmaceutical service (Augustine, 140312; Törndahl, 140303); however as explained under section “3.2.1.3 Extraction of Medicine” a nurse may have to place an emergency order (Petersson, 140312). The first step is when an employee from the Pharmaceutical Unit, once a year, has an inventory review together with nurses at Ward 3 (Törndahl, 140303; Petersson, 140312). At this
meeting; criteria for the replenishment of medicine of their basic inventory is discussed; which currently consists of 282 medicines. The minimum and maximum levels for each medicine is decided, based largely on an average of historic ordering data but also takes the nurses wishes into account. Consideration is also taken to the medicine’s price and turnover rate, as it is unfavourable to keep a large stock of more expensive medicine with a low turnover rate and it is also unfavourable to place many orders of a less expensive medicine with a high turnover as each single order line placed comes with a fixed fee. Consideration is also taken to the type of medicine, as it is easier to store and order pills as opposed to antibiotics and ampoules. (Törndahl, 140303)

The next step is the weekly replenishment. This entails that employees from the Pharmaceutical Unit comes to the ward once a week and verifies the quantity remaining of all the medicine in the ward’s storage. The barcode next to a medicine’s storage space provides information for the minimum level of that specific medicine which should be available. When the employees from the Pharmaceutical Unit finds that the amount of medicine is below the minimum level they manually scan the barcode with their hand-scanner which then registers a list of the medicine which needs to be ordered and replenished. This is a manual process where employees from the Pharmaceutical Unit needs to lift and check the amount of medicine remaining by either “shaking” the box or open it and look. (Törndahl, 140303; observation Anna Strömberg, Dispenser at the Pharmaceutical Unit, 140408) For medicines not kept inside the storage facility, such as a specific shower solution kept in a shower-room at the ward, the nurses need to manually fill in a list inside the storage facility for the employee from the Pharmaceutical Unit to order when making their weekly replenishment routines (Petersson, 140312); the same is done for specific medicines which usually is not part of the basic inventory, and not deemed urgent (Augustine, 140312). The Pharmaceutical Unit will check this list; if something is demanded for replenishment, the employee will take out a specific document with barcodes taped to it for these products which are part of the basic inventory, but not stored inside the storage facility. The employee will then scan the appropriate barcode(s) with its hand-scanner. If it is a product not part of the basic inventory, it will not have a barcode to be scanned. The employee will then write down the product, and manually place an order through Provider back at the Pharmaceutical Unit. (Törndahl, 140404; observation Strömberg, 140408)
After the employees from the Pharmaceutical Unit has verified the inventory of medicine at the ward and scanned the barcodes for those medicines that needs to be replenished, they return to the Pharmaceutical Unit and connect the hand-scanner to the computer. The information from the hand-scanner is then transferred into the hospital’s ordering system Provider. Thereafter the employees from the Pharmaceutical Unit reviews the list to make sure it is correct and manually alters to the order list if needed. (Törndahl, 140303; observation Strömberg, 140408)

The verification of inventory and placement of orders is done before noon. The medicine is then delivered the following day (Törndahl, 140303). The medicine is delivered in bigger boxes to the ward which signs that the medicine has been received (Augustine, 140312; Petersson, 1403012; Törndahl, 140303). Employees from the Pharmaceutical Unit then come to the ward and unpack the box of medicine and checks that the medicines delivered are correct according to the order and packing list. They then place each medicine in the correct storage space on the shelves or in the refrigerator. (Törndahl, 140303; observation Lundgren, 140409) The nurses at the ward only place orders themselves in case of emergency or an unusually high consumption of a specific medicine due to a patient with specific needs. (Augustine, 140312)

### 3.2.1.2 Stock Inventory of Medicine

The shelves in Ward 3’s storage facility are marked by stickers with barcodes; indicating where each medicine is to be placed and the minimum stock level allowed. As a part of the pharmaceutical service, a major stock inventory is the Pharmaceutical Unit’s responsibility. Once a month, employees from the Pharmaceutical Unit comes to the storage facility of Ward 3 and verifies the expiration date for all medicines in the basic inventory (Törndahl, 140303); which according to Munge (140428) is 282 items. If a medicine has reached or passed its expiration date, the Pharmaceutical Unit will discard it. Every third month, the Pharmaceutical Unit will mark all medicines that are to expire within the upcoming 6 months; this way, the Pharmaceutical Unit saves time as they do not have to verify all medicines during their monthly check-ups, but only those marked with a sticker. (Törndahl, 140303) By having the Pharmaceutical Unit performing this task, time has been saved for the nurses at Ward 3, who can now place this saved time to tend for patients instead; which is very positive (Petersson, 140312).
3.2.1.3 Extraction of Medicine

The medicine at Ward 3 is kept in a storage facility at the ward (Petersson, 140312). The storage facility is however not the only place in which the medicine is stored, as Ward 3 uses a system of trolleys placed in different rooms at the ward to accommodate the different patients. These trolleys have drawers assigned to specific patients, in which the required medicine is kept. These drawers are meant to provide sufficient medicine until the next replenishment point, meaning that the medicine ought to last around 3-4 days as the trolleys are replenished two times a week, at early afternoons on Mondays and Thursdays. This is done by extracting medicine from the storage facility. (Petersson, 140312)

The nurse has to “log in” by swiping a card in a card reader and enter a personal code, after which access is given to the storage facility. Then, according to each patient’s prescription list; the nurse will search for the medicines on the shelves, extract the amount needed and put it in the patient’s assigned trolley-drawer. (Petersson, 140312; observation Anneli Sollersjö, Nurse at Ward 3, 140423) A prescription list is a list of medicines, and their according dosages, to be provided to the patient (Löfqvist, 140306); this prescription list can be accessed from any computer in the ward and there is one available inside the storage facility (Augustine, 140312; observation Sollersjö, 140423). In case a medicine is not available in the storage facility, the nurse has to extract it from elsewhere, this will be explained further down in this section. When the trolleys are filled, they are put in their allocated destinations (Petersson, 140312).

The demand for medicine is triggered by a patient’s symptom, disease or the prescription list given by a physician. When a medicine is needed, the nurse first has to determine if it is a narcotic or not. If it is not a narcotic, the nurse will then check the patient’s assigned trolley-drawer to see if the required medicine is available there; if so the nurse will simply extract the dosage needed from the trolley-drawer. If the medicine is not available or if the need is urgent; the nurse will turn to the ward’s storage facility (Augustine, 140312; Petersson, 140312). The nurse will log in by swiping a card through a card reader and enter a personal code to access the storage facility. Once inside, the nurse will search for the required medicine, pick it up from the shelf and take the dosage needed. If possible, the nurse will put the remainder of the medicine back on its allocated shelf space. (Petersson, 140312)
If the medicine needed is a narcotic the nurse will go directly to the storage facility, as narcotics are not to be kept in trolley-drawers due to security reasons. The exception however is for a certain sleeping pill which is classified as a narcotic but which Ward 3 has anyhow allowed to be kept in trolleys. If this is the case, the nurse will first turn to the trolley-drawer to see if the narcotic is available. If it is not, the nurse will follow the same procedures as for other narcotics which is as follows; the extraction process from the storage facility is then the same as previously explained, with the exception that the nurse has to sign a document showing that a narcotic was extracted. This document is part of a record of narcotics in which the nurse registers its name, the patient’s details, the date of extraction as well as the amount and type of narcotics which is extracted. (Petersson, 140312) This is however cumbersome as all documents have to be archived for 10 years, leading to many folders needing storage space (Augustine, 140312).

If the medicine is not available in the ward’s storage facility, the nurse will first turn to the central storage (Augustine, 140312; Petersson, 140312; observation Malin Ivarsson, Nurse at Ward 3, 140417; observation Sollersjö, 140423). Here the nurse faces two options; either to place an order online through the AWS’s IT-system via a computer in Ward 3 prior to accessing the central storage; or by doing a direct extraction inside the central storage. If an AWS order is placed, it is stored as a reservation for four hours. This allows for plenty of time to extract the order as something urgent might come in between; this way, the order does not have to be typed in again if extracted within four hours. The time limit was agreed upon between the Pharmaceutical Unit and nurses at CLV. The direct extraction entails that the nurse walks to the central storage, and uses the computer there to access the AWS’s IT-system and place an order upon which the medicine will be immediately extracted. Also here, the nurse is faced with two options; either to extract only the dosage needed for the time being or to extract enough to last until the next trolley-replenishment. If the medicine not available is a narcotic, the routine is a bit different. If the narcotic needs to be extracted from the central storage AWS the nurse has to, regardless of an order placed through the AWS’s IT-system or a direct extraction made at the central storage; type in the patient’s personal code number in order to extract narcotics from an AWS. (Petersson, 140312; observation Ivarsson, 140417; observation Sollersjö, 140423)
The option of placing an order through the AWS’s IT-system is preferable, as then the nurse promptly sees if the medicine is available at the central storage or not; as opposed to choosing to make a direct extraction only to find out at the central storage that the medicine is not available (Petersson, 140312). In either case, when a nurse finds that the medicine is not available at the central storage either, the next step is to turn to the other AWSs located in either Ward 5 or Ward 34. This is done from the accessed AWS IT-system, either at Ward 3 or from inside the central storage depending on where the nurse is present. (Petersson, 140312; observation Sollersjö, 140423) If the medicine is available in another AWS, the nurse either places an order or goes directly to the ward and performs a direct extraction (Petersson, 140312).

Should the medicine not be available in any of the two AWSs at Ward 5 or 34 either, the nurse is faced with the next option; checking a list especially provided by the Pharmaceutical Unit depicting the basic inventory of the different medicinal wards (Augustine, 140312; Petersson, 140312). Törndahl (140429) adds however that this list will soon be removed as the nurses are to instead look in CLV’s ordering system. If the medicine is found to be present at one of these wards, the nurse will establish contact to see if it is possible to “lend” the medicine from the ward. If it is possible, the nurse will walk to that ward and extract the medicine from their storage facility in the same fashion as when extracting from the own storage facility.

If the medicine is however not found to be part of any ward’s basic inventory or if lending is not possible; the nurse is faced with the last option which is that of placing an own order in Provider. This is however only done if it is concluded that the need of medicine is urgent and cannot wait until the storage facility is replenished; these orders are called “emergency orders”. Sometimes when the need for a medicine is semi-urgent; meaning that there is no need for an emergency order to be placed but as well not enough time to wait for the storage facility’s replenishment; a nurse will ask a physician to prescribe the medicine upon which the nurse will walk with the patient down to CLV’s pharmacy and buy the medicine needed. (Petersson, 140312) If a prescribed medicine is neither available nor urgent the nurse will inform the physician that the prescribed medicine is not available and then inform the Pharmaceutical Unit of the medicine needed so that it can be included in the next storage facility replenishment. (Petersson, 140312; observation Sollersjö, 140423)
3.2.1.4 Reverse Logistics of Medicine

The first step for the nurse is to decide whether the medicine to be returned is a narcotic or not. If it is not; the nurse will simply go to the storage facility, swipe the card, log in with a personal code and gain access to the storage. Thereafter, the nurse will search for the right medicine on the shelves, take down the package and return the medicine at hand. This is then noted on a document inside the storage facility. (Petersson, 140312)

Ward 3 keeps its own stock of regularly needed narcotics; these are kept in what the ward refers to as a “cabinet of narcotics”. The routine of the ward is that a narcotic is only to be extracted when it will be promptly given to the patient; this in order to try to minimize the amount of returned unused narcotics. However on those occasions when a nurse at Ward 3 has to return a narcotic there is a specific procedure to follow. (Augustine, 140312; Petersson, 140312) First, the nurse must decide if the narcotic is suitable for return or not; an extracted liquid is not allowed to be returned to its ampoule and neither is pills divided into halves allowed to be returned. If this is the case, the narcotic will be properly discarded and not returned. (Augustine, 140312; observation Sollersjö, 140423) If the narcotic is deemed returnable, the nurse is faced with yet another question; was the narcotic extracted from the ward’s own cabinet of narcotics or was it extracted from an AWS in either Ward 5, 34 or at the central storage (Petersson, 140312).

If the narcotic was extracted from the ward’s own cabinet of narcotics the nurse will walk to the storage facility; swipe its card, type in a personal code and then gain access to the storage. Then, the nurse will open the cabinet of narcotics and take out the specific package of narcotics and count all the pills inside, add the returned amount and verify that the sum adds up. If it adds up, the nurse will record the return on a document with its name, the patient’s name, the date of return as well as the amount and type of narcotic which is returned. If the sum does not add up, the nurse will have to find another nurse to count the amount and verify the difference, which is then recorded as a deviation in the record of narcotics by both nurses. This record of narcotics is as previously mentioned a record which is to be archived. There is a risk of mistakes when it is the nurses’ responsibility to return narcotics due to time pressure or other impacting factors; a higher dose of a narcotic can for example be placed in a package of the same type of narcotic but with a lower dose, or when a narcotic is misplaced altogether in a
package of another type. (Augustine, 140312; Petersson, 140312) One nurse at Ward 3 is responsible for the narcotics, where its responsibility is to verify that the record of narcotics match the actual amount inside the cabinet of narcotics at any point in time; as well as to verify that the consumption of narcotics is reasonable according to the demand based on the currently hospitalized patients at Ward 3 (Petersson, 140312).

If the narcotic however was extracted from an AWS, the nurse has to follow another routine. First the nurse has to conclude from which AWS the narcotic was extracted and then walk to the storage facility where it is located (Petersson, 140312). There, the nurse will log in to the AWS’s IT-system and choose the return function. The nurse will type in the patient’s name and personal code number upon which a specific compartment in the AWS will open and the narcotic can be placed inside. (Munge, 140219) After this is done, the nurse’s work is finished (Petersson, 140312); the rest of the process is continued by the Pharmaceutical Unit (Munge, 140219), and their work regarding the reverse logistics of unused narcotics in an AWS will be further explained in the last paragraph of the following section 3.2.2.

3.2.2 The Material Management Process of Medicine for Ward 5 with an AWS

3.2.2.1 Replenishment of Medicine

The replenishment of medicine in Ward 5’s AWS is performed and controlled by the Pharmaceutical Unit (Granberg, 140306; Törndahl, 140303); however, as explained under section “3.2.1.3 Extraction of Medicine” a nurse at the ward might have to order medicine itself if it is not found at CLV (Löfqvist, 140306) Once a year, an employee from the Pharmaceutical Unit has an inventory review together with nurses at Ward 5 (Törndahl, 140303; Löfqvist, 140306). At this meeting, criteria for the replenishment of medicine are discussed. The minimum and maximum levels for each medicine is decided, largely based on an average of historic ordering data as well as considering the nurses wishes. Consideration is also taken to the medicine’s price and turnover rate, as it is unfavourable to keep a large stock of expensive medicine with a low turnover rate as well as it is unfavourable to place many orders of a low priced medicine with a high turnover as each order line placed is feed. Furthermore, a consideration needs to be taken to the type of medicine, as it is easier to store and order pills as opposed to antibiotics and ampoules. (Törndahl, 140303)
The next step is the weekly replenishment. Since Ward 5 has an AWS, it is replenished twice a week as opposed to a ward without an AWS which is replenished once a week. This as it takes longer to replenish an AWS as opposed to a ward without one; and the employees at the Pharmaceutical Unit feels that they would cause more of an inconvenience if they had to spend almost two hours occupying the AWS. (Törndahl, 140303; Löfqvist (140306) however explains that the nurses at the ward never feels that the Pharmaceutical Unit creates an inconvenience as they easily can log out and let the nurses extract their medicine before continuing with the replenishment process. But Törndahl (140303) also explains that another reason for dividing the replenishment into two occasions is to provide comfort that AWS will not run out of stock.

The replenishment process of Ward 5’s inventory works as follows; an employee from the Pharmaceutical Unit prints a list twice a week from the computer system connected to the AWS, showing all the medicine that has reached an inventory level which is at or below the minimum level. The employee from the Pharmaceutical Unit then enters this list of medicine manually into the ordering system Provider before noon. (Törndahl, 140303; observation Strömberg, 140408) The medicine is then delivered before noon the following day to the ward, where a nurse signs that the box has been delivered and then places it unopened inside the storage facility (Granberg, 140306; Löfqvist, 140306).

Employees from the Pharmaceutical Unit will then sometime during the afternoon come to the ward and access the storage (Törndahl, 140303). Inside the larger box is an order- and picking list, which the employee will cross-reference with its own order list to make sure that everything seems to be in order. Then, the employee will take out a medicine, make a fast check to ensure that there has been no damage and cross reference with the order- and picking list. (Cecilia Lundgren, Dispenser at the Pharmaceutical Unit, 140404; observation Lundgren, 140404) If the delivery does not match the order- and picking list, the employee will call the Pharmacy at CLV and report the mistake; it will also make a note on the order- and picking list. Further the employee will have to, after the replenishment is finished and the employee is back at the Pharmaceutical Unit, log into a program named Synergi which is connected to CLV’s pharmacy, and report the mistake. (Törndahl, 140404; Törndahl, 140429)
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If however the right quantity has been delivered, the employee ticks the order- and picking list and then walks to the computer inside the storage, logs in and chooses the function “replenishment from list”. Then, the employee will scan the barcode of the medicine question after which a window will open indicating the amount to be replenished and what the actual stock level should be. A light will light up somewhere in the AWS, indicating where the medicine should be inserted. (Lundgren, 140404; observation Lundgren, 140404)

The employee opens this compartment, and counts the stock level to make sure that it is as according to the AWS’s IT-system. If there happens to be more than it should it is not considered critical, and the employee will only correct the actual stock-level is it feels that there is enough time; if however the stock level is lower than it should this is considered critical and the employee must change the actual stock level. When changing the stock level, the employee will have to close the compartment, and walk to the computer inside the storage. There, the employee will choose the “inventory” function in which it will search for the medicine in question. The employee will then enter the correct stock-level amount, press OK and then then press save. (Lundgren, 140404; observation Lundgren, 140404) There is however a flaw in the AWS’s IT-system according to Lundgren (140404), as there is no possible way to report why there is a change in stock level. This is especially bad when the lower stock level considers narcotics as the system will only indicate that the employee has changed the stock level to be lower without any explanation, which could seem like the employee then has taken the narcotics for themselves or for any other purpose but giving it to a patient.

If the stock level is as according to the AWS’s IT-system, the employee will then begin the replenishment. If there is medicine still left in the compartment, the expiration date is checked. If it expires before the newer medicine, this medicine will have to be put first and then the replenishment will come after. Once a compartment has been filled, the employee will close it and then insert the compartment’s closest expiration date in the AWS’s IT-system. This process is then continued until all medicine inside the box has been replenished. (Lundgren, 140404; observation Lundgren, 140404) It is a tedious process to enter each medicine into the IT-system and then placing it in the specific storage space; especially for the narcotics which are stored in single storage spaces in the dispenser and which sometimes has to be cut from its chart pill by pill. (Törndahl, 140303; Lundgren, 140404; observation Lundgren, 140404)
It can happen that the ward has had to place an emergency order the same day as the weekly replenishment. Then the employee from the Pharmaceutical Unit will bring this medicine with it up to the ward. This medicine is replenished the same as the medicine from the delivered larger box with the exception that the employee will first have to choose the function “replenish manually”, scan the medicine’s barcode then manually enter the amount to be replenished. (Lundgren, 140404; Observation Lundgren, 140404)

When all medicine has been replenished, the employee will walk back to the Pharmaceutical Unit and log into Provider. There, the employee will choose the function “inbound delivery”, search for the delivery’s order number and choose it upon which information regarding the ward it concerns, who made the order and what it is that has been delivered will be displayed. The employee will verify the information, and if all is in order it will press “verify” and then sign the order- and picking list with its name and date. This list will be taken back to Ward 5 at the next replenishment and inserted into a special “inbound delivery folder” where all order- and picking lists are to be kept for two years as according to Swedish law. (Lundgren, 140404; Observation Lundgren, 140404)

Sometimes, the employee cannot find the order inside Provider if it concerns an order that the ward has placed itself inside E-builder instead. If that is the case, the employee will have to access E-builder instead, search for the order and then press on it. If everything seems to be in order, the employee will press “verify” and then sign the order- and picking list with its signature and date. Should however there be some sort of change in the order, where an ordered medicine has been replaced with an equal but of another brand; this will not be automatically updated in E-builder as it would have been inside Provider. Then, the employee will have to search for the actually delivered medicine, insert the delivered amount, delete the ordered medicine which is still inside the system and then press verify and sign the order- and picking list. (Lundgren, 140404; Observation Lundgren, 140404) As it is more complicated to handle orders placed through E-builder, it is the Pharmaceutical Unit’s wish that all wards would be using Provider instead (Törndahl, 140404; Lundgren, 140404)
3.2.2.2 Stock Inventory of Medicine

The responsibility of performing a major stock inventory is a part of the pharmaceutical service, and is therefore the responsibility of the Pharmaceutical Unit. Once a month, an employee from the Pharmaceutical Unit will print out a report from the AWS’s IT-system which indicates which medicines that are about to expire. If there are any medicines that have reached or passed their expiration date, employees from the Pharmaceutical Unit will go to Ward 5 and properly discard these medicines. (Törndahl, 140303) This is a much appreciated service among the nurses at Ward 5, who now feel that they have more time to devote to their patients without having to spend hours inventorying (Granberg, 140306).

