Technology and Logistics in Health Care Services
A Case Study of Länssjukhuset Ryhov

Master Thesis in Business Administration
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Abstract

Background
Swedish hospitals face intensified challenges due to elevated demands from patients, demographic changes and cost constraints. Furthermore, patient safety is negatively affected by the relatively high rate of health care associated infections (HAIs). Thus, enforced preventive measures have to be undertaken to improve medical institutions’ ability to provide a qualitative and safe health care. Hence, logistics and technology solutions are gaining presence in modern day medical institutions in order to deliver improved health care.

Purpose
The purpose of this study is to explore how a central automatic bed disinfection system could be implemented at a hospital, and investigate if this would improve the patient safety by minimizing the health care associated infections while enhancing the working environment for health professionals.

Method
This study takes the form of an exploratory single case study through the investigation of a Swedish hospital. Qualitative data was compiled through semi-structured interviews and observations, which were analyzed inductively.

Conclusion
The findings reveal that introducing a central automatic bed disinfection system may improve patient safety and the working environment for health care personnel. Additionally, more consistent hygiene standards and improved cleaning quality result in an augmented minimization of bacteria, which as a consequence reduces transmissions of HAIs. Through the implementation of an automatic bed disinfection system, the cleaning capacity is increased, thus the supply of beds becomes more responsive, which indirectly affects the patient flow. By developing a sound logistics system through a flow perspective, a more effective bed management at the hospital is enabled, which optimizes the patient throughput. Moreover, cost efficiencies may be obtained through a more efficient qualitative health care.
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I Introduction

This chapter will present a brief introduction to the topic of interest and provide a general overview of the Swedish health care industry. Furthermore, the problem to be investigated will be described in more detail and the delimitations of the study will be acknowledged.

Hospitals around the world are facing intensified challenges due to elevated demands from patients, pressures to limit expenditures and resources as well as significant shifts in demographic patterns (de Vries & Huijsman, 2011). Furthermore, increasing demands from the public in terms of more extensive use of advanced technology in health care and individualized care are widespread. All together, these forces inflict constant pressure and drive the need for rapid change within contemporary health care institutions.

Similar challenges are experienced by Swedish hospitals, with increasing cost pressures and a steadily aging population (Statistiska Centralbyrån, 2014). Consequently, with a diminishing number of care places in terms of available capacity, specifically a 20% reduction between 2000 and 2009, and a simultaneous raise in hospitalizations by 7-8%, dealing with these issues becomes an urgent matter (Sveriges Kommuner och Landsting, 2010). These new dynamics have resulted in longer waiting times for patients, increased bed occupancy rates to 89% as well as a reduction in time caring for each patient (Läkartidningen, 2010; Sveriges Kommuner och Landsting, 2010). Therefore, hospitals’ are losing their ability to remain flexible and keep margins for unexpected events. Moreover, health care is a large, vital industry with the main objective to provide high quality health care for the population at the lowest operational cost possible. Thus, there is a pressing need for operation improvements and a higher degree of efficiency and effectiveness to comply with such goals in order to enhance patient care and safety in the future.

In recent years, hospitals have recognized the need for more modern changes in their business processes to transform from the hierarchical and professional bureaucracy archetype they have today (Villa, Barbieri & Lega, 2009). In order to become more efficient, health care managers need to deal with the complexities hospitals face and pay particular attention to their various functional silos that operate mostly independently.

Central to the hospital’s service is the entire patient flow, which is highly dependent on the precise allocation and alignment of various services and resources to provide a complete patient care (Parnaby & Towill, 2008). Thus, the importance of effectively managing hospital beds becomes imperative in order to match the patient turnover with a reliable supply of beds. The most common methods when dealing with bed management is the use of quantitative modellings and queuing theories, methods that may be difficult for health care personnel to use in practice (Mackay & Millard, 1999). Therefore, more qualitative research needs to be conducted to add new perspectives to this field of study.

Logistics is increasingly recognized as a way to deliver health care more effectively, coordinate multiple services, and develop a more patient-centered care at a lower cost (Bamford, Thornto & Bamford, 2009). The quality of patient care is greatly affected by the planning and coordination of administering the correct treatment to each patient, which, if managed properly may result in increased patient throughput. Thus, more patients can be treated by
the same amount or fewer resources. Essentially, it is of utmost importance to get “the right patient, the right equipment, the right health care worker to the right place at the right time for the right treatment to be carried out in the right way” (Bamford et al., 2009, p.141). In line with this, lean techniques have started to appear within health care management theory as a means to generate more synchronized services, since waste reduction and some degree of standardization may be helpful when managing the rather unpredictable demand of health care services (Villa et al., 2009; Womack & Jones, 2003).