3.2.2.3 Extraction of Medicine

At Ward 5, the storage facility for medicine and medical supplies has an AWS installed; compiled by dispensers, cabinets, an electronic lock as well as a computer (Granberg, 140306; Munge, 140219). The storing spaces in the AWS are only marked with a number with no indication as to what medicine is to be stored in it, nor is the medicine in alphabetic order. There are also a few open shelves for medicines or supplies which do not fit in the dispensers or cabinets; however the nurse is not allowed to extract anything from the shelf without going through the AWS’s IT-system. (Munge, 140219)

In case of a power-out or breakdown, the AWS can be manually opened, by a key which is to be kept by CLV’s maintenance keeper (Granberg, 140306). Should such an event occur, there is a binder available listing the different medicines kept in stock as well as their allocated spaces (Munge, 140219; Löfqvist, 140306). Törndahl (140303) expresses that a slight disadvantage of an AWS is that the storage space provided is fixed, and there is less opportunity to “puzzle” with boxes and supplies as it is on the open shelves of a ward without an AWS.

The storage facility is not the only place where the ward stores its medicine as the ward also works by a system of trolleys stationed in the different patient-rooms. Each trolley has drawers assigned to specific patients, in which their prescript medicine is kept. These trolleys are refilled twice a week by nurses working the nightshift; leading to each patient-drawer to contain medicine calculated to last until the next refilling, which is approximately 3-4 days. The filling of these trolleys are done by extracting the medicine from the AWS according to the prescription list. (Löfqvist, 140306)
The extraction is done by logging into the AWS’s IT-system from a computer at the ward; creating orders for each patient (Löfqvist, 140306; observation Löfqvist, 140410). These orders are reserved online for 4 hours, which is an amount that the pharmaceutical unit and CLV’s nurses have compromised. It gives enough time to be able to extract the medicine in case of an emergency happening which interrupts the extraction process, without having to start over. (Granberg, 140306) The nurse then goes to the storage facility located at Ward 5, logs into the computer there and starts extracting the medicine, patient by patient. When a patient’s medicine is extracted, it is put into its assigned trolley-drawer; this is repeated until all necessary trolley-drawers are filled. When the trolleys are filled as demanded, they are then placed in their allocated destinations at the ward. In case a medicine is not available in the storage facility, the nurse will have to extract it from elsewhere (Löfqvist, 140306; observation Löfqvist, 140410); this process will be explained further below.

The demand for a medicine is triggered by a symptom arising in the patient or due to the patient’s prescription list; which is a list of medicines, and their according dosages, to be provided for the patient. When the demand for a medicine has been triggered, the first step for a nurse is to check whether the medicine is classified as a narcotic or not. If it is not; the nurse will check the patient’s trolley-drawer, to see if the medicine is available there. If it is available, the nurse will simply extract the prescript dosage from the drawer. If however it is not, the nurse will then have to extract it from the AWS. The normal routine for nurses in a case like this is to do a direct extraction; entailing that the nurse goes directly to the computer inside the storage facility and creates the order for the patient there and then immediately extracts it from the AWS. (Granberg, 140306; Löfqvist, 140306)

If the demand is for a medicine that is classified as a narcotic, the nurse will go to the storage facility and make a direct extraction from the AWS unless it’s a lighter narcotic such as a sleeping pill which is allowed to be kept in trolley-drawers (Granberg, 140306; Löfqvist, 140306). When doing the direct extraction for a narcotic; the nurse is required to type in the patient’s personal code number. There is also an option for nurses to not make a direct extraction but rather use the AWSs IT-system and submit a patient’s medicine order online in order to later extract it from the AWS. If it is a narcotic to be extracted, it is required also here to type in the patient’s personal code number. (Granberg, 140306; observation Löfqvist, 140410)
Regardless of the extraction being direct or from an online order; the nurse is faced with the option to either extract only the amount needed at the specific point in time; or to extract enough to last until the next scheduled extraction for the trolley-drawers. This is however not an option for narcotics since, as previously mentioned, these are not allowed to be kept in trolley-drawers. (Löfqvist, 140306)

There is a possibility that when either making a direct extraction or placing an order online; the medicine is not available at the AWS at Ward 5. The nurse can then check the AWS’s IT-system to see if it is available at the AWS located in CLV’s central storage. If it is, the nurse then faces two options; either to make an order online through the AWS’s IT-system and then within four hours walk to the central storage and extract it from its AWS, or to walk to the central storage and make a direct extraction from its AWS. Which option the nurse chooses often relates to how comfortable it feels with the online booking system and/or how urgent the patient’s need for promptly receiving a medicine is. If the nurse discovers that the central storage is out of stock as well, the nurse will check if the third AWS located at Ward 34 has the medicine available. If available, the nurse is once again faced with the same two options as previously mentioned. (Granberg, 140306; Löfqvist, 140306; observation Löfqvist, 140410)

If however the medicine is not available here either; the nurse will have to log into the ordering system Provider to see if a ward at CLV has recently placed an order of this medicine (Löfqvist, 140306). If there is such a ward, the nurse will establish contact and see if it is possible to “lend” the medicine. If possible; the nurse will then walk to that ward and extract the medicine. If not possible, or in case there had not been any ward that had placed an order for that medicine the nurse is faced with the last option; placing an order. Depending on the urgency of the medicine the order can either be an express or regular order. With the express order, the medicine can be available within the same day; however this is a more expensive option. The regular order is less expensive but takes 24 hours to be delivered. The order is to be placed through the ordering system Provider; however some nurses are more comfortable with the previous ordering system “E-builder” and still places their orders there. This is not preferable as it will make it harder for wards to see which wards that placed which orders, if it is done through two different systems. (Granberg, 140306; Löfqvist, 140306) The orders placed through the system Provider is managed by the Pharmaceutical Unit (Törndahl, 140303); this process was depicted earlier under section “3.2.1.1 Replenishment of Medicine”
On rare occasions during weekends if there is a stock-out at CLV and the pharmacy’s order and delivery service is closed; the nurses will ask a physician to write a prescription of the required medicine and then walk together with the patient down to the pharmacy and buy the medicine. If the patient is in an extremely urgent need of a certain medicine during weekends, there is also the possibility of having it flown here by helicopter from other hospitals in Sweden; this has however not yet occurred for CLV. (Granberg, 140306)

3.2.2.4 Reverse Logistics of Medicine

The first step for the nurse is to determine if the medicine that is to be returned is a narcotic or not. If it is not a narcotic, the medicine will be discarded; this as medicine which is not classified as a narcotic cannot be returned to an AWS. Previously, a nurse would put back unused medicine in its respective packages when they were just stored on shelves, but as this is no longer possible more medicine is discarded, which is perceived as a waste amongst the nurses. The ward is therefore now searching for new routines regarding the trolleys to try and minimize the discarded medicine due to the patient leaving, or if the prescription list is changed. (Granberg, 140306)

There is no detailed common return policy of narcotics for CLV; the wards without an AWS installed each have their own way of how to handle this. As Ward 5 does have an AWS, the returning of unused narcotics is now a part of the pharmaceutical service given by the Pharmaceutical Unit. (Törndahl, 140303) The return of unused narcotics at Ward 5 is done through the AWS; which has provided the nurses a sense of more secure handling of narcotics (Granberg, 140306). The process of returning narcotics is simple; the nurse logs in to the AWS’s IT-system and chooses the return-function, types in the patient’s personal code number and then places the narcotic in question in a special compartment inside the AWS. This compartment is designed so that objects can only be put in but not extracted, which eliminates the risk of somebody extracting narcotics undocumented. This compartment can only be emptied by employees of the Pharmaceutical Unit. (Munge, 140219; observation Lundgren, 140410)

Employees from the Pharmaceutical Unit come to the ward once a week to take care of the returned unused narcotics. At first, a list from the IT-system connected to the AWS is printed; showing all the registered returned narcotics. Then, the compartment with the returned unused narcotics is emptied and the employees from the Pharmaceutical Unit
verify that what is found in the compartment matches the list of registered returns. (Törndahl, 140303; observation Strömberg, 140415) The employee from the Pharmaceutical Unit will first sort the narcotics into piles according to their type on a counter (observation Strömberg, 140415). If the type of narcotic and its expiration date can be identified, it is then registered and inserted into the AWS for future use; if it cannot be identified, the narcotic will be registered as waste and properly discarded. (Törndahl, 140303; observation Strömberg, 140415)

3.3 Analysis for Research Question I

This chapter will treat the analysis for Research Question 1; the analysis will be conducted in two different parts. The first part will generate in different process maps for Ward 3 and Ward 5 after having discussed the theoretical and empirical findings. The second part will compare Ward 3’s process maps with their equivalent for Ward 5 in order to find similarities and differences. The aim of this chapter is to generate a basis for conclusion in order to be able to answer Research Question 1. Below follows an illustration of the analysis’ disposition:

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**Analysis Model for Research Question I**

**PART I**
- **Theory**
  - The Material Management Process
  - SCOR
  - Process Mapping

**PART II**
- **Process Maps Ward 3**
  - Replenishment of Medicine
  - Stock Inventory of Medicine
  - Extraction of Medicine for Trolley
  - Extraction of Medicine for Patient
  - Reverse Logistics of Medicine

- **Process Maps Ward 5**
  - Replenishment of Medicine
  - Stock Inventory of Medicine
  - Extraction of Medicine for Trolley
  - Extraction of Medicine for Patient
  - Reverse Logistics of Medicine

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**Analytical Discussion Outcome:**
Process Maps for Ward 3 and Ward 5

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**Analytical Discussion**

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**Empirical**
- The Material Management Process
- Replenishment of Medicine
- Stock Inventory of Medicine
- Extraction of Medicine
- Reverse Logistics of Medicine

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**Analytical Comparison**

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**Basis for Conclusion**

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Figure 8: Analysis’ Disposition for Research Question I

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3.3.1 Analysis Part I

Part I of the analysis will put theory and empirical findings are put against each other in a pattern matching through analytical discussions. The analysis begins with a general analytical discussion of the material management of medicine for both wards. This is followed by an analytical discussion ward by ward according to the SCOR-model’s different categories. It is here that the different process maps are created and illustrated.

3.3.1.1 The Material Management Process of Medicine at Ward 3 and Ward 5

The flow of material and information are two flows in supply chain that are considered to be connected according to Mattson (2012); further, Chandra et al. (2013), Jonsson (2008), Park et al. (2011), Alvarado-Iniesta et al. (2013) and Arnold et al., (2008) defines the material flow as a part of the material management process. This could be argued to hold true as according to Munge (140120) the installation of AWSs has enabled any ward to through any computer access the AWS IT-system and easier get updated information on stock-levels and thus save time when not having to run to different wards. This eased information flow then affects the material flow as it enables a nurse to find the material it is looking for and acquire it in a more effective way.

Callender & Grasman (2012) has described that inefficiencies in the health care sector can often be reduced by improvements in the material management process specifically in inventory management. This connects with de Vries & Huijsman (2011)’s statement that hospitals are now realizing that they need to focus more on their supply chain management. Munge (140120) concurs as he explains that CLV has now reached a point where it has understood that it must focus on its material management process of medicine in order to increase safety and possibly reduce costs.

In order to achieve this, Damelio (2011), Soliman (1998) and Bergman & Klefsjö (2010) suggest creating process maps as they make the work more visible and improve understanding and communication and Heinrich et al. (2009), Biazzo (2002) and Harrison & van Hoek (2011) concurs as they state that a process map allows for a systematic presentation as they provide a “snapshot” in time and Anklesaria (2008) and Recker et al (2010) adds that a process map can provide a common reference for those involved. Melan (1992) continues by explaining that once the process has been chosen; a beginning and an end must be defined and that within these boundaries; activities with
their input and output will be identified; which aligns with Slack et al., (2012) and Jacobs (2011)’s explanation of how a process consists of resources turning input into output as well as Heinrich et al (2009) and Biazzo (2002)’s explanation of how a process consists of activities people and data creating an output. Mattsson (2012) argues that a process begins with a demand, and that the process is fulfilled when the demand is satisfied. Damelio (2011), Yin (2014) and Singprasong & Eldabi (2011) suggest different ways of collecting data; for each process map this has been done through interviews with Törndahl (140303), Augustine (140312), Petersson (140312), Löfqvist (140306) and Granberg (140306) who then provided the information necessary for determining the beginning and end of a process, its triggering demand, when this demand has been fulfilled as well as all activities included between these boundaries.

The process maps are illustrated according to Damelio (2011) and Meyer et al. (2007)’s suggestion of using a flowchart, and the symbols used are according to those provided in table 6. At times, the flowchart will be illustrated as a swim lane diagram as according to Jonsson & Mattsson (2011), Damelio (2011) and Singprasong & Eldabi (2011). Before each process map there will be a description of why this has or has not been used. According to SCOR Supply Chain Council (2014) and Mattsson (2012) a way to divide an organisation’s material management process is according to the SCOR-model into for example plan, source and return. That aligns with Törndahl (140303) Augustine (140312), Petersson, (140312), Löfqvist (140306) and Granberg (140306) when explaining the different routines regarding the processes in the medicine handling; these fall under the different categories in the SCOR-model. These will be depicted in in the following sub sections.
3.3.1.2 Process Mapping the Material Management Process of Medicine at Ward 3 without an AWS

3.3.1.2.1 Plan

According to Mattson (2012) and Lumsden (2012) the planning of demand and supply should result in a balance between resources and requirement; this is achieved through replenishment, and the determination of business rules to measure and improve for example inventory. Here a replenishment point system is one approach where the quantity in stock is compared to the predefined quantity according to Lumsden (2012). According to Törndahl, (140303) Ward 3 has together with the Pharmaceutical Unit through their pharmaceutical service established rules for replenishment which aligns with above authors, and also as it uses a replenishment point system where each medicine has a minimum stock level when an order is placed, which is the equivalent to a replenishment point.

When the pharmaceutical has placed an order and it has arrived at Ward 3 they will inspect the delivery as they unpack the medicine to verify quantity according to Törndahl (140303); a quick quality control is also performed (Törndahl, 140404). This aligns with Lumsden (2012) who explains that when products arrive they need to be inspected; verification of quantity can be done through cross-referencing the delivered quantity with the packaging list, as done at Ward 3 according to Törndahl (140303).

Then according to Lumsden, (2012) after a delivery has been controlled and approved, the products will need to be put into the storage facility depending on the method of stock-keeping placement used. With a fixed placement; every product shall be placed at the same location every time whereas with a flexible placement an empty space can be used for any product. Törndahl (140303) explains that Ward 3 has barcodes indicating the placement of each medicine in the storage and therefore has a fixed placement for the inventory. The stock levels are according to Mattson (2012) commonly controlled
on a regular basis; this holds true for Ward 3 as Törndahl (140303) says that their routine is to check stock levels and replenish once a week, they do this using barcodes which is the most common way according to Mattson (2012).

Melan (1992) continues by explaining that once the process has been chosen; a beginning and an end must be defined and that within these boundaries activities will be identified. Mattsson (2012) argues that a process begins with a demand, and that the process is fulfilled when the demand is satisfied. In accordance to Törndahl’s (140303) explanations, it is clear that the process of replenishment begins with the demand for replenishment, and then therefore ends when the replenishment has been performed.

When reviewing the explanations given by Törndahl (140303) and Petersson (140312) it becomes clear that both the Pharmaceutical Unit and Ward 3 are a part of this process, making a swim lane diagram as according to Jonsson & Mattsson (2011), Damelio (2011) and Singprasong & Eldabi (2011) suitable for depicting the process. Having the Pharmaceutical Unit and Ward 3 as two functions aligns with Jonsson & Matsson’s (2011) as well as Gadde et al.’s (2012) suggestions; the Pharmaceutical Unit can be seen as a forecasting function, order treatment function, material control function, purchasing function and a material handling function and Ward 3 can be seen as a purchasing function and storage function.
Figure 15: Process Map of Replenishment of Medicine for Ward 3 without an AWS
The SCOR-model’s category Plan also includes according to Mattsson (2012) and Lumsden (2012) the activity of inventorying, which aligns with Törndahl’s (140303) explanation of the Pharmaceutical Unit’s routines. The inventory performed once a week by checking the medicines on the shelf does not include verifying the expiration date of the medicines. Inventoring can according to Mattsson (2012) be done on a daily, weekly or monthly basis; the latter is how often the Pharmaceutical Unit will inventory the expiration dates of medicine in Ward 3’s storage as explained by Törndahl (140303); this is done manually and every three months all medicine is verified and stickers are put on those which will expire within six months, this way the Pharmaceutical Unit does not have to go through all the medicines every month, only those with stickers. As there is only one function doing the stock inventory of medicine as according to Törndahl (140303) a swim lane diagram as proposed by Jonsson & Mattsson (2011), Damelio (2011) and Singprasong & Eldabi (2011) will not be relevant.

![Figure 16: Process Map of Stock Inventory of Medicine for Ward 3 without an AWS](image-url)
According to Mattson (2012) the SCOR-category Source includes the process of satisfying a demand by acquiring material. The demand for medicine at Ward 3 arises due to a patient’s symptom or from the prescription list given by a physician explains Augustine (140312) and Petersson (140312). Acquiring material can be done through inventory, which is kept in a physical storage facility says Mattson (2012); this is in line with the practice at Ward 3 as they have a storage of medicine at the ward and also trolleys where they keep medicine to satisfy the need of the patients hospitalized at the ward as explained by Petersson (140312). Further she states that the trolleys are used in the aim to minimize handling of medicine, since they prepare each patient’s trolley drawer they can in a more convenient manner look there when the demand arise and therefore not have to walk over to the ward’s storage each time. This is in line with Jonsson (2008) who expresses that the storage facility should be designed to minimize maintenance and handling costs.

The inventory is then taken from the trolley or in case it is not available there from the storage facility to its destination which is the patient by a nurse at Ward 3 says Petersson (143012). This concurs with Jonsson & Mattsson (2011) and Lumsden (2012) as they describe that the material can be brought to the destination by different means; either by different vehicles or by a physical person, the latter is in line with Ward 3’s case where this is done by a nurse.

What medicine the nurse is to pick is in most cases determined by the prescription list explains Petersson (140312) and the prescription list here then acts as what Jonsson & Mattsson (2011) and Grosse & Glock (2013) calls a picking list, which is what mediates the information of what is to be extracted. Mattson (2012) further discusses that this information can be sent in different ways and the one that is in accordance with Ward 3’s work is information system to man; which entails that a person, in Ward 3’s case a
nurse, initiates the communication of information at Ward 3 by verifying the prescription list, as explained by Petersson (140312) and Augustine (140312).

Jonsson & Mattsson (2011) and Grosse & Glock (2013) described that the extraction process can be done in different ways where one is the man-to-material method, which requires that a person physically goes to the storage and extract the product directly from the storage; many picking orders may be bundled as order picking is often time consuming. Augustine (140312) and Petersson (140312) describes that a nurse picks a medicine in the trolley or storage which is aligned with what the authors above described. Further Augustine (140312) and Petersson (140312) has explained that the ward will fill up the trolleys with specific patient-drawers twice a week in order to save time and have the medicine available more close at hand; this can therefore be considered as picking a bundle order as mentioned by above authors.

The extraction process of medicine for trolleys and patients is performed by the nurses at Ward 3 according to the explanations given by Petersson (140312) and Augustine (140312). As the extraction process of medicine for trolley or patient is quite extensive, each type of extraction will therefore be illustrated in its own process map. A swim lane diagram as suggested by Jonsson & Mattsson (2011), Damelio (2011) and Singprason & Eldabi (2011) will then not be suitable for depicting the processes.
Figure 18: Process Map of Extraction of Medicine for Trolley at Ward 3 without an AWS
Figure 19: Process Map over Extraction of Medicine for Patient at Ward 3 without an AWS
3.3.1.2.3 Return

WARD 3
RETURN

This step includes processes involving reverse logistics which is according to Mattson (2012, 2000) the role of logistics in return of products, waste disposal etc. The focus is here according to Arnold et al. (2008) and Rogers & Tibben-Lemke (2001) the flow back from the point of consumption to the origin and handling this flow in a bad manner can according to de Brito & Dekker (2004) cost the organization a lot. This is aligned with Ward 3 they have a flow of reversed logistics of medicine according to Petersson (140312) as they return most unused medicines to its package in the storage and unused narcotics to the cabinets of narcotics; this is done in order to decrease waste and reduce costs. There are however medicines such as half pills or ampoules that cannot be returned, these are then properly discarded says Petersson (140312) which then agrees with the authors above.

As there is only one function performing the stock inventory of medicine as according to Törndahl (140303) a swim lane diagram in line with Jonsson & Mattsson (2011), Damelio (2011) and Singprasong & Eldabi (2011)’s explanation will not be suitable for depicting this process.
Figure 21: Process Map of Reverse Logistics of Medicine for Ward 3 without an AWS
3.3.1.3 Process Mapping the Material Management Process of Medicine at Ward 5 with an AWS

3.3.1.3.1 Plan

Mattsson (2012) and Lumsden (2012) explains that under the SCOR-category Plan, steps including balancing resources and requirements are a part and that this is done through the replenishment of stock, and it’s related replenishment system. That makes what Törndahl (140303) and Löfqvist (140303) said regarding the replenishment routines and replenishment system for Ward 5 relevant for depicting this process. Within the replenishment process, Lumsden (2012) also explains how an order placed leads to delivery and that this delivery needs to be verified, which aligns with how Törndahl (140303) has explained the Pharmaceutical Unit’s working routines to be.

Lumsden (2012) also explains that the placement can be done in different ways; with either a fixed or flexible placement. As according to Törndahl (140303) and Munge (140219) the storage facility uses both systems. The shelves assigned to medical supplies which are too large to fit in an AWS are indicated with a barcode; therefore the replenishment follows a fixed placement. The cabinets follow as well a fixed placement as according to Munge (140219) the Pharmaceutical Unit has decided which medicine goes into which compartment as they do not want to have an alphabetical order, or medicine of the same type close to each other. This is done to avoid confusion and the risk of taking the wrong medication. The dispenser however, follows a flexible system as when the Pharmaceutical Unit logs in to make the replenishment, it will simply suggest an empty compartment (if the medicine is not already inside the dispenser) for the replenishment.
Törndahl (140303) and Löfqvist (140306) explain that both the Pharmaceutical Unit and Ward 5 are a part of this process, making a swim lane diagram as according to Jonsson & Mattsson (2011), Damelio (2011) and Singprasong & Eldabi (2011) suitable for depicting the process. Having them as two functions aligns with Jonsson & Mattsson’s (2011) and Gadde et al.’s (2012) suggestions; the Pharmaceutical Unit can here be seen as a forecasting, order treatment, material control, purchasing and material handling function and Ward 5 can here be seen as a purchasing and storage function.

Figure 23: Process Map over Replenishment of Medicine at Ward 5 with an AWS
The SCOR-category Plan includes as well according to Mattsson (2012) and Lumsden (2012) the activity of inventorying, which aligns with Törndahl’s (140303) explanation of the Pharmaceutical Unit’s routines. The inventory is performed on a daily basis by checking the AWS’s IT-system which then indicates if a medicine is at or after its expiration date, this aligns with Mattsson (2012) stating that inventorying can be performed on a daily, weekly or monthly basis through a completely automated information handling, where the computer system for example updates the new stock levels by itself and indicates when replenishment is needed.

As there is only one function doing the stock inventory process as according to Törndahl (140303) a swim lane diagram as proposed by Jonsson & Mattsson (2011), Damelio (2011) and Singprasong & Eldabi (2011) will not be relevant for depicting this process.

Figure 24: Process Map over Stock Inventory of Medicine for Ward 5 with an AWS

3.3.1.3.2 Source

Ward 5

SOURCE

Theory
- Process Mapping
- SCOR - Source

Analytical Discussion

Empirical
- The Material Management Process
- Extraction of medicine

Analytical Discussion Outcome:
Process Map of the Extraction of Medicine for Trolleys

Analytical Discussion Outcome:
Process Map of the Extraction of Medicine for Patients

Figure 25: Analysis’ Disposition over Subsection Source for Ward 5
As according to Mattsson (2012) the category of Source includes processes satisfying the demand for acquiring products; that makes it suitable to include the process of how extraction of medicine is performed at Ward 5 as according to Löfqvist (140306) and Granberg (140306). Jonsson (2008) explains that acquiring material can be done from a physical storage facility which is what Ward 5 has according to Granberg (140306). Lumsden (2012) and Jonsson & Mattsson (2011) further explains that this material can be taken out from the facility by a physical person through a man-to-material method, which aligns with the explanations given by Lofqvist (140306) and Granberg (140306) who explains that a nurse personally must walk to a storage and extract a medicine.

Jonsson & Mattsson (2011) and Grosse & Glock (2013) explains that information is needed for an extraction, and that this is mediated through a picking order; in the case for Ward 5 according to Lofqvist (140306) this is mediated through the patient’s prescription list. Aligned with Mattsson’s (2012) description of how this information is sent, the case for Ward 5 according to Lofqvist (140306) and Granberg (140306) it is sent by man to information system and information system to man as it is a nurse that enters the order electronically and then the system that indicates if the order is available or not. Jonsson & Mattsson (2011) and Grosse & Glock (2013) continues with explaining that it is always the exact amount depicted in the order which will be extracted; this aligns with Ward 5’s work according to Lofqvist (140306) and Granberg (140306) as the AWS will only allow access to the medicine depicted in the order. Jonsson & Mattsson (2011) and Grosse & Glock (2013) says that it is easier to bundle many picking orders into one; this holds true for Ward 5 according to Granberg (140306) and Lofqvist (140306) as they claim that it saves time and effort to make many orders at once through a computer at the ward rather than making single orders through direct extractions at the computer inside a storage facility.

The extraction process is made by both the night and day shift as according to the explanations given by Lofqvist (140306) and Granberg (140306). As the two shifts belong to the same function, Ward 5, they will not be treated as separate functions and therefore a swim lane diagram as according to Jonsson & Mattsson (2011), Singprasong & Eldabi (2011) and Damelio (2011) will not be relevant for depicting these processes. As the extraction process of medicine for trolley or patient is quite extensive, each type of extraction will be illustrated in its own process map.
Figure 26: Process Map of Extraction of Medicine for Trolleys at Ward 5 with an AWS
Figure 27: Process Map of Extraction of Medicine for Patients at Ward 5 with an AWS
The SCOR-category of Return includes according to Mattsson (2012) the reverse logistics of products. In alignment with Granberg (140306), Löfqvist (140306) and Törndahl (140303) this seems to be a process performed also at CLV as there are routines regarding the return of medicine. It could therefore be said that CLV has recognized its importance as according to Arnold et al. (2008), Rogers & Tibben-Lemke (2001) and de Brito & Dekker (2004) who all state that companies have increasingly understood the importance of reverse logistics. It seems however to be a flaw in the processes of reverse logistics of products at Ward 5, as the AWS has removed the possibility of returning medicine not classified as narcotics, and as according to Granberg (140306) this is perceived as a waste amongst the nurses who now has to discard medicine which could have been used on another patient. The AWS seem however to have brought a more standard routine regarding the return of logistics, because as according to Törndahl (140303) wards without an AWS have their own routines regarding this; in which some wards might not even return it at all. Now however, with the AWS it is the Pharmaceutical Unit who handles the reverse logistics of narcotics and applies the same routines regarding all AWSs, as explained by Törndahl (140303).

The Reverse Logistics of Medicine is performed by both Ward 5 and the Pharmaceutical Unit as according to all explanations given by Granberg (140306), Löfqvist (140306) and Törndahl (140303). As the process does not cross functions, a swim-lane diagram as according to Jonsson & Mattsson (2011), Singprason & Eldabi (2011) and Damelio (2011) will not be appropriate; the process of reverse logistics of medicine will instead be depicted in two separate process maps, one for Ward 5 and one for the Pharmaceutical Unit.
Figure 29: Process Map over Reverse Logistics of Medicine at Ward 5 with an AWS

Figure 30: Process Map over Reversed Logistics of Medicine by the Pharmaceutical Unit at Ward 5 with an AWS
3.3.2 Analysis Part II

Part II of the analysis will through a comparison generate a basis for conclusion from which Research Question I can later be answered. The comparison is enabled by analysing the processes as suggested by Karan et al. (2003), Damelio (2011), French et al. (2013), Haponava & Al-Jibouri (2010) and Singprasong & Eldabi (2011). This analysis will compare each process from Ward 3 with its equivalent from Ward 5; there will be a discussion regarding the processes’ deviations and similarities and why these have occurred. This section will not include theory as this was analysed in Part I.

In order to properly compare the different maps, the authors have found that it is best made by comparing sections of a process map for Ward 3 to a similar section in the equivalent process map for Ward 5. Therefore, the process maps have been divided into different coloured and numbered sections by the authors. The division is not following some theoretically logical pattern, but is based on where the authors feel that a natural division point is present. The sections themselves are not intended to prove or conclude anything, they are merely a help in sequentially comparing the different process maps.

3.3.2.1 Comparison of the Replenishment Process between Ward 3 and Ward 5

![Diagram: Analysis’ Disposition over Subsection Comparison of Replenishment Process]

Section 1:

The replenishment process is the same in the sense that both wards are replenished by the pharmaceutical service provided by the Pharmaceutical Unit. It differs that Ward 3 receives replenishment once a week whereas Ward 5 receives it twice a week. The process of replenishing for the Pharmaceutical Unit differs between the wards as one has an AWS system and the other open shelf storage with bar codes. This section seems to be more extensive at Ward 3, as it involves having to access the storage and manually scan each barcode, whereas at Ward 5 everything is performed at a computer at the Pharmaceutical Unit.
In regards to safety, there seems to be more room for error at Ward 3 as much is performed manually; the wrong bar code could easily be scanned, or the document with articles to be replenished not stored in the storage room could easily be missed. As everything at Ward 5 is performed through a computer, there is not much room for mistake.

Section 2:

The delivery time is 24 hours for both wards and each ward has to sign that they have received the medicine from the pharmacy upon delivery. Thereafter employees from the Pharmaceutical Unit will come and at both wards check the delivered medicines with the packaging list. Thereafter the process differs between the wards, and now it is Ward 5 that has a more extensive section. For Ward 3, the employee simply has to put each medicine on its allocated shelf space when at Ward 5 it has to be entered through the AWS IT-system, and sometimes divided into portions.

In regards to safety, there is more room for error at Ward 5 compared to Ward 3. An expiration date could be missed and wrongly typed into the AWS IT-system, or the wrong amount of medicine could be placed in the portioned dispensers. At Ward 3, there could be mistakes made as putting a medicine on a wrong shelf-place or missing to fill in the narcotics journal.
Analytical Comparison

- Section 1 is more extensive at Ward 3 compared to Ward 5
- Section 1 at Ward 3 includes more manual work and leaves more room for errors compared to Ward 5, where most is done through a computer
- Section 2 is more extensive for Ward 5 and includes much more detailed work compared to Ward 3
- Section 2 gives more room for error for Ward 5 compared to Ward 3
- Both wards receive pharmaceutical service
- Delivery time is 24 hours for both wards
3.3.2.2 Comparison of the Stock Inventory of Medicine Process between Ward 3 and Ward 5

Section 1:

The stock inventory of medicine process is handled by the Pharmaceutical Unit through their pharmaceutical service for both wards. The stock inventory is performed once a month for both wards and an inventory review takes place once a year with an employee from the Pharmaceutical Unit and nurses at the ward.

To find out if a medicine is at or after its expiration date is much more extensive at ward 3, as the medicine must be manually verified in the storage room. Every month, each medicine labelled with a sticker is verified, and every third month each medicine must be verified and possibly labelled. At Ward 5 however, the employee needs only to log into the AWS IT-system to verify.

Section 2:

Should there be anything at or after its expiration date, and therefore must be discarded, this is more extensive at Ward 5 as it includes the employee having to walk to the storage room, log into the IT-system and extract from the AWS whereas at Ward 3 the employee needs only to verify what it has already taken down from the shelf-space. If there is nothing to discard, this involves less work for Ward 5, as the employee then will not leave the Pharmaceutical Unit, but for Ward 3 the employee still had to access the storage room and manually verify the medicine.
Table 9: Comparison and Basis for Conclusion for the Stock-Inventory Process

Analytical Comparison

- Section 1 is more extensive for Ward 3 as medicine must be manually verified, compared to Ward 5 where it is electronically verified at the Pharmaceutical Unit.
- Section 2 is less extensive for Ward 3 as the employee is already inside the storage and can manually take the medicine from its shelf; whereas for Ward 5 the employee must first access the storage and then extract it from a computer.
- In section 2 if nothing is to be discarded, this is less extensive for Ward 5 as the employee then does nothing whereas as for Ward 3 where the employee regardless must perform the manual verification first.
- Both wards receive Pharmaceutical Service
- The inventory is performed once a month for both wards
- An inventory review is held once a year for both wards
3.3.2.3 Comparison of the Extraction Process for Trolleys between Ward 3 and Ward 5

Figure 33: Disposition over subsection Extraction Process for Trolleys

Section 1:
Section 1 includes all the activities of the process that takes place at the ward. It is more extensive for Ward 5 as they have two options in how they will extract medicine for the trolley. However it is worth noticing that Ward 3 has two different routines depending on if the medicine that is to be extracted is classified as narcotics or regular medicine.

Section 2:
The routine for how to handle a case of where a medicine is not available at CLV is the same for both wards.

Section 3:
This section includes the activities concerned with extracting medicine at AWSs which are not located at their ward. This is similar for both wards as it is checked through the AWS’s IT-system and they then have to physically go to the AWS and bring the medicine back. The nurse at Ward 5 has already made the decision if they will make a direct extraction or place an order; the nurse at Ward 3 now has to make this decision, therefore the section is slightly more extensive in their process map.
Analytical Comparison

- **Section 1** more extensive for Ward 5 as they have two options of how to go about the extraction.
- **Section 2** the same for both wards.
- **Section 3** is similar but slightly more extensive for Ward 3 as it includes having the option of two types of extraction, this decision has already been made at Ward 5.

Table 10: Comparison and Basis for Conclusion for the Process of Extraction of Medicine for Trolley
3.3.2.4 Comparison of the Extraction process for Patient between Ward 3 and Ward 5

Section 1:

Section 1 is the same for both wards as they turn to the patient’s trolley drawer to see if the medicine demanded is available here and if that is the case they will pick the medicine from here. If the medicine demanded is narcotics it is not stored in the trolley drawer and it has to be extracted from storage and this is part of the next section for both wards.

Section 2:

Section 2 includes all the activities of the process that takes place at the ward if the medicine demanded was not available in the patient’s trolley drawer. It is more extensive for Ward 5 as they have two options in how they will extract medicine for the trolley. However it is worth noticing that Ward 3 has two different routines depending on if the medicine that is to be extracted is classified as narcotics or regular medicine.

Section 3:

This section includes the activities concerned with extracting medicine at AWSs which are not located at their ward. This is similar for both wards as it is checked through the AWS’s IT-system and they then have to physically go to the AWS and bring the medicine back. The nurse at Ward 5 has already made the decision if they will make a direct extraction or place an order; the nurse at Ward 3 now has to make this decision, therefore the section is slightly more extensive in their process map.

Section 4:

The routine for how to handle a case of where a medicine is not available at CLV is the same for both wards. They will question how urgent the demand is and thereafter make the decision of what kind of order will be placed.
Analytical Comparison

- Section 1 is the same for both wards.
- Section 2 is about the same size but the decisions made are different.
- Section 3 is similar but slightly more extensive for Ward 3 as it includes having the option of two types of extraction, this decision has already been made at Ward 5.
- Section 4 is the same for both wards.

Table 11: Comparison and Basis for Conclusion for the Process of Extraction of Medicine for Patient
3.3.2.5 Comparison of the Process of Reverse Logistics of Medicine between Ward 3 and Ward 5

Section 1:
This is the same for both wards with the exception that Ward 5 must discard also regular medicine where Ward 3 can put it back on its allocated shelf space.

Section 2:
This section is the same for both Wards, as a return in an AWS is the same no matter which AWS it regards. The only difference is that Ward 3 must walk longer to this other AWS, when Ward 5 only needs to access its storage room.

Section 3:
There are large differences here as to how a narcotic is returned back to its storage inside the storage room. For Ward 5 this is entirely made by the Pharmaceutical Unit once a week, and involves an employee having to empty the narcotics compartment, sort all narcotics and eventually return those suitable through the AWS IT-system. For Ward 3, this is performed by a nurse continuously as narcotic needs to be returned; after counting and verifying the quantity, the narcotic is simply put back and noted in the narcotics journal.
In Section 1, Ward 5 cannot return a regular medicine as compared to Ward 3.

In Section 2, Ward 3 must walk longer to reach an AWS as compared to Ward 5.

In Section 3 the Pharmaceutical Unit handles all returns of narcotics for Ward 5 once a week, whereas in Ward 3 this is done continuously by the nurse returning a narcotic.

In Section 3 the return is manually documented at Ward 3 whereas for Ward 5 this is electronically registered through the AWS’s IT-system.

Table 12: Comparison and Basis for Conclusion for the Process of Reverse Logistics
3.3.3 Basis for Conclusion

Below follows a table where the authors have summarized their findings from comparing the process maps made for Research Question I. Here differences between Ward 3, without an AWS, and Ward 5, with an AWS are depicted. The table is divided into four different categories and each process is divided into different situations; these situations were chosen based on the authors’ opinion on what situations that characterizes the process and are similar at both wards so that a comparison can be made. The symbol “+” indicates that a ward is more according to the category compared to the other ward; the symbol “−” indicates the opposite. The symbol “+/−” indicates that both wards are equal and the abbreviation “N/A” indicates that it is not applicable for the ward. The table wishes to highlight where there is a difference between Ward 3 and Ward 5 by making the + and – large and bold; therefore +/− and N/A is illustrated in light grey.

<table>
<thead>
<tr>
<th>Process</th>
<th>Situation</th>
<th>Pharmaceutical Unit Involvement</th>
<th>Time Consumption</th>
<th>Waste</th>
<th>Safety &amp; Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replenishment of Medicine Process</td>
<td>Order placement</td>
<td>+/-</td>
<td>+/-</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Unpacking</td>
<td>+/-</td>
<td>+/-</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Stock Inventory of Medicine Process</td>
<td>Verification</td>
<td>+/-</td>
<td>+/-</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Taking Medicine</td>
<td>+/-</td>
<td>+/-</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Extraction of Medicine for Trolley Process</td>
<td>Being at ward</td>
<td>N/A</td>
<td>N/A</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Not being at ward</td>
<td>N/A</td>
<td>N/A</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Medicine not at CLV</td>
<td>N/A</td>
<td>N/A</td>
<td>+/-</td>
<td>+/-</td>
</tr>
<tr>
<td>Extraction of Medicine for Patient Process</td>
<td>Being at ward</td>
<td>N/A</td>
<td>N/A</td>
<td>+/-</td>
<td>+/-</td>
</tr>
<tr>
<td></td>
<td>Not being at ward</td>
<td>N/A</td>
<td>N/A</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Medicine not at CLV</td>
<td>N/A</td>
<td>N/A</td>
<td>+/-</td>
<td>+/-</td>
</tr>
<tr>
<td>Reverse Logistics of Medicine Process</td>
<td>Return regular medicine</td>
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<td>N/A</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Return narcotic</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Register return</td>
<td>-</td>
<td>+</td>
<td>+/-</td>
<td>+/-</td>
</tr>
</tbody>
</table>

Table 13: Basis for Conclusion for Research Question I
4. RESEARCH QUESTION II

“How do time and costs differ in the material management process of medicine between a ward with, and without, an AWS?”

This chapter aims to present the theory and empirical related to research question II. The empirical will separately treat Ward 3 without an AWS from Ward 5 with an AWS. The analysis will be performed in four steps, which will result in a basis for conclusion.