1.1 Background

Discussions about patient safety in Sweden were intensified in the 1990’s, however, it was not until 2008 when research and development on the matter was truly initiated (Läkartidningen, 2012). Since then, strong national efforts have been made to enhance patient safety and bring attention to health care induced injuries that affect the quality of health care provided (Sveriges Kommuner och Landsting, 2014). The majority of health care induced injuries, approximately 35%, include various infections incurred from medical institutions. Thus, through a patient’s perspective, ‘health care associated infections are infections acquired in the hospital while receiving treatment of other conditions’ (Polin, Denson & Brady, 2012, p.1104). Moreover, health professionals may also acquire such infections as a result of their chosen professions. Health care associated infections (HAIs) occur when microorganisms are transmitted either by contamination from other individuals, directly via hands or indirectly through infected objects or surfaces located nearby patients, or from the patients’ own bodies (Sveriges Kommuner och Landsting, 2014). Furthermore, they may have the ability to survive in hospital environments for several weeks, as a result of their increased resistance towards several antibiotics (Dancer, 2011). Examples of such microbes are for instance meticillin-resistant Staphylococcus aureus (MRSA) and vancomycin-resistant enterococci (VRE). They have the ability to cause HAIs such as abscess, infections in existing wounds, skin infections and urinary tract infections just to name a few (Dancer, 2011).

The current HAI rate in Sweden has, despite great national efforts, not seen a significant reduction during the last four years (Sveriges Kommuner och Landsting, 2014). In 2008, the infection rate was at 11% with a target to half this rate by 2009, however this goal is yet to be achieved. Thus, the present rate of approximately 9% on average for Swedish hospitals means that about every tenth patient faces the risk of contracting an infection (Vårdförbundet, 2014). Therefore, diminishing the existence of HAIs in Sweden is an urgent matter as it contradicts the goal of health care providers to cure their patients; additionally increasing the patients’ length of stay has proven to be highly costly. Figures show that Swedish patients spend an extra 750 000 days per year in medical institutions at a cost of 6,5 billion SEK (Swedish Krona) as a result of these obtained infections (Sveriges Kommuner och Landsting, 2014). For the future, another urgent matter is the expected increase in resistance towards the contemporary antibiotics (Wright, 2013). This concern exerts even more pressure on hospitals to reduce HAIs in order to minimize the frequent use of such drugs (Sveriges Kommuner och Landsting, 2014).

As a consequence of the longer treatment periods in hospitals, there is a general care place shortage which diminishes a medical institutions’ ability to provide high quality health care
for the population. Recently, Sweden has found itself among one of the lower ranking countries in the Organization for Economic Cooperation and Development (OECD) in terms of care places per 1000 inhabitants, which is noted as extremely low for such an otherwise developed nation (Läkartidningen, 2010). According to Sveriges Kommuner och Landsting (2014), new solutions are needed to counteract the shortage of care places. One important element that affects the shortage of care places is the inaccessibility of hospital beds. Therefore, an efficient circulation of hospital beds and rigorous handling and cleaning of beds is critical in increasing the number of care places and improving hygiene standards (Läkartidningen, 2010). An attempt to confront this issue internationally has been the introduction of various automatic bed disinfection systems, although such solutions are not yet highly prevalent in Swedish health care (Anell, Glenngard & Merkur, 2012). Mechanical cleaning procedures are implemented with the aim to both standardize processes and guarantee a sterile environment that meets hospital standards and presumably reduces the transmissions of HAIs (Hopman, Nillesen, de Both, Teerenstra, Hulscher & Voss, 2015).

1.2 Problem Specification

The relatively high HAI rate in Sweden has serious consequences for patient safety, which not only prolongs care time and produces higher operating costs but also contributes to the mortality rate at hospitals (Läkartidningen, 2006). According to Svensk Förening för Vårdhygien (SFVH) (2012), the patient zone consisting of both hospital beds and ward equipment is a high-risk area for infections to spread. Thus, clinical guidelines and hygiene standards are necessary preventive actions to combat this issue as they lead health professionals to practice more standardized and reliable cleaning procedures.

On the one hand, a decentralized manual bed cleaning procedure performed separately at each department of a hospital has its benefits, as it requires less initial investment and minimizes the traffic within the ward due to limited transportation of hospital beds (SINTEF, 2012). Nonetheless, it also imposes risks of manual handling injuries for health care personnel, detracts valuable time from patient care and is also subject to human error and the possibility that hospital beds are not cleaned sufficiently (Winkelmann, Flessa, Leisten and Kramer, 2008). Such factors raise the interest of implementing a centralized mechanical cleaning procedure, which means that all beds are transported to and cleaned at a designated location of a hospital. The expected outcome of such a procedure is to eliminate the cleaning of beds by health professionals entirely, in order to spend more time treating patients more attentively as well as assure a clinical cleaning of the beds (Winkelmann et al., 2008). However, there are challenges that will need to be confronted in this case as well. For example, the allocation of sufficient and optimally located space necessary for a bed disinfection system, as well as the major financial investment required, not to mention the struggle of configuring the logistics behind the efficient transportation of hospital beds.

Therefore, due to the scarcity of mechanical bed cleaning procedures in Swedish hospitals, it is of academic relevance to explore the potential benefits of introducing a central automatic bed disinfection system at a hospital not currently employing such a technological solution. Furthermore, a proposal of how the logistics behind such a change could be optimized may help to further the theoretical advancement of this field.
1.3 Purpose

The purpose of this study is to explore how a central automatic bed disinfection system could be implemented at a hospital, and to investigate if this would improve the patient safety by minimizing the HAIs while enhancing the working environment for health professionals. Specifically, this explorative study will be carried out at Länssjukhuset Ryhov in Jönköping, Sweden.

1.4 Research Questions

In order to fulfill the purpose of this study, the following research questions need to be explored. When referring to quality, this will primarily be measured against national cleaning guidelines since these are acceptable practices to follow in Swedish health care. Furthermore, specifying the advantages and disadvantages are important for the decision of implementing a centralized mechanical cleaning procedure, thus it is a precursor for the third research question.

RQ 1: How is the current manual bed cleaning procedure undertaken at the explored hospital and does it imply a qualitative manner of cleaning?

RQ 2: What are the advantages and disadvantages of implementing a central automatic bed disinfection system?

RQ 3: How would a transition from a decentralized to a centralized bed cleaning procedure affect the bed management of the explored hospital, in order to conform to the changes associated with implementing a central automatic bed disinfection system?

1.5 Delimitations

First, the thesis is primarily focused on Länssjukhuset Ryhov, which is a middle-sized acute hospital in Sweden. Due to the unique configuration of hospitals as an entity, problems that arise within the areas of logistics and bed management are exclusive. However, general problems in these areas still exist and are experienced by all medical institutions. Thus, the authors do not intend to generalize this specific case, however the findings could still prove to be of relevance to other parties of interest. Furthermore, the research focuses entirely on one specific product, namely the automatic bed and mattress disinfection system from SEMI-STAAL. Hence, applying the outcome to other types of automatic bed disinfection systems or other industries would prove difficult. Due to the time frame, the authors will only focus on certain chosen departments within Länssjukhuset Ryhov instead of including the entire facility. Additionally, financial considerations have not been central to this research, thus the economic aspects of implementing an automatic bed disinfection system will not be explored in detail.
1.6 Disposition

1. Introduction
This chapter presents the overall research topic with background information concerning challenges within health care as well as a problem specification, purpose and research questions that together determine the course of this thesis.

2. Theoretical Framework
This chapter presents theories on health care logistics, lean and agile health care and process mapping. This theory will be used as a means to perform the mapping of the current bed cleaning process and analyzing the empirical findings.

3. Methodology
This chapter describes how this qualitative study is conducted, and provides the reader with an idea of the motivation for the chosen method. An examination of the trustworthiness of the research is also stated.

4. Empirical Findings
This chapter presents the case study, Länsjukhuset Ryhov, and information concerning their current bed cleaning process as well as contents collected from interviews and observations. Also, a precedent hospital is introduced that strengthens the analysis.

5. Analysis
This chapter analyzes the empirical findings in combination with the theories presented in the theoretical framework. First, the current state is analyzed and consequently a prospective state will be developed.

6. Conclusion
This chapter reflects back on the purpose of the research and summarizes the main conclusions drawn from the analysis.