Figure 36: Overview of Chapter Four’s Disposition
4.1 Theory of Time-Driven Activity-Based Costing (TDABC)

By using metrics and measurements, management can more easily see whether performance has improved or not (Lambert & Pohlen, 2011). One such concept is that of TDABC which is an expansion of the traditional Activity-Based Costing; it entails a process’ costs being derived from time consumption and resource consumption such as an employee’s monthly salary plus surcharges. It uses time in order to allocate costs directly on cost objects. Kaplan & Andersson (2007) Using time as an allocator is reasonable as Bregman (2013) states, a business’ time consumption affects its costs. TDABC can be used in a health care setting in order to measure costs of a process. This is due to the fact that a health-care delivery process is complex and therefore makes an accurate measurement of time, costs and employee resource consumption otherwise difficult. (French et al., 2013) This aligns with Christopher (2011) who explains that costs can be hidden within a material flow. TDABC combined with flowcharts is a powerful way to measure and analyse costs and time within health care (French et al., 2013; Damelio, 2011; Meyer et al., 2007). To have made a process map for the purpose of cost management helps those involved to understand the cost elements for every activity; and this information can be used as a base when deciding what to measure and where to measure it. (Anklesaria, 2008; Damelio, 2011)

4.1.1. Time in TDABC

The main input in TDABC is the time required for an activity to be performed such as the time it takes to process an order, or the time it takes to serve a customer (Kaplan & Andersson, 2007). Accurate time consumption is necessary and can be obtained by; accumulating time from 50-100 direct observations and then calculating an average; interviewing employees; using process maps; receiving a time estimate (Kaplan & Andersson, 2007; Harrison & Van Hoek, 2011). It is important to keep in mind that not only the activities resulting in an output needs to be timed, but also waiting stations, idle time and delays. When gathering data, the table below can be used. (Harrison & van Hoek, 2011) French et al. (2013) also recommends that each activity is assigned the employee performing it.
4.1.1.1. Time Equation

According to Kaplan & Andersson (2007) one of the main advantages of the TDABC is that it is simple to use and it covers variations in a good way by the use of time equations. Activities are combined into one process using only one equation and allows for a larger variety and complexity. If a process becomes more complex, more terms will be added but the process and its equations stay the same. (Kaplan & Andersson, 2007) Below follows an example of a time equation taking different variations into account:

| Order processing time (minutes) = | 10 + 5 [if new customer] + 2 * number of line items + 4 * number of rate quotes + [if international order] (2 [if customs form] + 5 [if shipping declaration] + 10 [if consular clearance]) + [if special services] (5 [if rush order] + 10 [if credit hold] + 2 [if hazardous material]) |

Table 15: TDABC Time Equation with Variations (Kaplan & Andersson, 2007)

4.1.2 Allocating Costs using TDABC

As previously mentioned, Kaplan & Andersson (2007) suggests the use of an employee’s monthly salary plus surcharges as the cost to use in TDABC. This cost will then need to be allocated on the employee’s practical capacity. This entails that from the theoretical capacity, which is the amount of time per month that the employee is available for working; the time for breaks, education, travel et cetera is subtracted. The employee’s cost is then divided by the practical capacity in order to get a capacity cost per minute. It is easy to allocate costs through a time equation; once the capacity cost/minute has been established, this is multiplied by the different times given in the time equation. (Kaplan & Andersson, 2007)
4.2 Empirical Data on Costs and Time

4.2.1 Data on Costs for the Ward 3, Ward 5 and the Pharmaceutical Unit.

Augustine (140513) and Granberg (140417) provided the authors with the following data for a nurse at Ward 3 and Ward 5:

<table>
<thead>
<tr>
<th>Provided Data for Ward 3 and Ward 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hourly rate including surcharges</td>
</tr>
<tr>
<td>Working hours per month</td>
</tr>
<tr>
<td>Overtime per month</td>
</tr>
</tbody>
</table>

Table 16: Provided Data on Costs for Ward 3 and Ward 5

Munge (140422) provided the authors with the following data for an employee at the Pharmaceutical Unit which works with AWSs:

<table>
<thead>
<tr>
<th>Provided Data for the Pharmaceutical Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monthly Salary</td>
</tr>
<tr>
<td>Working hours per day</td>
</tr>
<tr>
<td>Surcharges</td>
</tr>
</tbody>
</table>

Table 17: Provided Data on Costs for Pharmaceutical Unit
Below the authors will present their gathered data on time in timetables based on Harrison & Van Hoek (2011). Each timetable represents a process.

<table>
<thead>
<tr>
<th>Description</th>
<th>Time</th>
<th>Notes</th>
<th>Observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Access Ward 3’s storage</td>
<td>00:05:05</td>
<td>Average based on 00:05:05 and 00:05:10, Elevator</td>
<td>Lundgren (140429)</td>
</tr>
<tr>
<td>Consult doctor</td>
<td>00:00:06</td>
<td>Average based on total time of 00:24:34 divided by the basic inventory of 282 medicines</td>
<td>Strömberg (140408)</td>
</tr>
<tr>
<td>Scan the barcode and the article number</td>
<td>00:00:56</td>
<td>Stairs</td>
<td>IT</td>
</tr>
<tr>
<td>Insert data from the hand-scanner to Provider</td>
<td>00:00:56</td>
<td>Stairs</td>
<td>IT</td>
</tr>
<tr>
<td>Review each order</td>
<td>00:00:32</td>
<td>Average based on total time of 00:00:44 to review 22 order lines</td>
<td>IT</td>
</tr>
<tr>
<td>Send the orders</td>
<td>00:00:01</td>
<td></td>
<td>IT</td>
</tr>
<tr>
<td>Wait for delivery</td>
<td>00:00:00</td>
<td></td>
<td>IT</td>
</tr>
<tr>
<td>Receive and sign for delivery</td>
<td>00:00:36</td>
<td></td>
<td>IT</td>
</tr>
<tr>
<td>go to computer inside the storage and log</td>
<td>00:05:05</td>
<td></td>
<td>IT</td>
</tr>
<tr>
<td>Access storage</td>
<td>00:05:05</td>
<td>Average based on 00:05:00 and 00:05:10, Elevator</td>
<td>Lundgren (140429)</td>
</tr>
<tr>
<td>Unpack delivery</td>
<td>00:00:46</td>
<td>Average based on total time of 00:17:00 to unpack 22 order lines</td>
<td>IT</td>
</tr>
<tr>
<td>Note mistake</td>
<td></td>
<td></td>
<td>IT</td>
</tr>
<tr>
<td>Shelf the medicine</td>
<td></td>
<td></td>
<td>IT</td>
</tr>
<tr>
<td>Table 18: Time Table for Replenishment of Medicine for Ward 3</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table Inventory of Medicine**

<table>
<thead>
<tr>
<th>Description</th>
<th>Time</th>
<th>Notes</th>
<th>Observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Access storage</td>
<td>5:30</td>
<td></td>
<td>Lundgren (140429)</td>
</tr>
<tr>
<td>Check expiration date on all medicines with stickers</td>
<td>00:00:05</td>
<td>Average based on total time of 00:24:00 divided by the basic inventory of 282 medicines</td>
<td>Strömberg (140408)</td>
</tr>
<tr>
<td>Discard medicine</td>
<td>00:00:10</td>
<td>Average based on total time of 00:00:20 for discarding 2 medicines</td>
<td>Ivarsson (140417)</td>
</tr>
<tr>
<td>Label with stickers</td>
<td>00:45:00</td>
<td></td>
<td>IT</td>
</tr>
<tr>
<td>Fill in narcotics journal</td>
<td></td>
<td></td>
<td>IT</td>
</tr>
<tr>
<td>Put medicine back to Ward 3</td>
<td></td>
<td></td>
<td>IT</td>
</tr>
<tr>
<td>Count medicines</td>
<td></td>
<td></td>
<td>IT</td>
</tr>
<tr>
<td>Unpack delivery</td>
<td></td>
<td></td>
<td>IT</td>
</tr>
<tr>
<td>Table 19: Time Table for Stock Inventory of Medicine for Ward 3</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Reverse Logistics of Medicine**

<table>
<thead>
<tr>
<th>Description</th>
<th>Time</th>
<th>Notes</th>
<th>Observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Access narcotics cabinet</td>
<td>00:00:15</td>
<td>Narcotic suitable for return, taken from Ward 3</td>
<td>A. Johansson (140429)</td>
</tr>
<tr>
<td>Find medicine in allocated shelf space</td>
<td>00:00:15</td>
<td>Regular medicine</td>
<td>A. Johansson (140429)</td>
</tr>
<tr>
<td>Fill in deviant narcotics journal</td>
<td></td>
<td></td>
<td>IT</td>
</tr>
<tr>
<td>Put back in narcotics cabinet</td>
<td></td>
<td></td>
<td>IT</td>
</tr>
<tr>
<td>Take the narcotics back to the AWS</td>
<td>00:02:00</td>
<td>Time to walk to the central storage space</td>
<td>IT</td>
</tr>
<tr>
<td>Get to computer inside the storage</td>
<td>00:00:10</td>
<td></td>
<td>IT</td>
</tr>
<tr>
<td>Log into AWS IT system and choose return function</td>
<td>00:00:48</td>
<td></td>
<td>IT</td>
</tr>
<tr>
<td>Enter narcotics to be returned</td>
<td>00:00:48</td>
<td></td>
<td>IT</td>
</tr>
<tr>
<td>Table 20: Time Table for Reverse Logistics of Medicine for Ward 3</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Extraction of Medicine for Trolley**

<table>
<thead>
<tr>
<th>Description</th>
<th>Time</th>
<th>Notes</th>
<th>Observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verify patients prescription list</td>
<td>00:00:15</td>
<td></td>
<td>Sollersjö (140423)</td>
</tr>
<tr>
<td>Pick up medicine from shelf</td>
<td>00:00:43</td>
<td>Average based on total time of 00:02:30 picking 4 medicines</td>
<td>Ivarsson (140427)</td>
</tr>
<tr>
<td>Access narcotics cabinet</td>
<td>00:00:59</td>
<td>Time based on picking one narcotic</td>
<td>Ivarsson (140427)</td>
</tr>
<tr>
<td>Count &amp; return</td>
<td>00:00:10</td>
<td></td>
<td>Ivarsson (140427)</td>
</tr>
<tr>
<td>Go to a computer and log into AWS IT-system, check AWs</td>
<td>00:00:43</td>
<td>Not in stock</td>
<td>Ivarsson (140427)</td>
</tr>
<tr>
<td>Register an order for a medicine</td>
<td>00:00:47</td>
<td>Time based on pre-order of one medicine</td>
<td>Ivarsson (140427)</td>
</tr>
<tr>
<td>Access that storage</td>
<td>00:02:05</td>
<td></td>
<td>Sollersjö (140423)</td>
</tr>
<tr>
<td>Go to computer inside storage and log into AWS IT-system</td>
<td>00:00:10</td>
<td>Pre-order</td>
<td>Sollersjö (140423)</td>
</tr>
<tr>
<td>Go to computer inside storage and log into AWS IT-system</td>
<td>00:00:10</td>
<td>Direct extraction</td>
<td>Sollersjö (140423)</td>
</tr>
<tr>
<td>Register an order for a medicine</td>
<td>00:00:47</td>
<td>Average based on 00:00:59 for ordering 4 medicines</td>
<td>Ivarsson (140427)</td>
</tr>
<tr>
<td>Begin extraction</td>
<td>00:00:48</td>
<td>Average based on 00:00:13 for extracting 4 medicines</td>
<td>Ivarsson (140427)</td>
</tr>
<tr>
<td>Take medicine back to Ward 3</td>
<td>00:02:06</td>
<td></td>
<td>A. Johansson (140429)</td>
</tr>
<tr>
<td>Put in trolley</td>
<td>00:00:10</td>
<td></td>
<td>A. Johansson (140429)</td>
</tr>
<tr>
<td>Place emergency order</td>
<td>00:00:30</td>
<td>If not in stock and urgent</td>
<td>A. Johansson (140429)</td>
</tr>
</tbody>
</table>

**Extraction of Medicine for Patient**

<table>
<thead>
<tr>
<th>Description</th>
<th>Time</th>
<th>Notes</th>
<th>Observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Access Storage</td>
<td>5:30</td>
<td></td>
<td>Lundgren (140429)</td>
</tr>
<tr>
<td>Check expiration date on all medicines with stickers</td>
<td>00:00:05</td>
<td>Average based on total time of 00:24:00 divided by the basic inventory of 282 medicines</td>
<td>Strömberg (140408)</td>
</tr>
<tr>
<td>Discard medicine</td>
<td>00:00:10</td>
<td>Average based on total time of 00:00:20 for discarding 2 medicines</td>
<td>Ivarsson (140417)</td>
</tr>
<tr>
<td>Label with stickers</td>
<td>00:45:00</td>
<td></td>
<td>IT</td>
</tr>
<tr>
<td>Fill in narcotics journal</td>
<td></td>
<td></td>
<td>IT</td>
</tr>
<tr>
<td>Put medicine back to Ward 3</td>
<td></td>
<td></td>
<td>IT</td>
</tr>
<tr>
<td>Count medicine to be returned and cross-reference with stock level</td>
<td>00:00:45</td>
<td></td>
<td>IT</td>
</tr>
<tr>
<td>Table 21: Time Table for Extraction of Medicine for Trolley Process for Ward 3</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Extraction of Medicine for Patient**

<table>
<thead>
<tr>
<th>Description</th>
<th>Time</th>
<th>Notes</th>
<th>Observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verify patients prescription list</td>
<td>00:00:15</td>
<td></td>
<td>Sollersjö (140423)</td>
</tr>
<tr>
<td>Pick up medicine from trolley</td>
<td>00:00:10</td>
<td>Regular medicine not in trolley</td>
<td>A. Johansson (140429)</td>
</tr>
<tr>
<td>Access Ward 3’s storage</td>
<td>00:00:15</td>
<td>Average based on 00:00:30 and 00:00:35, Elevator</td>
<td>Lundgren (140429)</td>
</tr>
<tr>
<td>Pick up the medicine from shelf in storage</td>
<td>00:00:05</td>
<td>Ill in stock</td>
<td>A. Johansson (140429)</td>
</tr>
<tr>
<td>Access narcotics cabinet</td>
<td>00:00:15</td>
<td>Narcotic</td>
<td>A. Johansson (140429)</td>
</tr>
<tr>
<td>Count &amp; extract narcotics &amp; in stock</td>
<td>00:00:45</td>
<td>Narcotic and in stock</td>
<td>A. Johansson (140429)</td>
</tr>
<tr>
<td>Go to the computer and log into AWS IT system, check AWs</td>
<td>00:00:43</td>
<td>Not in stock</td>
<td>Ivarsson (140427)</td>
</tr>
<tr>
<td>Register an order for a medicine</td>
<td>00:00:45</td>
<td>Average based on total time of 00:00:30 and 00:00:35, Pre-order</td>
<td>Ivarsson (140427)</td>
</tr>
<tr>
<td>Access storage</td>
<td>00:02:00</td>
<td>Pre-order</td>
<td>Ivarsson (140427)</td>
</tr>
<tr>
<td>Go to computer inside storage and log into AWS IT-system</td>
<td>00:00:10</td>
<td></td>
<td>Sollersjö (140423)</td>
</tr>
<tr>
<td>Go to computer inside storage and log into AWS IT-system</td>
<td>00:00:10</td>
<td>Direct extraction</td>
<td>Sollersjö (140423)</td>
</tr>
<tr>
<td>Register an order for a medicine</td>
<td>00:00:45</td>
<td>Average based on 00:00:30 and 00:00:35, Pre-order</td>
<td>Sollersjö (140423)</td>
</tr>
<tr>
<td>Begin extraction</td>
<td>00:00:44</td>
<td></td>
<td>Sollersjö (140423)</td>
</tr>
<tr>
<td>Take medicine back to Ward 3</td>
<td>00:02:00</td>
<td></td>
<td>A. Johansson (140429)</td>
</tr>
<tr>
<td>Place emergency order</td>
<td>00:00:30</td>
<td>If not in stock and urgent</td>
<td>A. Johansson (140429)</td>
</tr>
</tbody>
</table>

**Table 22: Time Table for Extraction of Medicine for Patient Process for Ward 3**
## 4.2.3 Data on Time in the Material Management Process of Medicine for Ward 5 with an AWS

Below the authors will present their gathered data on time in timetables based on Harrison & Van Hoek (2011). Each timetable represents a process.

### Replacement of Medicine

<table>
<thead>
<tr>
<th>Description</th>
<th>Time</th>
<th>Notes</th>
<th>Observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Access Hospital</td>
<td>00:00:00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Print out list of medicine</td>
<td>00:00:40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Double check list</td>
<td>00:00:02</td>
<td>Average based on 15 order lines</td>
<td></td>
</tr>
<tr>
<td>Change the mistake</td>
<td>00:00:02</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Enter orders manually and send</td>
<td>00:00:20</td>
<td>Average based on 15 order lines taking 00:05:00</td>
<td></td>
</tr>
<tr>
<td>Wait for delivery</td>
<td>12:00:00</td>
<td>Estimated</td>
<td></td>
</tr>
<tr>
<td>Receive and sign for delivery</td>
<td>00:03:30</td>
<td>Estimated</td>
<td></td>
</tr>
<tr>
<td>Access emergency</td>
<td>00:03:36</td>
<td>Stairs</td>
<td></td>
</tr>
<tr>
<td>Log into AWS system</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Check quantity and quality</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Note mistake</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scan the barcode on medicine</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Enter normal order</td>
<td>00:02:30</td>
<td>Average based on 00:47:00 for 19 order lines</td>
<td></td>
</tr>
<tr>
<td>Correct the registered to match the actual stock level</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Check the expiration date</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Enter this shorter expiration date</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Access the Pharmaceutical Unit and confirm delivery</td>
<td>00:02:25</td>
<td>Stairs</td>
<td></td>
</tr>
</tbody>
</table>

Table 23: Time Table for Replacement of Medicine Process for Ward 5

### Stock Inventory of Medicine

<table>
<thead>
<tr>
<th>Description</th>
<th>Time</th>
<th>Notes</th>
<th>Observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log into Provider</td>
<td>00:00:15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Display medicines at or after its expiration date</td>
<td>00:01:30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Access Ward 5’s storage</td>
<td>00:05:30</td>
<td>If there are any</td>
<td></td>
</tr>
<tr>
<td>Log into AWS IT-system</td>
<td></td>
<td>Average based on 6 medicines that expired 00:14:00</td>
<td></td>
</tr>
<tr>
<td>Enter medicine to be discarded</td>
<td>00:02:30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extract that medicine from the AWS</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 24: Time Table for Stock Inventory of Medicine Process for Ward 5

### Extraction of Medicine for Trolley

<table>
<thead>
<tr>
<th>Description</th>
<th>Time</th>
<th>Notes</th>
<th>Observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Go to a computer at Ward 5 and log into AWS IT-system</td>
<td>00:08:32</td>
<td>Pre-order</td>
<td></td>
</tr>
<tr>
<td>Verify patient’s prescription</td>
<td>00:00:27</td>
<td>Pre-order</td>
<td></td>
</tr>
<tr>
<td>Register an order for a medicine</td>
<td>00:00:27</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Access Ward 5’s storage</td>
<td>00:00:26</td>
<td>Pre-order, in stock</td>
<td></td>
</tr>
<tr>
<td>Go to computer inside storage and log into AWS IT-system</td>
<td>00:00:26</td>
<td>Pre-order, in stock</td>
<td></td>
</tr>
<tr>
<td>Access Ward 5’s storage</td>
<td>00:00:26</td>
<td>Direct extraction</td>
<td></td>
</tr>
<tr>
<td>Go to computer inside storage and log into AWS IT-system</td>
<td>00:00:26</td>
<td>Direct extraction</td>
<td></td>
</tr>
<tr>
<td>Register an order for a medicine</td>
<td>00:00:27</td>
<td>Direct extraction</td>
<td></td>
</tr>
<tr>
<td>Begin extraction</td>
<td>00:00:27</td>
<td>Direct extraction</td>
<td></td>
</tr>
<tr>
<td>Check other AWS’s through computer + pre order</td>
<td>00:00:41</td>
<td>Not in stock at ward</td>
<td></td>
</tr>
<tr>
<td>Access that storage</td>
<td>00:00:41</td>
<td>Not in stock at ward</td>
<td></td>
</tr>
<tr>
<td>Go to computer inside storage and log into AWS IT-system</td>
<td>00:00:41</td>
<td>In stock in other AWS</td>
<td></td>
</tr>
<tr>
<td>Begin extraction</td>
<td>00:00:27</td>
<td>Direct extraction</td>
<td></td>
</tr>
<tr>
<td>Take medicine back to Ward 5</td>
<td>00:01:37</td>
<td>In stock in other AWS</td>
<td></td>
</tr>
<tr>
<td>Put in trolley</td>
<td>00:00:10</td>
<td>When medicine extracted and present at ward 5</td>
<td></td>
</tr>
<tr>
<td>Place emergency order</td>
<td>00:04:30</td>
<td>Not in stock in other AWS, urgent</td>
<td></td>
</tr>
<tr>
<td>Place normal order in Provider</td>
<td>00:04:30</td>
<td>Not in stock in other AWS, not urgent</td>
<td></td>
</tr>
</tbody>
</table>