7. Discussion
This final chapter discusses the theoretical, managerial, and practical contributions of the thesis as well as opportunities for future research.
2 Theoretical Framework

This chapter will present the theoretical framework used in this thesis. Academic literature in the field of logistics, lean, agile, business process reengineering, process mapping and their relevance for health care services will be discussed in-depth. To conclude the theoretical framework, a working conceptual model will illustrate the combination of the chosen theories and will provide a lens through which the data can be subsequently analyzed.

2.1 Health Care Logistics

Hospitals are large, complex institutions that comprise of a great variety of departments, occupational groups and different services, which all need to be aligned in order to fulfill the required service and provide as great patient care as possible (Villa et al., 2009). The patient flow is dependent on various professional groups and services that are either directly or indirectly involved in the patient treatment. As such, many parallel logistics systems and flows maintain the patient services. Traditionally a horizontal, departmental view is taken by hospitals when resolving logistics issues, which often disregards the parallel services that also contribute to the value chain (Mayfield, 2009). As observed in literature, many hospitals lack a holistic and vertical view of the entire hospital logistics system, which has resulted in sub-optimization of the system (Mayfield, 2009; Pan & Pokharel, 2007).

In this thesis, logistics is defined as “[…]that part of supply chain management that plans, implements, and controls the efficient, effective forward and reverses flow and storage of goods, services and related information between the point of origin and the point of consumption in order to meet customers' requirements” (Council of Supply Chain Management Professionals, 2015). Logistics is found in all types of organizations and is critical for any organization’s competitive advantage (Pan & Pokharel, 2007). Accordingly, as much as 30-46 % of hospitals’ aggregate expenditure is logistics related. Henceforth, there is great potential of using logistics more efficiently (Poulin, 2003).

Logistics is used for several purposes in hospitals, however, its prime attention is placed on the direct services for patients. Thus, the majority of health care institutions are moving towards a patient-oriented care (Villa et al., 2009). The main logistics flow at hospitals is the patient flow, supported by and dependent on secondary flows. These are for instance employee, resource and information flows among others, either directly or indirectly involved with the patient.

The hospital logistics system consists of well-defined sequence of processes, since they vary considerably from occasion to occasion (Pan & Pokharel, 2007). Normally, even similar groups of patients experience dissimilar patient journeys since every patient needs an individual treatment. Nevertheless, every patient treatment has to function optimally with the correct allocation and sequence of processes, desirably only value-adding ones. Through a process-view, health care practitioners may illustrate the logistics system in a more holistic manner, however such a process-view is yet rare within the health care industry (Pan & Pokharel, 2007).
Some factors make health care logistics management more complex than in other industries. For instance, it is difficult to measure the value of the service and the customer satisfaction, as well as predicting the demand for services (Porter, 2010). Furthermore, this becomes even more problematic as the term customer is very ambiguous in this setting. Hospitals commonly perceive not only the patient itself, but also related family members following the patient, caregivers, decision-makers and the public as customers (Buttell, Hendler & Daley, 2008). Further, the patients themselves are the “product” in the patient flow, meaning that the customers experience the whole value chain themselves, which is why service throughout the whole value chain is important. Due to the uniqueness of each treatment, the end product is impossible to foresee. In addition, the customers usually demand the service because of an urgent need because of illness and non-desirable events, and not because of a personal desire for the service (Berry & Bendapudi, 2007). Therefore, it is difficult to measure the final satisfaction and the experienced value of the service (Porter, 2010).

Dealing with the unpredictable demand in patient services is an inescapable issue for health care providers, since the rate of incoming patients, the length of stay, as well as the need for resources are impossible to control or schedule in advance (Pan & Pokharel, 2007). These factors exert even more pressures on the health care system to provide a holistic view over the organization and to rely on sound logistic systems that can provide effective workflows and handle the variability and complexity of demand (de Vries & Huijsman, 2011).

Moreover, health care institutions are highly knowledge and information-intensive, meaning that they rely greatly on technology and Information Technology (IT), even more so in the future (Lin & Stead, 2009). Technology is a self-evident tool to help employees carry out tasks in an easier and more automated way, as well as it aims to achieve higher organizational efficiencies. However, the degree of automated operations in health care is limited due to the mentioned high variability and unpredictable demands (de Vries & Huijsman, 2011). IT is already used extensively within health care since many daily routines are reliant on various IT-systems and other patient diagnostics for safe treatments (Lin & Stead, 2009). Evidently, technology and IT are definitely not lacking within health care services, still, most research is concentrated on improvements directly aimed at the patient treatment. However, how technology and IT can drive improvements in other areas of health care logistics is much less explored.

2.1.1 Bed Management

One supportive flow that largely affects the patient throughput in hospitals is the allocation and flow of hospital beds (Winkelman et al., 2008). Overcrowding in hospital departments is an acute problem worldwide and bed management needs to be enforced to combat this issue (Proudlove, Gordon & Boaden, 2003). Thus, hospital managers must continuously match and coordinate the supply and demand of beds so that a sufficient number is available to meet the highly volatile demand from patients (Winkelman et al., 2008). Since the length of stay and turnover of beds are highly variable and dependent on random events,
managers need proper forecasts, and up-to-date information about patient admittances and discharges.

Essentially, excess demand for beds leads to additional waiting time and stress that spills over on other departments and patients risk not receiving the care they require (Gorunescu, McClean & Millard, 2002). In turn, excess supply of beds is seen as a waste of valuable resources. Maintaining a stock of hospital beds is useful when being responsive to the highly volatile demand in order to buffer against acute in-patients and avoid inefficiencies related to mismatches in supply and demand of beds. An efficient bed flow facilitates patient throughput, shortens waiting times, and enables early detection of bed blockages (Mackay & Millard, 1999).

Bed management can be facilitated by the use of technology to control and coordinate the flow of hospital beds (Kumar, Swanson & Tran, 2008). For instance, Radio-Frequency Identification (RFID) technology has the potential to track beds efficiently to enable a smoother flow. RFID tags are electronic chips inserted in the product of choice, and serves as a tool to track the location of the bed. Hence, relevant and real-time information can be obtained from the system, and the scheduling and availability of beds will be based on more accurate information, which will reduce miscommunications (Tzeng, Chen & Pai, 2008). Such a system is costly and usually needs a business reengineering project to be fully integrated in the organization, but is easy to use in practice. Until recently, RFID has been used in other industries but its potential is becoming increasingly recognized within health care.

One discussion within bed management is whether to keep a decentralized or centralized bed reprocessing, although comprehensive research on this subject seems to have been inadequate (Winkelmann et al., 2008). Bed reprocessing comprises of activities such as cleaning, transportation and staffing needed to provide a clean, disinfected bed for every new patient admittance. Decentralized reprocessing takes place when a bed is vacated at the ward and is part of the staffs’ daily working procedures. A cost-analysis study in Germany concluded that from a cost perspective, decentralized bed reprocessing was the more cost-effective choice (Winkelmann et al., 2008).

Centralized cleaning can be either manual or mechanical in the form of a machine and takes place at a dedicated place at the hospital (Winkelmann et al., 2008). The latter option necessitates higher investment and maintenance costs, more transportation of beds and more time for bed reprocessing. However, it is believed to cause less physical burden for personnel. Based on the results from the German study, the cost of personnel was observed as the biggest cost factor for both decentralized and centralized cleaning, regardless of which occupational group that conducted the chore. However, this cost was two- to threefold higher for the centralized reprocessing. A suggestion was hence that the least costly personnel should take care of bed reprocessing (Winkelmann et al., 2008).

2.1.2 Manual versus Mechanical Cleaning

A manual bed cleaning procedure is normally conducted by a nurse or an assistant nurse in a health care setting where the use of washcloths, water, and detergents are combined. The
objective is to wipe off any visible dirt or stains from the hospital beds after a patient is discharged (Winkelmann et al., 2008). Nevertheless, manual-handling activities normally require individuals to either lift, lower, carry or move objects, which usually leads to associate injuries (Retsas & Pinikahana, 2000). Health professionals such as nurses experience frequent back and shoulder injuries due to their chosen professions, and such injuries are still highly common (Owen, Keene & Olson, 2002). It is indeed recognized that nurses often move heavy objects from awkward positions such as bending over or underneath beds while their backs are flexed in often uncomfortable manners (Retsas & Pinikahana, 2000). Nonetheless, several attempts have been made in terms of prevention programs for nurses and other employees to reduce manual handling injuries, however, extensive education and training have had little impact on the problem at hand (Owen et al. 2002).

A mechanical bed cleaning procedure on the other hand, is usually performed by designated personnel in charge of the bed cleaning. Moreover, it generally entails the use of an automatic bed disinfection system that together with detergents in a washing cycle decontaminates hospital beds (Winkelmann et al., 2008). In order for electrical beds to be mechanically disinfected, they need to possess certain characteristics. Specifically, all electrical equipment and components require solid encapsulations that resist dust and water ingress (Glamox, 2015). Encapsulations are rated against an IP (Ingress Protection) scale for dust protection from 1-6 and against fluids from 1-7. The higher the number, the more protection is provided. As an example, IP66 that is usually the requirement for mechanical treatment implies that the first number of the marking has the highest degree of protection towards dust, and the second number has the second highest ingress protection towards fluids.