Table 26: Time Table for Extraction of Medicine for Trolley Process for Ward 5

### Extraction of Medicine for Patient

<table>
<thead>
<tr>
<th>Description</th>
<th>Time</th>
<th>Notes</th>
<th>Observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extract from trolley</td>
<td>00:00:25</td>
<td>Regular in casualty</td>
<td></td>
</tr>
<tr>
<td>Go to a computer at Ward 5 and log into AWS IT-system</td>
<td>00:00:15</td>
<td>Pre-order</td>
<td></td>
</tr>
<tr>
<td>Register an order for a medicine</td>
<td>00:00:15</td>
<td>Pre-order</td>
<td></td>
</tr>
<tr>
<td>Access Ward 5’s storage</td>
<td>00:00:20</td>
<td>Direct extraction</td>
<td></td>
</tr>
<tr>
<td>Go to computer inside storage and log into AWS IT-system</td>
<td>00:00:21</td>
<td>Direct extraction</td>
<td></td>
</tr>
<tr>
<td>Register an order for a medicine</td>
<td>00:00:27</td>
<td>Direct extraction</td>
<td></td>
</tr>
<tr>
<td>Begin extraction</td>
<td>00:00:43</td>
<td>Average based on 00:00:50 and 00:00:35, In stock at ward</td>
<td></td>
</tr>
<tr>
<td>Check other AWS’s through computer + pre order</td>
<td>00:01:19</td>
<td>Not in stock at ward</td>
<td></td>
</tr>
<tr>
<td>Access that storage</td>
<td>00:00:49</td>
<td>Average based on 00:02:00 and 00:01:37</td>
<td></td>
</tr>
<tr>
<td>Go to computer inside storage and log into AWS IT-system</td>
<td>00:00:21</td>
<td>In stock in other AWS</td>
<td></td>
</tr>
<tr>
<td>Begin extraction</td>
<td>00:00:43</td>
<td>Average based on 00:00:50 and 00:00:35, In stock in other AWS</td>
<td></td>
</tr>
<tr>
<td>Take medicine back to Ward 5</td>
<td>00:01:49</td>
<td>In stock in other AWS</td>
<td></td>
</tr>
<tr>
<td>Place emergency order</td>
<td>00:06:30</td>
<td>Not in stock in other AWS, urgent</td>
<td></td>
</tr>
<tr>
<td>Place normal order in Provider</td>
<td>00:04:30</td>
<td>Not in stock in other AWS, not urgent</td>
<td></td>
</tr>
</tbody>
</table>

Table 27: Time Table for Extraction of Medicine for Patient Process for Ward 5
The analysis for Research Question II is divided into three different parts. The first part will through a pattern matching, analytically discuss theory and empirical in order to determine the capacity cost per minute for Ward 3, Ward 5 and the Pharmaceutical Unit. The second part of the analysis will through an analytic discussion and pattern matching of theory and empirical generate time-equations for Ward 3 and Ward 5. The third part will through an analytic discussion and pattern matching between theory and the outcomes of the previous parts generate in calculated scenarios for Ward 3 and 5. This is done by applying the capacity cost per minute from part I into the different time-equations from part II. This then results in a proposed process cost according to predetermined assumptions for the calculated scenarios. In order to be able to compare the wards to each other, each process has been given a calculated average cost by taking all possible cost outcomes divided by the amount of calculated scenarios for a process. In order to cover possible deviations the observations might not have covered; a sensitivity analysis will be performed and included in the process average costs. The different costs for Ward 3 and Ward 5 are then compared to each other to give a basis for conclusion in order to be able to answer Research Question II. Below follows an illustration of the analysis’ disposition:
Figure 9: Analysis’ Disposition for Research Question II
For Ward 3 and Ward 5, the first step will be to calculate the cost to use, which according to Kaplan & Andersson (2007) is the monthly salary plus surcharges. Granberg (140417) and Augustine (140513) provided the information of 212 SEK per hour including surcharges, 150 working hours per month as well as overtime of 2000 SEK per month. This leads to that the cost to use is 33 800 SEK. The next step according to Kaplan & Andersson (2007) is to calculate the practical capacity, by taking the theoretical capacity minus breaks, education, travel et cetera. Granberg (140417) and Augustine (140513) provided the information of the theoretical capacity being 150 hours per month. Finally, Kaplan & Andersson (2007) explains that the capacity cost per minute needs to be calculated; this is done by taking the cost divided by the practical capacity, and then dividing that sum by 60. Based on the information given by Granberg (140417) and Augustine (140513) the capacity cost per minute for a nurse at Ward 3 and Ward 5 is 3,75 SEK per minute. The equation for calculating the capacity cost is as follows:

\[
\frac{(212\times 150) + 2000}{150} = \frac{225}{60} = 3,75\text{SEK/minute}
\]

Equation 1: Capacity Cost per Minute for a Nurse at Ward 3 and Ward 5

For The Pharmaceutical Unit, the first step will be to calculate the cost to use, which according to Kaplan & Andersson (2007) is the monthly salary plus surcharges. Munge (140222) provided the information of 31 000 SEK and the surcharges being 50 % of the monthly salary. This leads to the cost to use is 46 500 SEK. The next step according to Kaplan & Andersson (2007) is to calculate the practical capacity, by taking the theoretical capacity minus breaks, education, travel et cetera. Munge (140422) provided the information of the theoretical capacity being eight hours per day. By multiplying this with the working days per month which is 25, the practical capacity is 160 hours...
per month. Finally, Kaplan & Andersson (2007) explains that the capacity cost per minute needs to be calculated; this is done by taking the cost divided by the practical capacity, and then divide that sum by 60. Based on the information given by Munge (140422) the capacity cost per minute for an employee at the Pharmaceutical Unit working with AWSs is 4.85 SEK per minute. The equation for calculating the capacity cost is as follows:

\[
\frac{31000 + (31000 \times 0.5)}{(8 \times 5 \times 4)} = \frac{291}{60} = 4.85 \text{SEK/minute}
\]

Equation 2: Capacity Cost per Minute for an Employee at the Pharmaceutical Unit

Below are the capacity costs per minute for a more comprehensive overview:

<table>
<thead>
<tr>
<th>Employee</th>
<th>Capacity Cost per Minute</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nurse at Ward 3</td>
<td>3.75 SEK</td>
</tr>
<tr>
<td>Nurse at Ward 5</td>
<td>3.75 SEK</td>
</tr>
<tr>
<td>Employee at the Pharmaceutical Unit</td>
<td>4.85 SEK</td>
</tr>
</tbody>
</table>

Table 28: Summary of Capacity Costs per Minute

4.3.2 Analysis Part II

According to French et al. (2013), Anklesaria (2008), Meyer et al. (2007) and Damelio (2011) a process map helps understanding and determining what to measure, where to measure it and that flowcharts together with TDABC is a powerful way to measure and analyse costs and time within health care and possibly finding hidden costs as according to Christopher (2011). Therefore, it was the process maps created in chapter 3.3.1 which were the base when creating the process documents for time as suggested by Harrison & Van Hoek (2011). It aligns as well with Kaplan & Andersson (2007) who says that time is the main input for TDABC and that this is collected by the help of a process map. These time tables were however modified as the authors felt that the column for symbols would not add value for this project, and they therefore added another column instead stating the observation from which the time was gathered, which is in line with
French et al. (2013)’s suggestion of assigning an activity the employee performing it. The process maps and their different steps and activities were timed; this aligns with Lambert & Pohlen, 2001 and Harrison & Van Hoek (2011) who recommends that measurements are placed throughout a whole process and that it includes all activities as well as waiting times. The gathered time was made through direct observations, interviews as well as estimates which aligns with Kaplan & Andersson (2007)’s directives.

It is from these time tables that the data on relevant time was collected for this analysis, which will result in time equations allowing variations for each process, as explained by Kaplan & Andersson (2007). These variations were found in the time tables which derive from the process maps in chapter 3.3.1; and each variation depends on a decision node and the path taken from there. The time presented in sub section 4.2. is written in hours, minutes and seconds but for the time equations all data has been converted into minutes only, as according to the theoretical model provided by Kaplan & Andersson (2007) but also in order to ease the calculations. This has led to all data in the time equations being based on the calculation that 1 second equals 0.017 minutes. Below follows all time equations for the processes for Ward 3 and Ward 5, based on the data on time from chapter 4.2.2 and 4.2.3 and according to the model provided by Kaplan & Andersson (2007).
### 4.3.1.1 Building Time Equations for the Material Management Process of Medicine for Ward 3 without an AWS

#### Replenishment of Medicine

<table>
<thead>
<tr>
<th>Replenishment (minutes) =</th>
<th>By Pharmaceutical Unit</th>
<th>By Ward 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.09</td>
<td>+0.10*Amount of medicine in basic inventory</td>
<td>+0.51</td>
</tr>
<tr>
<td>5.96</td>
<td>+0.03*amount of order lines</td>
<td></td>
</tr>
<tr>
<td>0.98</td>
<td>+0.02</td>
<td></td>
</tr>
<tr>
<td></td>
<td>By Ward 3</td>
<td>+0.51</td>
</tr>
<tr>
<td></td>
<td>By Pharmaceutical Unit</td>
<td>+5.09</td>
</tr>
<tr>
<td></td>
<td>+0.78*amount of order lines</td>
<td></td>
</tr>
</tbody>
</table>

**Equation 3:** Time Equation for Replenishment of Medicine for Ward 3 without an AWS

#### Stock-Inventory

<table>
<thead>
<tr>
<th>Stock-Inventory (minutes) =</th>
<th>By Pharmaceutical Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>+ 5.51</td>
<td>[If not more than three months since last inventory]</td>
</tr>
<tr>
<td></td>
<td>* + 0.09 * amount of medicines in basic inventory</td>
</tr>
<tr>
<td></td>
<td>* + 0.17 * types of medicine to discard</td>
</tr>
<tr>
<td></td>
<td>[If it has been more than three months since last inventory]</td>
</tr>
<tr>
<td></td>
<td>* + 45.00</td>
</tr>
</tbody>
</table>

**Equation 4:** Time Equation for Stock Inventory of Medicine for Ward 3 without an AWS

#### Reverse Logistics of Medicine

<table>
<thead>
<tr>
<th>Reverse Logistics of Medicine (minutes) =</th>
<th>By Ward 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>+ 0.29</td>
<td>[If regular medicine]</td>
</tr>
<tr>
<td></td>
<td>* + 0.09 * amount of medicine</td>
</tr>
<tr>
<td></td>
<td>[If narcotic suitable for return and from Ward 3]</td>
</tr>
<tr>
<td></td>
<td>* + 0.14 * amount of medicine</td>
</tr>
<tr>
<td></td>
<td>[If the Narcotic does not add up]</td>
</tr>
<tr>
<td></td>
<td>* + 3.00* amount of narcotics not adding up</td>
</tr>
<tr>
<td></td>
<td>[If narcotic suitable for return and from an AWS]</td>
</tr>
<tr>
<td></td>
<td>+ 0.26</td>
</tr>
<tr>
<td></td>
<td>* + 0.77 * amount of narcotics</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>[If not in stock at ward, pre-order in another AWS]</td>
</tr>
<tr>
<td></td>
<td>+2.09</td>
</tr>
<tr>
<td></td>
<td>+0.73*orders to register</td>
</tr>
<tr>
<td></td>
<td>[in stock in other AWS]</td>
</tr>
<tr>
<td></td>
<td>* + 2.00</td>
</tr>
<tr>
<td></td>
<td>* + 0.17</td>
</tr>
<tr>
<td></td>
<td>* + 0.41* amount to extract</td>
</tr>
<tr>
<td></td>
<td>* + 2.00</td>
</tr>
<tr>
<td></td>
<td>[if not in stock at CLV]</td>
</tr>
<tr>
<td></td>
<td>+ 0.73*orders to be placed</td>
</tr>
<tr>
<td></td>
<td>+ 5.00 * orders to be placed</td>
</tr>
<tr>
<td></td>
<td>[If not in stock at ward but in stock in other AWSs, direct extraction]</td>
</tr>
<tr>
<td></td>
<td>* + 2</td>
</tr>
<tr>
<td></td>
<td>* + 0.17</td>
</tr>
<tr>
<td></td>
<td>[In stock in other AWS]</td>
</tr>
<tr>
<td></td>
<td>* + 0.41 * amount to extract</td>
</tr>
<tr>
<td></td>
<td>* + 2.00</td>
</tr>
<tr>
<td></td>
<td>[if not in stock at CLV]</td>
</tr>
<tr>
<td></td>
<td>* + 0.73*orders to be placed</td>
</tr>
<tr>
<td></td>
<td>* + 5.00 * orders to be placed</td>
</tr>
</tbody>
</table>

**Equation 5:** Time Equation for Reverse Logistics of Medicine for Ward 3 without an AWS

#### Extraction of Medicine for Trolley

<table>
<thead>
<tr>
<th>Extraction of Medicine for Trolley (minutes) =</th>
<th>By Ward 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>+0.26</td>
<td>[if regular medicine in stock]</td>
</tr>
<tr>
<td>* +0.73 * amount of medicine</td>
<td></td>
</tr>
<tr>
<td>* + 0.17 * amount of medicine</td>
<td></td>
</tr>
<tr>
<td>[if narcotic in stock]</td>
<td></td>
</tr>
<tr>
<td>* +1 * amount of narcotics</td>
<td></td>
</tr>
<tr>
<td>* + 0.17 * amount of narcotics</td>
<td></td>
</tr>
<tr>
<td>[if not in stock at ward, pre-order in another AWS]</td>
<td></td>
</tr>
<tr>
<td>* +0.73*amount of orders</td>
<td></td>
</tr>
<tr>
<td>* + 0.80 * amount of orders</td>
<td></td>
</tr>
<tr>
<td>* + 2.09</td>
<td></td>
</tr>
<tr>
<td>* + 0.17</td>
<td></td>
</tr>
<tr>
<td>* + 0.80 * amount to be extracted</td>
<td></td>
</tr>
<tr>
<td>* + 2.09</td>
<td></td>
</tr>
<tr>
<td>[if not in stock at CLV]</td>
<td></td>
</tr>
<tr>
<td>* + 5*amount to be ordered</td>
<td></td>
</tr>
<tr>
<td>[if not in stock at ward, direct extraction from another AWS]</td>
<td></td>
</tr>
<tr>
<td>* + 2.09</td>
<td></td>
</tr>
<tr>
<td>* + 0.80 * orders to be placed</td>
<td></td>
</tr>
<tr>
<td>* + 0.80 * amount to be extracted</td>
<td></td>
</tr>
<tr>
<td>* + 2.09</td>
<td></td>
</tr>
<tr>
<td>* + 0.17 * amount to be inserted</td>
<td></td>
</tr>
<tr>
<td>[if not in stock at CLV]</td>
<td></td>
</tr>
<tr>
<td>* +0.73*amount to order</td>
<td></td>
</tr>
<tr>
<td>* + 5.00 * amount to be ordered</td>
<td></td>
</tr>
</tbody>
</table>

**Equation 6:** Time Equation for Extraction of Medicine for Trolley for Ward 3 without an AWS

#### Extraction of Medicine for Patient

<table>
<thead>
<tr>
<th>Extraction of Medicine for Patient (minutes) =</th>
<th>By Ward 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>+1.34 * amount of patients</td>
<td>[If regular medicine]</td>
</tr>
<tr>
<td>[In trolley]</td>
<td></td>
</tr>
<tr>
<td>* + 0.17 * types of medicine</td>
<td></td>
</tr>
<tr>
<td>[Not in trolley but at ward]</td>
<td></td>
</tr>
<tr>
<td>* + 0.29</td>
<td></td>
</tr>
<tr>
<td>* + 0.09 * types of medicine</td>
<td></td>
</tr>
<tr>
<td>[If narcotic]</td>
<td></td>
</tr>
<tr>
<td>[In trolley]</td>
<td></td>
</tr>
<tr>
<td>* + 0.17 * types of medicine</td>
<td></td>
</tr>
<tr>
<td>[Not in trolley but at ward]</td>
<td></td>
</tr>
<tr>
<td>* + 0.29</td>
<td></td>
</tr>
<tr>
<td>* + 0.26</td>
<td></td>
</tr>
<tr>
<td>* + 0.77 * types of narcotic</td>
<td></td>
</tr>
<tr>
<td>[If not in stock at ward, pre order]</td>
<td></td>
</tr>
<tr>
<td>* + 0.73</td>
<td></td>
</tr>
<tr>
<td>* + 0.17</td>
<td></td>
</tr>
<tr>
<td>* + 0.77* orders to register</td>
<td></td>
</tr>
<tr>
<td>[in stock in other AWS]</td>
<td></td>
</tr>
<tr>
<td>* + 2.00</td>
<td></td>
</tr>
<tr>
<td>* + 0.17</td>
<td></td>
</tr>
<tr>
<td>* + 0.41* amount to extract</td>
<td></td>
</tr>
<tr>
<td>* + 2.00</td>
<td></td>
</tr>
<tr>
<td>[if not in stock at CLV]</td>
<td></td>
</tr>
<tr>
<td>* + 0.73*orders to be placed</td>
<td></td>
</tr>
<tr>
<td>+ 5.00 * orders to be placed</td>
<td></td>
</tr>
<tr>
<td>[If not in stock at ward but in stock in other AWSs, direct extraction]</td>
<td></td>
</tr>
<tr>
<td>* + 2</td>
<td></td>
</tr>
<tr>
<td>* + 0.17</td>
<td></td>
</tr>
<tr>
<td>[In stock in other AWS]</td>
<td></td>
</tr>
<tr>
<td>* + 0.41 * amount to extract</td>
<td></td>
</tr>
<tr>
<td>* + 2.00</td>
<td></td>
</tr>
<tr>
<td>[if not in stock at CLV]</td>
<td></td>
</tr>
<tr>
<td>* + 0.73*orders to be placed</td>
<td></td>
</tr>
<tr>
<td>* + 5.00 * orders to be placed</td>
<td></td>
</tr>
</tbody>
</table>

**Equation 7:** Time Equation for Extraction of Medicine for Patient for Ward 3 without an AWS
### Replenishment of Medicine

**Equation 6:** Time Equation for Replenishment of Medicine for Ward 5 with an AWS

\[
\text{Replenishment of Medicine (minutes) = By Pharmaceutical Unit + 0.37} \\
+ 1.68 \\
+ 0.03 \times \text{amount of order lines} \\
+ 0.34 \times \text{amount of order lines By Ward 5 + 0.51 By Pharmaceutical Unit + 6.61 + 2.51 \times \text{amount of order lines + 7.43}}
\]

### Stock-Inventory

**Equation 7:** Time Equation for Stock Inventory for Ward 5 with an AWS

\[
\text{Stock-Inventory (minutes) = By Pharmaceutical Unit} \\
+ 0.26 \\
+ 1.51 \\
[\text{If anything is expiring}] \\
* + 5.51 \\
* + 2.34 \times \text{amount of medicine}
\]

### Reverse Logistics of Medicine

**Reverse Logistics of Medicine (minutes) =**

- **By Ward 5:**
  - + 0.26 [if anything to discard]
  - + 0.17 [if anything to return]
  - + 0.27 [if anything has been returned]
  - + 0.70 [amount of different medicines to be returned]

- **By Pharmaceutical Unit:**
  - + 3.03 [if anything has been returned]
  - + 5.51
  - + 0.14
  - + 0.17
  - + 0.27 [amount of order lines]
  - + 0.97 [amount of order lines]
  - + 0.17

### Extraction of Medicine for Trolley

**Equation 8:** Time Equations for Extraction of Medicine for Trolley for Ward 5 with an AWS

\[
\text{Extraction of Medicine for Trolley (minutes) = By Ward 5} \\
[\text{If pre-order}] \\
\times + 0.54 \\
[\text{If pre-order and in stock at ward}] \\
\times +0.46 \times \text{amount of medicine} \\
\times +0.44 \\
\times +0.46 \times \text{amount of medicine By Ward 5} \\
[\text{If pre-order and not in stock at ward}] \\
\times + 0.73 * \text{Amount of types of medicine} \\
[\text{If not in stock at ward but in another AWS}] \\
\times + 0.46 * \text{amount of orders to place} \\
\times + 1.97 \\
\times + 0.46 * \text{amount of orders placed to extract} \\
\times + 1.97 \\
\times + 0.17 \times \text{amount of extracted orders to put in trolley By Ward 5} \\
[\text{If not in stock at CLV}] \\
\times + 4.51 \\
[\text{If direct extraction}] \\
\times + 0.44 \\
[\text{If direct extraction and in stock at ward}] \\
\times + 0.46 * \text{amount of orders} \\
\times + 0.46 * \text{amount of orders to extract} \\
\times + 0.17 * \text{amount of medicine to put in trolley By Ward 5} \\
[\text{If direct extraction and not in stock at ward, but in stock in another AWS}] \\
\times + 1.97 \\
\times + 0.46 * \text{amount of orders} \\
\times + 0.46 * \text{amount of orders to extract} \\
\times + 1.97 \\
\times + 0.17 * \text{amount of extracted medicine to put in trolley By Ward 5} \\
[\text{If not in stock at CLV}] \\
\times + 0.73 * \text{amount of orders} \\
\times + 0.73 * \text{amount of orders to extract} \\
\times + 1.83 \\
[\text{if not in stock at CLV}] \\
\times + 1.32 * \text{orders to place} \\
\times + 0.34 \\
\times + 0.85 * \text{amount of medicine to extract By Ward 5} \\
[\text{If not in stock at ward but in other AWS}] \\
\times + 1.32 * \text{orders to place} \\
\times + 1.83 \\
\times + 0.36 \\
\times + 0.73 * \text{amount to extract} \\
\times + 1.83 \\
[\text{if not in stock at CLV}] \\
\times + 1.32 * \text{orders to place} \\
\times + 4.50 * \text{orders to place By Ward 5} \\
[\text{If not in stock at ward, but in stock in another AWS}] \\
\times + 1.83 \\
\times + 0.36 \\
\times + 0.73 * \text{amount of medicine to extract By Ward 5} \\
[\text{If not in stock at ward but in other AWS}] \\
\times + 0.45 * \text{amount of medicine to extract} \\
\times + 0.73 * \text{amount of medicine to extract By Ward 5} \\
[\text{If not in stock at ward}] \\
\times + 1.83 \\
\times + 0.36 \\
[\text{in stock in other AWS}] \\
\times + 1.32 * \text{orders to register} \\
\times + 0.73 * \text{amount to extract} \\
\times + 1.83 \\
[\text{if not in stock at CLV}] \\
\times + 1.32 * \text{orders to place} \\
\times + 4.50 * \text{orders to place}
\]

### Extraction of Medicine for Patient

**Equation 9:** Time Equation for Extraction of Medicine for Patient for Ward 5 with an AWS

\[
\text{Extraction of Medicine for Patient (minutes) = By Ward 5} \\
[\text{If in trolley}] \\
\times + 0.26 \\
[\text{If not in trolley, pre order}] \\
\times + 0.17 \\
[\text{In stock at ward}] \\
\times + 1.26 * \text{orders to place} \\
\times + 0.34 \\
\times + 0.85 * \text{amount of medicine to extract By Ward 5} \\
[\text{If not in stock at ward but in other AWS}] \\
\times + 1.32 * \text{orders to place} \\
\times + 1.83 \\
\times + 0.36 \\
\times + 0.73 * \text{amount to extract} \\
\times + 1.83 \\
[\text{if not in stock at CLV}] \\
\times + 1.32 * \text{orders to place} \\
\times + 4.50 * \text{orders to place By Ward 5} \\
[\text{If not in stock at ward, but in stock in another AWS}] \\
\times + 1.83 \\
\times + 0.36 \\
[\text{in stock at ward}] \\
\times + 0.45 * \text{amount of medicine to extract} \\
\times + 0.73 * \text{amount of medicine to extract By Ward 5} \\
[\text{If not in stock at ward but in other AWS}] \\
\times + 1.32 * \text{orders to register} \\
\times + 0.73 * \text{amount to extract} \\
\times + 1.83 \\
[\text{if not in stock at CLV}] \\
\times + 1.32 * \text{orders to place} \\
\times + 4.50 * \text{orders to place}
\]

### Extraction of Medicine for Patient

**Equation 10:** Time Equation for Extraction of Medicine for Patient for Ward 5 with an AWS

\[
\text{Extraction of Medicine for Patient (minutes) = By Ward 5} \\
[\text{If in trolley}] \\
\times + 0.26 \\
[\text{If not in trolley, direct extraction}] \\
\times + 0.26 \\
[\text{in stock at ward}] \\
\times + 0.45 * \text{amount of medicine to extract} \\
\times + 0.73 * \text{amount of medicine to extract By Ward 5} \\
[\text{If not in stock at ward}] \\
\times + 1.83 \\
\times + 0.36 \\
[\text{in stock in other AWS}] \\
\times + 1.32 * \text{orders to register} \\
\times + 0.73 * \text{amount to extract} \\
\times + 1.83 \\
[\text{if not in stock at CLV}] \\
\times + 1.32 * \text{orders to place} \\
\times + 4.50 * \text{orders to place}
\]

### Equation Table

<table>
<thead>
<tr>
<th>Equation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>Time Equation for Replenishment of Medicine for Ward 5 with an AWS</td>
</tr>
<tr>
<td>9</td>
<td>Time Equation for Stock Inventory for Ward 5 with an AWS</td>
</tr>
<tr>
<td>10</td>
<td>Time Equation for Reverse Logistics of Medicine for Ward 5 with an AWS</td>
</tr>
<tr>
<td>11</td>
<td>Time Equation for Extraction of Medicine for Trolley for Ward 5 with an AWS</td>
</tr>
<tr>
<td>12</td>
<td>Time Equation for Extraction of Medicine for Patient for Ward 5 with an AWS</td>
</tr>
</tbody>
</table>
4.3.3 Analysis Part III

Figure 39: Analysis’ Disposition Part III for Research Question II

4.3.3.1 Calculated Scenarios

This subsection of the analysis will allocate costs to the different processes for Ward 3 and Ward 5 by using TDABC. This is done by using the capacity cost per minute and multiplying it with the different times in the time equation as according to Kaplan & Andersson (2007). Allocating these costs will be done through what the authors have chosen to name as calculated scenarios. Should a time equation include variations, there will be different calculated scenarios covering the different possible outcomes of a process. Each calculated scenario is based on certain assumptions, which will be explained before each calculation is performed. These assumptions are not theoretically based, but can be seen as educated assumptions provided by the authors from their gained understanding from interviews and observations. These assumptions which are the same for both wards are; that the direct extractions are performed without disturbance; that the reverse logistics of medicine is calculated from a weekly point of view; that the extraction of medicine for patients is calculated from when one round is performed for a patient. All the calculated scenarios can be found in appendix 1 and 2.
In order to get a comparable result between the wards, the authors decided to calculate an average of a process by adding together the different outcomes and divide by the amount of calculated scenarios for a process. This way, it does not make a difference if one ward happens to have one more calculated scenario compared to another. The calculations for these process averages can be found in appendix 3 and below is a summarizing table. For this table, the costs have been rounded to the nearest integer. The costs have been calculated so that they can be comparable between the wards; therefore the same educated assumptions have been given for similar calculated scenarios.

<table>
<thead>
<tr>
<th>Process</th>
<th>Average Process Cost Ward 3</th>
<th>Average Process Cost Ward 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replenishment of Medicine</td>
<td>173 SEK</td>
<td>720 SEK</td>
</tr>
<tr>
<td>Stock inventory of Medicine</td>
<td>201 SEK</td>
<td>92 SEK</td>
</tr>
<tr>
<td>Extraction of Medicine for Trolley</td>
<td>169 SEK</td>
<td>171 SEK</td>
</tr>
<tr>
<td>Extraction of Medicine for Patient</td>
<td>21 SEK</td>
<td>18 SEK</td>
</tr>
<tr>
<td>Reverse Logistics of Medicine</td>
<td>72 SEK</td>
<td>133 SEK</td>
</tr>
</tbody>
</table>

Table 29: Average Process Costs for Ward 3 & Ward 5

4.3.3.2 Sensitivity Analysis

Kaplan & Andersson (2008) suggests gathering data on time by calculating an average from 50-100 direct observations. Due to this project’s limited time, it is not possible to perform that many observations on all processes. The authors have however in many cases in the presented data in 4.2.2 and 4.2.3 calculated an average based on an activity being performed many times. However, even though the activity was performed multiple times, it was mostly performed during the same observation and therefore by the same nurse or employee from the Pharmaceutical Unit. This could make the gathered data less reliable than had more observations been conducted on different nurses and employees from the Pharmaceutical Unit, as there might be deviations occurring which the authors have not been able to capture.

The sensitivity analysis found in Appendix 4 shows a linear relationship between time and costs, when a change in time is applied to a whole process. This is logical as the TDABC drives cost through time, and the two variables depend on each other. In order to cover possible deviations on single activities, and show how this would affect a process a second sensitivity analysis will also be performed on a few handpicked calculated scenarios, where the variables have different changes in time. This is done in order to show that the authors may have underestimated the time consumption for different activities.
The authors have chosen to perform a sensitivity analysis on the process of extraction of medicine for trolley and patient for Ward 3. This, as the authors feel that a nurse’s time consumption at an AWS could deviate significantly depending on their willingness to adapt to working with new technology. The authors have assumed that the nurses at Ward 5 are well acquainted with the AWS as they work with it all the time, every day, and therefore a sensitivity analysis where time consumption is added would therefore not give a fair result in the authors’ opinion. The authors feel as well that the activities performed by the Pharmaceutical Unit ought to not deviate significantly as the employees have a well-developed routine and work in a very similar manner; and therefore a sensitivity analysis is not needed.

The different calculated scenarios will be given increased time consumption of 40, 50, or 60 percent; these percentage changes will be added randomly throughout the sensitivity analysis on activities including an AWS. The calculations for this sensitivity analysis can be found in appendix 5. Below is a concluding table with the new process averages based on that sensitivity analysis; also here the numbers have been rounded to the nearest integer.

The sensitivity analysis show that a nurse’s deviating time consumption with an AWS does not have a significant impact on the outcome, and that even if the authors’ observations did not cover all possible deviations, their result is still a fair view of reality.

<table>
<thead>
<tr>
<th>Process</th>
<th>Average process cost Ward 3</th>
<th>Average process cost Ward 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replenishment of Medicine</td>
<td>170 SEK</td>
<td>720 SEK</td>
</tr>
<tr>
<td>Stock inventory of Medicine</td>
<td>200 SEK</td>
<td>90 SEK</td>
</tr>
<tr>
<td>Extraction of Medicine for Trolley</td>
<td>177 SEK</td>
<td>170 SEK</td>
</tr>
<tr>
<td>Extraction of Medicine for Patient</td>
<td>22 SEK</td>
<td>20 SEK</td>
</tr>
<tr>
<td>Reverse Logistics of Medicine</td>
<td>70 SEK</td>
<td>130 SEK</td>
</tr>
</tbody>
</table>

Table 30: Average Process Costs for Ward 3 & Ward 5 including sensitivity analysis
4.3.3.3 Comparing Process Average Costs including Sensitivity Analysis together with a Basis for Conclusion

This sub section will present a new calculated process average, where the sensitivity analysis has been taken into account. This has been done by adding the average process cost from table 28, with the cost from table 29, and then divide it by two. The findings are presented in the table below. This table will also indicate which ward that is more expensive compared to the other and provide a basis for conclusion. In this table, the numbers have been rounded to the nearest ten for an easier comparable overview.

<table>
<thead>
<tr>
<th>Process</th>
<th>Average process cost with sensitivity analysis</th>
<th>Basis for Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ward 3</td>
<td>Ward 5</td>
</tr>
<tr>
<td>Replenishment of Medicine</td>
<td>170</td>
<td>-</td>
</tr>
<tr>
<td>Stock inventory of Medicine</td>
<td>200</td>
<td>+</td>
</tr>
<tr>
<td>Extraction of Medicine for Trolley</td>
<td>170</td>
<td>+/-</td>
</tr>
<tr>
<td>Extraction of Medicine for Patient</td>
<td>20</td>
<td>+/-</td>
</tr>
<tr>
<td>Reverse Logistics of Medicine</td>
<td>70</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 31: Comparing Process Average Costs based on the Sensitivity Analysis together with a Basis for Conclusion
5. RESEARCH QUESTION III

“How has the instalment of a central storage affected the number of orders placed for wards?”

This chapter aims to present the theory and empirical related to research question III. The analysis will compare the empirical findings to the theory; which will result in a basis for conclusion.

Figure 40: Overview of Chapter Five’s Disposition
5.1 Theory of Centralised Inventory in Material Management of Medicine

For products which need to be available with a short delivery time, a low centralisation is favourable (Jonsson & Mattsson, 2011). Therefore hospitals keep in-house inventories on ward levels to ensure the least possible lead time to the patient regardless of inventory costs (Harrison & van Hoek, 2011). However, a high centralization offers the opportunity of economies of scale with for example the investment in automated storage solutions; the numbers of non-value adding activities being reduced and the risk of obsolescence being reduced (Jonsson & Mattson, 2011); thus, costs and waste decreases and efficiency increases (Shahabi et al 2013). A hospital normally has at least one in-house central storage (Pan & Pokharel, 2007).

A centralised inventory approach entails according to Abdelaziz & Mejri (2012), that the inventory is perceived as a shared pool of goods across multiple units. A centralised inventory requires a well-developed IT-system in order for all information to be properly stored, handled and coordinated so that real-time stock-levels can be acquired. By having such a centralised information system, each participant knows more about each other and treats them as strategic partners. (Marklund, 2002; Seo et al., 2000; Nicholson et al., 2004; Yu et al., 2001) Having a centralised inventory ought to lead to a duplication reduction, which in turn lowers the overall costs (Harrison & van Hoek, 2011; Arnold et al., 2008), this as a centralised inventory lessens the burden on each unit of having to manage storage space and safety stock levels for each item and reduces the behaviour of a decentralised system where each unit tries to reach its own objectives and goals without consideration of the other units (Abdelaziz & Mejri, 2012).

Demand and supply will never be fully synchronized and therefore there are uncertainties in material management process (Jonsson & Mattson, 2011). It is hard for hospitals to anticipate the demand of medicine as it is not possible to predict the patient mix and their requirements (Pan & Pokharel, 2007; Slack et al., 2012; Baboli et al., 2011). To handle this uncertainty safety stock is put in place as it provides more quantity in stock than what is expected to be demanded; therefore if demand unexpectedly rises a stock out is avoided. (Arnold et al., 2008; Jonsson & Mattson, 2011) The amount of safety stock kept should be based on a weighing of cost of an order and carrying cost (Jonsson & Mattson, 2011).
The material management process serves to establish the quantity and time of placement of orders needed for the organization. Every unique article or product in an order represents an order line. The aim in order placement is to be as effective as possible in regard to binding of capital, delivery service and resource utilization within the organization. (Jonsson & Mattsson, 2011) The cost of an order does not depend on the quantity which has been ordered, but rather the amount of orders placed. Reducing these costs can be made by ordering more each time, so that fewer orders are placed in total. (Arnold et al., 2008)

5.2. Empirical Data on Effects of Installing a Central Storage

5.2.1 Qualitative Data

According to Munge (140428) the reason there is a decline in orders before the central storage was installed is because it was not until 2011 that the wards, receptions and units at CLV recognized that each order line came with a price; after that, the wards tried to place less orders which resulted in the decline. Elisabeth Johansson, nurse at Ward 40, (140506) concurs to this as she feels the nurses’ awareness of the cost of placing for example an emergency order has risen. She further explains that since they started receiving pharmaceutical service the nurses spend less time on placing orders which is positive as this has provided more time to be spent on other tasks.

Munge (140120) has noticed that orders have decreased because with a central storage the nurses go there first for medicine rather than ordering it when it is not found in their basic inventory. This way they just pick up the amount they need at the central storage and there will not be extra medicine left at a ward where it is not regularly used only to be discarded. This way, the wards’ basic inventories has been reduced. Further by not having to search the whole hospital by for example calling other wards, the nurses who before might have skipped this step and placed an order, are more prone to search for it in-house through the AWS IT-system. Granberg (140306) adds that he has seen a significant reduction in orders placed by nurses at the ward since the pharmaceutical service was put in place.
Johanna Roth, nurse at Ward 19, (140506) is one of the nurses responsible for ordering for Ward 19 and she has noticed a significant reduction in order placement since the instalment of the central storage. E. Johansson (140506) agrees with Roth (140406) that she has noticed a significant reduction in orders placed by the nurses at the ward since the central storage. Monika Mlynarz, nurse at Ward 4, (140506) finds that they place fewer orders at the ward, now the only orders they place are for medicine in specific cases or patients, all other medicine needed not found in their own storage can be found in the central storage. Johanna Gustafsson, nurse at Ward 33, (140506) has experienced that the number of emergency orders have decreased at their ward as they can now go to the central storage while they wait for medicine in question to be ordered with the regular weekly replenishment of medicine performed by the pharmaceutical unit. Kristin Oertel, nurse at Ward 13, (140506) says it feels like forever ago since they placed orders themselves at the ward, and the reason for this is due to the pharmaceutical service and the central storage. This is positive as they now get the medicine right away rather than order and wait for a medicine to arrive the next day.

Nurses at many wards agree that they find it very convenient to have a central storage to turn to for the medicines they do not store at their ward. They do not have to look in a binder nor in the order system to see which other ward have the medicine they need which they do not themselves have in stock. This then saves them to not have to call other wards and ask to lend it. Further they do not have to then walk to multiple other wards to collect the medicines they needed to lend. Now with the central storage they will just verify online, unless it is one of the wards right next to the central storage as they might just walk over and verify, that the medicine is available at the central storage. They then place an order in the AWS’ IT-system or do a direct extraction when they get to the central storage. (Roth, 140506; Mlynarz, 140506; E. Johansson, 140506; Emma Olofsson, nurse at Ward 34, 140506; Oertel, 140506; Gustafsson, 140506; Lina Karlsson, nurse at Ward , 140506; Helen Ahlgren, Nurse at Ward 3, 140423) Roth (140506) also points out that it is a good system with the narcotics in the AWS as it is traceable who has extracted the narcotics and it feels more secure. It is also convenient to no have to count and sign when extracting narcotics at the central storage.
In this subsection, quantitative data on orders placed is presented. In appendix 6 a full table provided by Munge (140428) is presented, where each ward, reception and clinic with access to the central storage is depicted. The authors have from that table chosen to extract the data for wards, as these are the ones who are included in this project’s focus area. The authors chose to use data from January-March which is indicated as Q1; this as the central storage was installed in December 2013 and when writing this thesis it is not possible to get data later than March 2014. The authors have chosen to use these months for every year back to 2011.

The reason for the authors not collecting data further back is due to the establishment of the Pharmaceutical Unit being in year 2011, and the authors felt that the data before that would not be representative as the orders placed were “out of control” as according to Granberg (140306). The subsection ends with a graph illustrating the data provided in the table below in order to easily present the changes in order lines placed.

<table>
<thead>
<tr>
<th>Ward</th>
<th>2011-Q1</th>
<th>2012-Q1</th>
<th>2013-Q1</th>
<th>2014-Q1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ward 40</td>
<td>776</td>
<td>654</td>
<td>491</td>
<td>478</td>
</tr>
<tr>
<td>Ward 17</td>
<td>674</td>
<td>817</td>
<td>510</td>
<td>466</td>
</tr>
<tr>
<td>Ward 5</td>
<td>634</td>
<td>567</td>
<td>510</td>
<td>450</td>
</tr>
<tr>
<td>Ward 34</td>
<td>539</td>
<td>753</td>
<td>543</td>
<td>434</td>
</tr>
<tr>
<td>Ward 3</td>
<td>477</td>
<td>583</td>
<td>493</td>
<td>411</td>
</tr>
<tr>
<td>Ward 1 Heart Intensive Care</td>
<td>451</td>
<td>933</td>
<td>545</td>
<td>365</td>
</tr>
<tr>
<td>Intensive Care Ward</td>
<td>757</td>
<td>622</td>
<td>598</td>
<td>355</td>
</tr>
<tr>
<td>Ward 33</td>
<td>476</td>
<td>611</td>
<td>519</td>
<td>330</td>
</tr>
<tr>
<td>Ward 13</td>
<td>323</td>
<td>502</td>
<td>337</td>
<td>310</td>
</tr>
<tr>
<td>Emergency Care Ward</td>
<td>410</td>
<td>471</td>
<td>399</td>
<td>299</td>
</tr>
<tr>
<td>Ward 19</td>
<td>618</td>
<td>845</td>
<td>476</td>
<td>299</td>
</tr>
<tr>
<td>Ward 4</td>
<td>256</td>
<td>363</td>
<td>332</td>
<td>238</td>
</tr>
<tr>
<td>Ward 11</td>
<td>311</td>
<td>315</td>
<td>278</td>
<td>214</td>
</tr>
<tr>
<td>Ward 8 Maternity Ward</td>
<td>223</td>
<td>260</td>
<td>218</td>
<td>196</td>
</tr>
<tr>
<td>Ward 8 Gynaecology</td>
<td>286</td>
<td>190</td>
<td>180</td>
<td>142</td>
</tr>
<tr>
<td>Ward 10 Neonatal Ward</td>
<td>139</td>
<td>190</td>
<td>103</td>
<td>131</td>
</tr>
<tr>
<td>X-ray Ward</td>
<td>23</td>
<td>43</td>
<td>72</td>
<td>103</td>
</tr>
<tr>
<td>Child Day Care</td>
<td>75</td>
<td>150</td>
<td>105</td>
<td>69</td>
</tr>
<tr>
<td><strong>Total Order Lines Placed</strong></td>
<td><strong>7448</strong></td>
<td><strong>8869</strong></td>
<td><strong>6709</strong></td>
<td><strong>5290</strong></td>
</tr>
</tbody>
</table>

Table 32: Total Order Lines Placed (extracted from Appendix 1)
5.3 Analysis for Research Question III

The analysis for Research Question III will be performed by putting the theory against the empirical findings by an analytical discussion through a pattern matching. The analysis will sometimes mention references which are not depicted in the empirical chapter for Research Question III; this is because it has already been depicted earlier in the project and the authors felt it would be redundant to write the same data twice. This sub section ends with a table showing the basis for conclusion in order to answer Research Question III. This table will provide different statements as according to what CLV has expressed they wished the central storage would achieve and based on the findings from the analytical discussion, the statements will either hold true or not as shown in the table. Below follows an illustration of the analysis’ disposition:

![Analysis Model for Research Question III](image)

Figure 10: Analysis’ Disposition for Research Question III
Jonsson & Mattsson (2011) and Harrison & van Hoek (2011) explains that for products which need a short delivery time, it is favourable with a low centralisation and that hospitals therefore keep stock at wards; this holds true for CLV as each ward has its own storage (Törndahl, 2011). However, Munge 2011 expresses that it was found that the wards placed too many orders by themselves, and also placed orders for medicine already available in-house. Jonsson & Mattsson (2011) as well as Arnold (2008) argues that an order represents one or several order lines. Order placement must therefore be effective due to costs being related to each order line and not the quantity per order line. This is the situation at CLV as according to Munge (2011)’s explanation of how each order line comes with a fixed price depending on its delivery time, and that it is the hope that a centralised inventory will reduce the order lines placed by wards themselves by having a central storage acting as a safety stock installed.

This is in line with the arguments presented by Pan & Pokharel (2007) that each hospital normally has at least one in-house central storage and by Harrison & van Hoek (2011), Arnold et al. (2008) and Abdelaziz & Mejri (2012) that a centralised inventory is perceived as a shared pool of goods and ought to lead to a duplication reduction. Which it has, according to the collected qualitative data in 5.2.1 where nurses at different wards have expressed that much less orders are placed from the wards since the establishment of the Pharmaceutical Unit and as well due to the instalment of a central storage as they now have one more place to search for medicine before placing an order and that they are more aware of the costs connected to each order line placed.

This is also verified by the quantitative data presented in subsection 5.2.2 where a reduction in orderliness is clearly shown as of 2012, which is when the Pharmaceutical Unit was fully operational and had been able to make all employees cost-aware. It is however from the quantitative data not possible to clearly indicate that the central storage has led to a major fall in order lines placed as the order lines were declining also before its instalment due to the Pharmaceutical Unit and its Pharmaceutical Service (Granberg, 2011); It can instead from the qualitative data be established that the central storage has led to less orders placed as the nurses have a safety stock to turn to, it has led to a ward’s basic inventory being reduced and it is saving time for nurses to be able to tend to other matters, such as caring for the hospitalized patients.
As explained by Marklund (2002), Seo et al. (2000), Nicholson et al. (2004) and Yu et al. (2001) a centralised inventory requires a well-developed IT-system from which participants can know more about each other and real-time stock levels can be acquired. This holds true at CLV as Munge (140120) explains that all ward have access to the central storage and ought to be able to find medicine relevant for them there. The nurses interviewed in 5.2.1 concurs as they explain that they turn to the central storage when a medicine is not in stock at the Ward, and that it is convenient that there now exists a possibility to verify through the AWS IT-system if a medicine is in stock or not at the central storage without having to go there.

The AWS being installed in the central storage aligns with Jonsson & Mattsson (2011) who explain that having a centralised inventory opens up for the opportunity of installing automated storage solutions. It was according to Munge (140120) the reason CLV got an AWS in the first place. Having a centralised inventory also reduces the risk for obsolescence, decreases costs and waste while increasing efficiency according to Jonsson & Mattsson (2011) and Shahabi et al. (2013); this holds true at CLV as according to Munge (140120) when less excessive orders are placed, the risk for having too much medicine which finally turns obsolete decreases. It also lowers the risk of abuse of narcotics, as according to Roth (140423) the AWS in the centralised storage makes this handling more secure as it is electronically registered which nurse that extracts a narcotic. The centralised storage at CLV can therefore be argued to have fulfilled its function as a safety stock as it according to Jonsson & Mattsson (2011), Pan & Pokharel (2007); Slack et al. (2012); Baboli et al., 2011 and Arnold (2008) is a stock put in place in order to buffer the unbalance between supply and demand in material management; especially as in hospitals the demand is hard to predict.

<table>
<thead>
<tr>
<th><strong>Basis for Conclusion</strong></th>
<th><strong>Findings</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Order lines have been reduced</td>
<td>Correct, however it is not possible to claim exactly how large of the reduction which is due to the central storage</td>
</tr>
<tr>
<td>The central storage functions as a Safety Stock</td>
<td>Correct, as nurses claim to first verify the central storage before placing their own orders.</td>
</tr>
</tbody>
</table>

Table 33: Basis for Conclusion for Research Question III
6. CONCLUSION AND RECOMMENDATION

This chapter aims to present the authors’ conclusions which are drawn from the different basis for conclusions found in the previous chapters 3.3, 4.3 and 5.3. The authors will also use this chapter to express their recommendations for CLV.
6.1 Conclusion

When comparing the time consumption, and the excessiveness of the different processes, it seems to be similar in total for both wards, just allocated differently; almost always, when one section of a process takes more time for Ward 3, another section in the same process takes more time for Ward 5 and vice versa. However, when allocating costs to the processes there are sometimes larger differences; this is then due to the involvement of the Pharmaceutical Unit as they carry a higher capacity cost.

In terms of safety and accuracy Ward 5 exceeds Ward 3. This due to having and AWS and by having laid responsibility on the Pharmaceutical Unit which has a more focused competence in medicine and can devote more time on for example replenishing, returning narcotics and unpacking compared to a nurse; this decreases the risk of mistakes occurring. The AWS has led to more waste for Ward 5, as it is no longer possible to return regular medicine, whereas Ward 3 can. The aspects of waste and security cannot be covered through a TDABC but should be given consideration.

It is not possible to give an exact figure on how much the central storage has affected the number of order lines being placed; this due to that the Pharmaceutical Service provided by the Pharmaceutical Unit continuously improving the wards’ ordering routine. It can however be assumed that it is contributing to less order lines being placed; this as nurses at different wards have confirmed that they use the central storage as a safety stock and that it is always verified first before an order is placed by the ward.

6.2 Recommendation

The authors would like to recommend CLV to install AWS dispensers for storing narcotics in all wards. This way, each ward would have a unanimous routine for handling narcotics, the security would rise significantly as each extraction and return would be electronically documented. The return of narcotics would also become more secure as the responsibility would be placed with the Pharmaceutical Unit who has the proper time to take in performing this task; as opposed to a nurse who might be stressed with patients in need of care and therefore hastily returns a narcotic and increases the chance of it being returned in a wrong package or miscalculating the amount.
Further, the authors would like to recommend CLV to, as soon as possible, find a solution for AWSs being able to return regular medicine as well. This due to the fact that both the authors but also interviewed nurses see it as a waste that proper medicine must be thrown simply because no return function is available. Should no such function be possible to implement, CLV ought to think over if regular medicine should be placed in AWSs at all then. It increases security, however it increases costs in terms of possible waste.

Another reason to consider regarding storing regular medicine is the time it takes for the Pharmaceutical Unit to replenish the medicine into AWSs compared to if they would only shelf it, which could be seen from the calculated scenarios where there was a significant cost difference between Ward 3 and Ward 5 regarding replenishment. A consideration must then be taken by CLV if the added security is high enough to bear the added costs.

The authors would also like to recommend CLV to perhaps once again hold educations for nurses in how to use the AWS; this due to the authors finding when performing their observations and interviews that there were still a few nurses who felt uncomfortable working with AWSs as they felt they did not understand them; and therefore consuming unnecessary time, taking help from other nurses and therefore binding up even more time consumption as well as increasing the risk of performing mistakes with the AWS.

It is as well important that this education stresses the importance of returning narcotics back to the AWS it came from instead of throwing it; this based on an experience the authors had where a nurse threw newly extracted narcotics in the trash because the wrong narcotic was accidentally extracted, instead of returning it before extracting the correct narcotic. If CLV can reduce the waste of regular medicine and narcotics; there is potential of cost savings.
7. REFLECTION AND SELF-CRITICISM

This chapter aims to reflect the authors’ performance and work progress in accordance to the criteria stated in chapter 2.9.
The authors are pleased with the progress of this project. The authors had from the start a clear structure and a reasonable timetable which was followed throughout the project. The clear structure helped the work and ensured that right data was always in the right place. The authors early developed models which throughout the project clearly show the dispositions and relationships in and between the project’s different chapters. This has ensured that the project has internal validity.

The collection of theory began early and the authors feel that the theory presented in the project is concise, to the point, up to date, highly relevant as well as mixture of wide range of literature and scientific articles. This has ensured the project’s construct validity. It took however a little while for the authors to fully understand the project’s scope and throughout the whole project, theory was added and removed. Had this project been conducted again, the authors would have tried to gain a more clear understanding earlier in the process in order to save time spent on finding, reading and compiling unnecessary theory.

The collection of empirical data has been a large part of the work in making this project. The authors are pleased with the progress of collecting the data, as the employees at CLV were always eager to help and the authors felt they could easily gather the necessary data. The empirical findings have been double checked with the interviewees in order to ensure that the information has been rightfully interpreted. This has ensured that the project has construct validity. As previously mentioned, the gathering of empirical data was a large part and quite extensive and took much time as many observations and interviews were performed. The authors however feel that this was never a problem as they always felt that they were in phase with their timetable.

One obstacle the authors had to face was something which the theory warned them about; letting the work of creating process maps become too detailed. At a certain point the authors had to realize that they were at risk of getting into too much detail and had to draw a boundary of how detailed a process should be; especially as it made the gathering of time data more complicated as activities taking sometimes less than a second would then have to be timed. Had the authors understood this earlier, it could have eased the process; however the authors feel that facing this obstacle did not affect the project’s quality in a negative way.
The authors wish there would have been more time for observations in order to gather data on time as a more reliable average could then have been presented. The authors have tried to show how possible deviations not caught in their observations could affect the capacity cost by conducting a sensitivity analysis; however they wish that this would not have been necessary. This could affect the project’s construct validity as it could be argued that not enough sources have been used. However, the construct validity is strengthened by the fact that this project has fulfilled its purpose and the wishes given by CLV. It has even performed more, as Research Question I and II treats an area which the authors themselves took the initiative to examine.

The project’s process and findings have been thoroughly documented, and throughout the project the authors have in detail explained why something is done, what it is based on and through different models illustrated different dispositions. This has been done in order to enable the research being repeated by somebody else and therefore the project has ensured reliability. The project will also be able to serve as a help and guidance for others in a health-care setting who are considering installing a central storage and/or investing in Automated Ward Solutions. The project is also a support for others who wish to apply process mapping and TDABC in a real context as both the theory, empirical and analysis clearly shows how this is made. Therefore, the project has ensured that it is analytically generalizable and in turn holds external validity.
8. FURTHER RESEARCH

This chapter aims to give suggestions for the continuing of this study in aspects which this project does not include.
The authors find that it would be interesting to examine a ward by itself, and not only to lay the focus in comparing it with another ward. This as the authors found when conducting their time-study that there can be differences in time, which could lead to significant changes in cost-outcome from a TDABC application, depending on what choices a nurse makes. For example, it is found that there is a risk of a direct extraction being a more expensive choice in case the medicine is not found in that AWS; and therefore unnecessary time has been consumed. Realizing this, it would probably be wise for CLV to properly inform nurses of the benefits from making a pre-order and try to make this their routine. The authors feel that there are probably many more aspects such as this one to be found in a ward’s way of working which could be examined so that suggestions for a more effective process can be presented.

The authors find that it would have been interesting to perform a benchmarking with another hospital’s ward that has an AWS installed, and compare their way of working with Ward 5 or Ward 34 at CLV in order to see if there are possible improvements to be made.

The authors find that it would be interesting to examine the possibilities of installing software that allows for a patient’s electronic journal to be connected to the AWS. This way, patient security could be even higher and it would also save time as nurses would not have to verify the patient’s prescription list manually. CLV has expressed a wish to install such software and the authors wish that they could have helped them with that.

The authors find that it would have been interesting to examine the replenishment points and basic inventory of different wards to ensure that these are at the most optimal level. This could be done by classifying medicines in an ABC-XYZ classification, taking into consideration seasonal fluctuations in medicines.

Finally, the authors find it would have been interesting to have had examined the investment of AWSs taking into consideration depreciation et cetera, together with this project’s findings, in order to see if further investments should be made or not.
9. THE PROJECT’S CONTRIBUTION

This chapter aims to explain the project’s contribution to CLV as well as its contribution in a socioeconomic aspect.
This project will help CLV in various aspects. For one it provides CLV with the possibility to calculate the cost of different processes, which can enable them to stimulate different changes in work processes and see the difference in cost outcome. When considering if another AWS should be installed, CLV can then use the calculated scenarios to see if an investment is worth making or not.

Further CLV was helped by the project in getting a better overview over who does what, and how the work is distributed between a ward and the Pharmaceutical Unit and the differences of having an AWS on the ward or not. This will also help in the decision of whether or not to install more AWSs at CLV.

The project has also examined the effects of having a centralised storage which has helped CLV understanding the routines of different wards and what needs to be done to make all wards utilise the central storage and realize its benefits. It also helps CLV to receive confirmation that their investment in a central storage was a correct choice as it has fulfilled what they had hoped it would.

Reviewing the project from a socioeconomic aspect shows that it is of importance; this as by showing the benefits of having a centralised storage, other health care institutions could install the same which frees up time for nurses that can instead be spent on caring for hospitalized patients. It also shows that having an AWS installed increases security and accuracy and thereby increases patient security which is important.
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Appendix 1: Calculated Scenarios in the Material Management Process of Medicine for Ward 3 without an AWS

**Replenishment of Medicine**

1) This calculated scenario is based on the assumption that Ward 3 has a basic inventory of 282 medicines and that 20 order lines have been placed. The capacity cost per minute relating the activities performed by the Pharmaceutical Unit will 4,85SEK and the capacity cost per minute relating to the activities performed by Ward 3 will be 3,75SEK. Based on the above stated criteria, the equation is as follows:

\[
(5.09 + (0.10 \times 20) + 5.96 + 0.98 + (0.03 \times 20) + 0.02) \times 4.85
\]
\[
+ [(0.51 \times 3.75)] + [(5.09 + (0.78 \times 20)) \times 4.85] = 173,31SEK
\]

**Stock-Inventory of Medicine**

1) This calculated scenario is based on the assumption that the last large inventory at Ward 3 was less than three months ago, that the basic inventory consists of 282 medicines and that five medicines need to be discarded. The capacity cost per minute related to the activities performed by the Pharmaceutical Unit will be 4.85SEK. Based on the above stated criteria, the equation will be as follows:

\[
(5.51 + (0.09 \times 282) + (0.17 \times 5)) \times 4.85 = 153,94SEK
\]

2) This calculated scenario is based on the assumption that the last large inventory at Ward 3 was more than three months ago, that the basic inventory is 282 medicines and that five medicines need to be discarded. The capacity cost per minute related to the activities performed by the Pharmaceutical Unit will be 4.85SEK. Based on the above stated criteria, the equation will be as follows:

\[
(5.51 + 45 + (0.17 \times 5)) \times 4.85 = 249,10SEK
\]

**Extraction of Medicine for Trolley**

1) This calculated scenario is based on the assumption that medicine is in stock at the ward, that there are 35 regular medicines and five narcotics in need of extraction and to be inserted in the trolley. The capacity cost per minute relating to the activities
performed by Ward 3 will be 3,75SEK. Based on the above stated criteria, the equation will be as follows:

\[(0,26 + (0,73 \times 35) + (0,17 \times 35) + (1 \times 5) + (0,17 \times 5)) \times 3,75 = 141,04SEK\]

2) This calculated scenario is based on the assumption that 33 regular medicines and four narcotics are in stock at the ward and will be extracted and inserted in the trolley, that the decision of pre-order through an AWS has been taken and that two regular medicines and one narcotic will be extracted from there and inserted in the trolley. The capacity cost per minute relating to the activities performed by Ward 3 will be 3,75SEK. Based on the above stated criteria, the equation will be as follows:

\[(0,26 + (0,73 \times 33) + (0,17 \times 33) + (1 \times 4) + (0,17 \times 4) + (0,73 \times 3) + (0,8 \times 3) + 2,09 + 0,17 + (0,8 \times 3) + 2,09 + (0,17 \times 3)) \times 3,75 = 174,34SEK\]

3) This calculated scenario is based on the assumption that 32 regular medicines and four narcotics are in stock at the ward and will be extracted and inserted in the trolley, that the decision of pre-order through an AWS has been taken and that one regular medicine and one narcotic will be extracted from there and inserted in the trolley and that one regular medicine has to be ordered through Provider. The capacity cost per minute relating to the activities performed by Ward 3 will be 3,75SEK. Based on the above stated criteria, the equation will be as follows:

\[(0,26 + (0,73 \times 33) + (0,17 \times 33) + (1 \times 4) + (0,17 \times 4) + (0,73 \times 2) + (0,8 \times 2) + 2,09 + 0,17 + (0,8 \times 2) + 2,09 + (0,17 \times 2) + (5 \times 1)) \times 3,75 = 183,71SEK\]

4) This calculated scenario is based on the assumption that 33 regular medicines and four narcotics are in stock at the ward and will be extracted and inserted in the trolley, that the decision of direct extraction at an AWS has been taken and that two regular medicines and one narcotic will be extracted from there and inserted in the trolley. The capacity cost per minute relating to the activities performed by Ward 3 will be 3,75SEK. Based on the above stated criteria, the equation will be as follows:

\[(0,26 + (0,73 \times 33) + (0,17 \times 33) + (1 \times 4) + (0,17 \times 4) + 2,09 + (0,8 \times 3) + (0,8 \times 3) + 2,09 + (0,17 \times 3)) \times 3,75 = 165,49SEK\]
5) This calculated scenario is based on the assumption that 33 regular medicines and four narcotics are in stock at the ward and will be extracted and inserted in the trolley, that the decision of direct extraction at an AWS has been taken and that one regular medicine and one narcotic will be extracted from there and inserted in the trolley and that one regular medicine has to be ordered through Provider. The capacity cost per minute relating to the activities performed by Ward 3 will be 3.75SEK. Based on the above stated criteria, the equation will be as follows:

\[
(0.26 + (0.73 \times 33) + (0.17 \times 33) + (1 \times 4) + (0.17 \times 4) + 2.09 + (0.8 \times 2) \\
+ (0.8 \times 2) + 2.09 + (0.17 \times 2) + (0.73 \times 1) + (5 \times 1)) \times 3.75 \\
= 180.34SEK
\]

**Extraction of Medicine for Patient**

1) This calculated scenario is based on the assumption that the patient has been prescribed 1 regular medicine or narcotic and that this is in the trolley. The capacity cost per minute relating to the activities performed by Ward 3 will be 3.75SEK. Based on the above stated criteria, the equation will be as follows:

\[
((1.34 \times 1) + (0.17 \times 1)) \times 3.75 = 5.66SEK
\]

2) This calculated scenario is based on the assumption that the patient has been prescribed 1 regular medicine and that this is not found in the trolley. The capacity cost per minute relating to the activities performed by Ward 3 will be 3.75SEK. Based on the above stated criteria, the equation will be as follows:

\[
((1.34 \times 1) + 0.29 + (0.09 \times 1)) \times 3.75 = 6.45SEK
\]

3) This calculated scenario is based on the assumption that the patient has been prescribed 1 narcotic and that this is not found in the trolley. The capacity cost per minute relating to the activities performed by Ward 3 will be 3.75SEK. Based on the above stated criteria, the equation will be as follows:

\[
((1.34 \times 1) + 0.29 + 0.26 + (0.77 \times 1)) \times 3.75 = 9.98SEK
\]

4) This calculated scenario is based on the assumption that the patient has been prescribed 1 regular medicine or narcotic, that this is not found at the ward and that the decision of making a pre-order has been taken. The capacity cost per minute relating to the
activities performed by Ward 3 will be 3,75SEK. Based on the above stated criteria, the equation will be as follows:

$\left( (1,34 \times 1) + 0,73 + (0,77 \times 1) + 2 + 0,17 + (0,41 \times 1) + 2 \right) \times 3,75 = 27,83SEK$

5) This calculated scenario is based on the assumption that the patient has been prescribed 1 regular medicine or narcotic, that the decision of making a pre-order has been taken and that this is not found at CLV. The capacity cost per minute relating to the activities performed by Ward 3 will be 3,75SEK. Based on the above stated criteria, the equation will be as follows:

$\left( (1,34 \times 1) + 0,73 + (0,77 \times 1) + (0,73 \times 1) + (5 \times 1) \right) \times 3,75 = 32,14SEK$

6) This calculated scenario is based on the assumption that the patient has been prescribed 1 regular medicine or narcotic, that this is not found at the ward and that the decision of making a direct extraction has been taken. The capacity cost per minute relating to the activities performed by Ward 3 will be 3,75SEK. Based on the above stated criteria, the equation will be as follows:

$\left( (1,34 \times 1) + 2 + 0,17 + (0,77 \times 1) + (0,41 \times 1) + 2 \right) \times 3,75 = 25,09SEK$

7) This calculated scenario is based on the assumption that the patient has been prescribed 1 regular medicine or narcotic, that the decision of making a direct extraction has been taken and that this is not found at CLV. The capacity cost per minute relating to the activities performed by Ward 3 will be 3,75SEK. Based on the above stated criteria, the equation will be as follows:

$\left( (1,34 \times 1) + 2 + 0,17 + (0,77 \times 1) + (0,73 \times 1) + (5 \times 1) \right) \times 3,75 = 37,52SEK$

**Reverse Logistics of Medicine**

1) This calculated scenario is based on the assumption that 20 regular medicines are to be returned. The capacity cost per minute relating to the activities performed by Ward 3 will be 3,75SEK. Based on the above stated criteria, the equation will be as follows:

$(0,29 + (0,09 \times 20) + (0,14 \times 20)) \times 3,75 = 18,34SEK$

2) This calculated scenario is based on the assumption that 20 regular medicines are to be returned and that 10 narcotic will be returned, and that it adds up. The authors will also add an estimated time for the work of a nurse continuously having to verify the
narcotics journal, and possibly investigate if something seems odd; this based on interviews with Petersson (140312) and Törndahl (140429). This time is estimated to be one minute per narcotic, which in this scenario makes it to 10 minutes. The capacity cost per minute relating to the activities performed by Ward 3 will be 3,75SEK. Based on the above stated criteria, the equation will be as follows:

\[
(0,29 + (0,09 \times 20) + (0,14 \times 20) + 0,26 + (0,77 \times 10) + 10) \times 3,75 = 85,69SEK
\]

3) This calculated scenario is based on the assumption that 20 regular medicines are to be returned and that 10 narcotic will be returned, and that one of them does not add up. The authors will also add an estimated time for the work of a nurse continuously having to verify the narcotics journal, and possibly investigate if something seems odd; this based on interviews with Petersson (140312) and Törndahl (140429). This time is estimated to be one minute per narcotic, which in this scenario makes it to 10 minutes. The capacity cost per minute relating to the activities performed by Ward 3 will be 3,75SEK. Based on the above stated criteria, the equation will be as follows:

\[
(0,29 + (0,09 \times 20) + (0,14 \times 20) + 0,26 + (0,77 \times 9) + (3 \times 1) + 10) \times 3,75 = 94,05SEK
\]

4) This calculated scenario is based on the assumption that 20 regular medicines are to be returned, that 10 narcotics will be returned, and that one of them will be returned to an AWS. The authors will also add an estimated time for the work of a nurse continuously having to verify the narcotics journal, and possibly investigate if something seems odd; this based on interviews with Petersson (140312) and Törndahl (140429). This time is estimated to be one minute per narcotic, which in this scenario makes it to 9 minutes. The capacity cost per minute relating to the activities performed by Ward 3 will be 3,75SEK. Based on the above stated criteria, the equation will be as follows:

\[
(0,29 + (0,09 \times 20) + (0,14 \times 20) + 0,26 + (0,77 \times 9) + 2 + 0,32 + (0,82 \times 1) + 9) \times 3,75 = 90,83SEK
\]
Appendix 2: Calculated Scenarios in the Material Management Process of Medicine for Ward 5 with an AWS

Replenishment of Medicine

1) Since the replenishment of medicine is performed twice a week at Ward 5, the result of the equation will therefore be multiplied by two to get a fair view of reality. This calculated scenario will assume that 20 order lines have been placed. The capacity cost per minute related to the activities performed by the Pharmaceutical Unit is 4,85SEK and the capacity cost per minute related to the activities performed by Ward 5 is 3,75SEK. Based on the above stated criteria, the equation will be as follows:

\[
\begin{align*}
&\left[(0,37 + 1,68 + (0,03 \times 20) + (0,34 \times 20)) \times 4,85\right] + [(0,51 \times 3,75)] \\
&\quad + [(6,61 + (2,51 \times 20) + 7,73) \times 4,85] = 360,76SEK \\
&360,76 \times 2 = 721,52SEK
\end{align*}
\]

Stock-Inventory of Medicine

1) This calculated scenario is based on the assumption that 5 items are expiring. The capacity cost per minute related to the activities performed by the Pharmaceutical Unit is 4,85SEK. Based on these criteria the equation is as follows:

\[
(0,26 + 1,51 + 5,51 + (2,34 \times 5)) \times 4,85 = 92,05
\]

Extraction of Medicine for Trolley

1) This calculated scenario is based on the assumption that the decision of pre order has been taken, that the medicine is in stock at the ward, and that 40 medicines will be extracted and put in the trolley. The capacity cost per minute related to the activities performed by Ward 5 is 3,75SEK. Based on these criteria equation is as follows:

\[
(0,54 + (0,46 \times 40) + 0,44 + (0,46 \times 40)) \times 3,75 = 141,68SEK
\]

2) This calculated scenario is based on the assumption that the decision of pre order has been taken, that 37 medicines are in stock at the ward but that three medicines will be extracted from another AWS and put in the trolley. The capacity cost per minute related to the activities performed by Ward 5 is 3,75SEK. Based on these criteria equation is as follows:
3) This calculated scenario is based on the assumption that the decision of pre order has been taken, that 37 medicines are in stock at the ward, that two medicines will be extracted from another AWS and put in the trolley and that 1 medicine has to be ordered through Provider. The capacity cost per minute related to the activities performed by Ward 5 is 3,75SEK. Based on these criteria equation is as follows:

\[
(0.54 + (0.46 \times 37) + 0.44 + (0.46 \times 37) + (0.73 \times 3) + (0.46 \times 3) + 1.97 \\
+ (0.46 \times 3) + 1.97 + (0.17 \times 3)) \times 3.75 = 166,58SEK
\]

4) This calculated scenario is based on the assumption that the decision of direct extraction has been taken, that the medicine is in stock at the ward, and that 40 medicines will be extracted and put in the trolley. The capacity cost per minute related to the activities performed by Ward 5 is 3,75SEK. Based on these criteria equation is as follows:

\[
(0.44 + (0.46 \times 40) + (0.46 \times 40) + (0.17 \times 40)) \times 3.75 = 165,15SEK
\]

5) This calculated scenario is based on the assumption that the decision of direct extraction has been taken, that 37 medicines are in stock at the ward but that three medicines will be extracted from another AWS and put in the trolley. The capacity cost per minute related to the activities performed by Ward 5 is 3,75SEK. Based on these criteria equation is as follows:

\[
(0.44 + (0.46 \times 37) + (0.46 \times 37) + (0.17 \times 37) + 1.97 + (0.46 \times 3) + (0.46 \times 3) \\
+ 1.97 + (0.17 \times 3)) \times 3.75 = 179,93SEK
\]

6) This calculated scenario is based on the assumption that the decision of direct extraction has been taken, that 37 medicines are in stock at the ward, that two medicines will be extracted from another AWS and put in the trolley and that 1 medicine has to be ordered through Provider. The capacity cost per minute related to the activities performed by Ward 5 is 3,75SEK. Based on these criteria equation is as follows:

\[
(0.44 + (0.46 \times 37) + (0.46 \times 37) + (0.17 \times 37) + 1.97 + (0.46 \times 2) + (0.46 \times 2) \\
+ 1.97 + (0.17 \times 2) + (0.73 \times 1) + (4.5 \times 1)) \times 3.75 = 195,45SEK
\]
Extraction of Medicine for Patient

1) This calculated scenario is based on the assumption that a patient has been prescribed one medicine and that this is in the trolley. The capacity cost per minute related to the activities performed by Ward 5 is 3,75SEK. Based on these criteria equation is as follows:

\[(0,26 + (0,43 \times 1)) \times 3,75 = 2,59SEK\]

2) This calculated scenario is based on the assumption that a patient has been prescribed one medicine and that this is not found in the trolley but at the ward and that the decision of pre-order has been taken. The capacity cost per minute related to the activities performed by Ward 5 is 3,75SEK. Based on these criteria equation is as follows:

\[(0,26 + 0,26 + (1,26 \times 1) + 0,34 + (0,85 \times 1)) \times 3,75 = 11,14SEK\]

3) This calculated scenario is based on the assumption that a patient has been prescribed one medicine and that this is not found in the trolley but at another AWS and that the decision of pre-order has been taken. The capacity cost per minute related to the activities performed by Ward 5 is 3,75SEK. Based on these criteria equation is as follows:

\[(0,26 + 0,26 + (1,32 \times 1) + 1,83 + 0,36 + 0,73 + 1,83) \times 3,75 = 24,71SEK\]

4) This calculated scenario is based on the assumption that a patient has been prescribed one medicine, that the decision of pre-order has been taken and that it is not found at CLV. The capacity cost per minute related to the activities performed by Ward 5 is 3,75SEK. Based on these criteria equation is as follows:

\[(0,26 + 0,26 + (1,32 \times 1) + (4,5 \times 1)) \times 3,75 = 23,78SEK\]

5) This calculated scenario is based on the assumption that a patient has been prescribed one medicine and that this is not found in the trolley but at the ward and that the decision of direct extraction has been taken. The capacity cost per minute related to the activities performed by Ward 5 is 3,75SEK. Based on these criteria equation is as follows:

\[(0,26 + 0,26 + 0,36 + (0,45 \times 1) + (0,73 \times 1)) \times 3,75 = 7,73SEK\]
6) This calculated scenario is based on the assumption that a patient has been prescribed one medicine, that the decision of direct extraction has been taken and that it is not found at the ward. The capacity cost per minute related to the activities performed by Ward 5 is 3,75SEK. Based on these criteria equation is as follows:

\[
(0,26 + 0,26 + 0,36 + 1,83 + 0,36 + (1,32 \times 1) + (0,73 \times 1) + 1,83) \times 3,75
\]

\[= 26,06SEK\]

7) This calculated scenario is based on the assumption that a patient has been prescribed one medicine, that the decision of direct extraction has been taken and that it is not found at CLV. The capacity cost per minute related to the activities performed by Ward 5 is 3,75SEK. Based on these criteria equation is as follows:

\[
(0,26 + 0,26 + 0,36 + 1,83 + 0,36 + (1,32 \times 1) + (4,5 \times 1)) \times 3,75 = 33,34SEK
\]

**Reverse Logistics of Medicine**

1) This calculated scenario will assume that there is something to discard by both Ward 5 and the Pharmaceutical Unit and that 10 order line is in need of return for Ward 5 and the Pharmaceutical Unit. The capacity cost per minute related to the activities performed by Ward 5 is 3,75SEK and the capacity cost per minute related to the activities performed by the Pharmaceutical Unit is 4,85SEK. Based on these criteria the equation is as follows:

\[
[(0,26 + 0,17 + 0,27 + (0,7 \times 10)) \times 3,75]
\]
\[+ [(3,03 + 5,51 + 0,14 + 0,17 + (0,27 \times 10) + (0,97 \times 10) + 0,17)
\]
\[\times 4,85] = 132,76SEK\]
Appendix 3: Calculated Process Averages

- Replenishment of Medicine for Ward 3:
  \[ \frac{173.31}{1} = 173,31\text{SEK} \]

- Stock Inventory of Medicine Ward 3:
  \[ \frac{153.94 + 249.10}{2} = 201,52\text{SEK} \]

- Extraction of Medicine for Trolley Ward 3:
  \[ \frac{141.04 + 174.34 + 183.71 + 165.49 + 180.34}{5} = 168,98\text{SEK} \]

- Extraction of Medicine for Patient Ward 3:
  \[ \frac{5.66 + 6.45 + 9.98 + 27.83 + 32.14 + 25.09 + 37.52}{7} = 20,67\text{SEK} \]

- Reverse Logistics of Medicine Ward 3:
  \[ \frac{18.34 + 85.69 + 94.05 + 90.83}{4} = 72,23\text{SEK} \]

- Replenishment of Medicine Ward 5:
  \[ \frac{721.52}{1} = 721,52\text{SEK} \]

- Stock Inventory of Medicine Ward 5:
  \[ \frac{92.05}{1} = 92,05\text{SEK} \]

- Extraction of Medicine for Trolley Ward 5:
  \[ \frac{141.68 + 166.58 + 176.66 + 165.15 + 179.93 + 195.45}{6} = 170,91\text{SEK} \]

- Extraction of Medicine for Patient Ward 5:
  \[ \frac{2.59 + 11.14 + 24.71 + 23.78 + 7.73 + 26.06 + 33.34}{7} = 18,48\text{SEK} \]

- Reverse Logistics of Medicine Ward 5:
  \[ \frac{132.76}{1} = 132,76\text{SEK} \]
## Appendix 4: Sensitivity Analysis

### Ward 3:

<table>
<thead>
<tr>
<th>Process</th>
<th>-30%</th>
<th>-10%</th>
<th>Original Average process cost Ward 3</th>
<th>+10%</th>
<th>+30%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replenishment of Medicine</td>
<td>121</td>
<td>156</td>
<td>173</td>
<td>190</td>
<td>225</td>
</tr>
<tr>
<td>Stock inventory of Medicine</td>
<td>141</td>
<td>181</td>
<td>201</td>
<td>221</td>
<td>261</td>
</tr>
<tr>
<td>Extraction of medicine for Trolley</td>
<td>118</td>
<td>152</td>
<td>169</td>
<td>186</td>
<td>220</td>
</tr>
<tr>
<td>Extraction of medicine for Patient</td>
<td>15</td>
<td>19</td>
<td>21</td>
<td>23</td>
<td>27</td>
</tr>
<tr>
<td>Reverse Logistics of Medicine</td>
<td>50</td>
<td>65</td>
<td>72</td>
<td>79</td>
<td>94</td>
</tr>
</tbody>
</table>

### Ward 5:

<table>
<thead>
<tr>
<th>Process</th>
<th>-30%</th>
<th>-10%</th>
<th>Original Average process cost Ward 5</th>
<th>+10%</th>
<th>+30%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replenishment of Medicine</td>
<td>504</td>
<td>648</td>
<td>720</td>
<td>729</td>
<td>936</td>
</tr>
<tr>
<td>Stock inventory of Medicine</td>
<td>64</td>
<td>83</td>
<td>92</td>
<td>101</td>
<td>120</td>
</tr>
<tr>
<td>Extraction of medicine for Trolley</td>
<td>120</td>
<td>154</td>
<td>171</td>
<td>188</td>
<td>222</td>
</tr>
<tr>
<td>Extraction of medicine for Patient</td>
<td>13</td>
<td>16</td>
<td>18</td>
<td>20</td>
<td>23</td>
</tr>
<tr>
<td>Reverse Logistics of Medicine</td>
<td>93</td>
<td>120</td>
<td>133</td>
<td>146</td>
<td>173</td>
</tr>
</tbody>
</table>
Appendix 5: Sensitivity Analysis 2

Ward 3:

Extraction of Medicine for Trolley

1) \((0,26 + (0,73 \times 35) + (0,17 \times 35) + (1 \times 5) + (0,17 \times 5) ) \times 3,75 = 141,04SEK\)

2) This calculated scenario is based on the assumption that 33 regular medicines and four narcotics are in stock at the ward and will be extracted and inserted in the trolley, that the decision of pre-order through an AWS has been taken and that two regular medicines and one narcotic will be extracted from there and inserted in the trolley. The capacity cost per minute relating to the activities performed by Ward 3 will be 3,75SEK. Based on the above stated criteria, the equation will be as follows:

\[
(0,26 + (0,73 \times 33) + (0,17 \times 33) + (1 \times 4) + (0,17 \times 4) + ((0,73 \times 1,4) \times 3) \\
+ ((0,8 \times 1,5) \times 3) + 2,09 + (0,17 \times 4) + ((0,8 \times 1,6) \times 3) + 2,09 \\
+ (0,17 \times 3) ) \times 3,75 = 187,78SEK
\]

3) This calculated scenario is based on the assumption that 32 regular medicines and four narcotics are in stock at the ward and will be extracted and inserted in the trolley, that the decision of pre-order through an AWS has been taken and that one regular medicine and one narcotic will be extracted from there and inserted in the trolley and that one regular medicine has to be ordered through Provider. The capacity cost per minute relating to the activities performed by Ward 3 will be 3,75SEK. Based on the above stated criteria, the equation will be as follows:

\[
(0,26 + (0,73 \times 33) + (0,17 \times 33) + (1 \times 4) + (0,17 \times 4) + ((0,73 \times 1,5) \times 2) \\
+ ((0,8 \times 1,6) \times 2) + 2,09 + (0,17 \times 4) + ((0,8 \times 1,6) \times 2) + 2,09 \\
+ (0,17 \times 2) + (5 \times 1)) \times 3,75 = 193,91SEK
\]

4) This calculated scenario is based on the assumption that 33 regular medicines and four narcotics are in stock at the ward and will be extracted and inserted in the trolley, that the decision of direct extraction at an AWS has been taken and that two regular medicines and one narcotic will be extracted from there and inserted in the trolley. The capacity cost per minute relating to the activities performed by Ward 3 will be 3,75SEK. Based on the above stated criteria, the equation will be as follows:
5) This calculated scenario is based on the assumption that 33 regular medicines and four narcotics are in stock at the ward and will be extracted and inserted in the trolley, that the decision of direct extraction at an AWS has been taken and that one regular medicine and one narcotic will be extracted from there and inserted in the trolley and that one regular medicine has to be ordered through Provider. The capacity cost per minute relating to the activities performed by Ward 3 will be 3,75SEK. Based on the above stated criteria, the equation will be as follows:

\[
(0.26 + (0.73 \times 33) + (0.17 \times 33) + (1 \times 4) + (0.17 \times 4) + 2.09 + ((0,8 \times 1,6) \times 3) + ((0,8 \times 1,5) \times 3) + 2.09 + (0.17 \times 3)) \times 3.75 = 175.39SEK
\]

Process Average from the Sensitivity Analysis:

<table>
<thead>
<tr>
<th>Process Average from the Sensitivity Analysis:</th>
</tr>
</thead>
<tbody>
<tr>
<td>141.04 + 187.78 + 193.91 + 175.39 + 186.34</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>= 176.89SEK</td>
</tr>
</tbody>
</table>

Extraction of Medicine for Patient

1) \(((1,34 \times 1) + (0,17 \times 1)) \times 3.75 = 5.66SEK\)

2) \(((1,34 \times 1) + 0,29 + (0,09 \times 1)) \times 3.75 = 6.45SEK\)

3) \(((1,34 \times 1) + 0,29 + 0,26 + (0,77 \times 1)) \times 3.75 = 9.98SEK\)

4) This calculated scenario is based on the assumption that the patient has been prescript 1 regular medicine or narcotic, that this is not found at the ward and that the decision of making a pre-order has been taken. The capacity cost per minute relating to the activities performed by Ward 3 will be 3,75SEK. Based on the above stated criteria, the equation will be as follows:

\[
((1,34 \times 1) + 0.73 + ((0,77 \times 1,4) \times 1) + 2 + (0,17 \times 1,5) + ((0,41 \times 1,4) \times 1) + 2) \times 3.75 = 29.91SEK
\]
5) This calculated scenario is based on the assumption that the patient has been prescribed regular medicine or narcotic, that the decision of making a pre-order has been taken and that this is not found at CLV. The capacity cost per minute relating to the activities performed by Ward 3 will be 3,75SEK. Based on the above stated criteria, the equation will be as follows:

\[
(1,34 \times 1) + 0,73 + ((0,77 \times 1,4) \times 1) + ((0,73 \times 1,6) \times 1) + (5 \times 1) \times 3,75
= 34,94SEK
\]

6) This calculated scenario is based on the assumption that the patient has been prescribed regular medicine or narcotic, that this is not found at the ward and that the decision of making a direct extraction has been taken. The capacity cost per minute relating to the activities performed by Ward 3 will be 3,75SEK. Based on the above stated criteria, the equation will be as follows:

\[
((1,34 \times 1) + 2 + (0,17 \times 1,4) + ((0,77 \times 1,6) \times 1) + ((0,41 \times 1,5) \times 1) + 2) \times 3,75 = 27,84SEK
\]

7) This calculated scenario is based on the assumption that the patient has been prescribed regular medicine or narcotic, that the decision of making a direct extraction has been taken and that this is not found at CLV. The capacity cost per minute relating to the activities performed by Ward 3 will be 3,75SEK. Based on the above stated criteria, the equation will be as follows:

\[
((1,34 \times 1) + 2 + (0,17 \times 1,5) + ((0,77 \times 1,5) \times 1) + ((0,73 \times 1,5) \times 1) + (5 \times 1)) \times 3,75 = 40,67SEK
\]

<table>
<thead>
<tr>
<th>Process Average from the Sensitivity Analysis:</th>
</tr>
</thead>
</table>
| \[
\frac{5,66 + 6,45 + 9,98 + 29,91 + 34,94 + 27,84 + 40,67}{7} = 22,21
\] |
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