Recently, a study was conducted in the Netherlands comparing mechanical versus manual cleaning of hospital beds and their accompanying mattresses (Hopman et al., 2015). More specifically, the study was developed to compare the quality of manual cleaning with the quality of mechanical cleaning under routine conditions. Meaning that best practice methods were designed for both cleaning techniques. Manual cleaning was improved through extensive training of domestic service personnel alongside instructions written down in a cleaning protocol. The mechanical cleaning on the other hand involved a bed washing system with pre specified instructions for use that were conveyed to the cleaning personnel. Furthermore, the study went through rigorous microbiological evaluations where contamination levels were assessed before and after respective cleaning.

The results demonstrated a significant reduction of bacterial counts after a mechanical cleaning compared to a manual cleaning, for which the difference in contamination levels was not as significant before and after cleaning was conducted (Hopman et al., 2015). Furthermore, visual observations of the manual cleaning were performed and it was confirmed that the hospital beds were cleaned in conformity with the cleaning protocol. However, it is worth mentioning that the microorganisms that give rise to HAIs are in fact invisible to the naked eye. Therefore, visual assessments of cleanliness are proven insufficient due to them being based on subjective judgments by each individual performing them (Dancer, 2009).

As the study suggests, it is possible to enhance existing manual cleaning procedures with
detailed protocols and comprehensive training and in turn improve the outcome of the cleaning (Hopman et al., 2015). However, the results from the study still verify that mechanical cleaning provides less fluctuations in cleaning quality and demonstrates consistently lower contamination levels than manual cleaning, since the amount of bacteria and potential transmissions of them are significantly reduced.

2.2 Lean Thinking

Lean is a management philosophy that has been well discussed in literature previously, primarily for its use in the manufacturing industry (Plsek, 2013; Weinstock, 2008). The concept originates from process reengineering methodologies and is based on the Toyota Production System (TPS), developed in Japan between 1948 and 1975. Initially, the aim was to merge mass production systems with small-batch production systems to achieve efficiencies (Plsek, 2013; Waring & Bishop, 2010).

Lean activities seek to standardize processes and capture best practices in order to coordinate the various flows in the value stream efficiently (Plsek, 2013). Thus, lean methodologies should not be seen as an occasional tool to fix organizational problems, but as a new cultural mind-set (Fillingham, 2007). Ultimately, it is not only about technical solutions but rather an effective leadership that supports and facilitates learning, creates the right environment for change and distributes lean thinking through the whole organization (Plsek, 2013; Weinstock, 2008).

A revised concept of lean was later declared in the book “Lean Thinking”, which took the philosophy to a new level of thought and proposed the applicability of lean to other industries (Womack & Jones, 1996). However, lean methods have been much more common within the manufacturing industry and it is only recently that it has been implemented in other industries, such as in the service industry (Portioli-Staudacher, 2012). Service industries that previously lagged behind the manufacturing sector are now growing intensively in developed nations. Thus, new means to spur growth, increase efficiencies and provide more competitive services are required. The most predominant use of lean has been seen within financial services and only recently, the philosophy has been more recognized within the health care industry as well. Nevertheless, implementations of lean methods are still rare in this industry since they are more often implemented for high volume and low variability processes. Furthermore, service organizations require frequent interactions with customers, flexibility to changes in demands needs to be accounted for (Portioli-Staudacher, 2012).

Lean techniques have been popularly used to eliminate waste and add value through the reconfiguring of processes to develop a smooth, streamlined flow (Womack & Jones, 2003; Weinstock, 2008). Hence, all wasteful activities (Mudas) can be referred to as non-value adding (NVA) operations that should either be reduced or even eliminated. Examples of such activities could be excessive waiting times and redundant handling of products or services offered (Hines & Rich, 1997). On the other hand, activities that are value adding (VA) should be encouraged and used as a strategic advantage against competitors as well as bringing value to the final customer (Mariott, Garza-Reyes, Soriano-Meier, & Antony,
Nevertheless, there are still some activities that do not directly contribute with or add value to a product or a service but are still necessary for the existing procedures to function; such operations are referred to as necessary non-value adding activities (NNVA). One example might be walking long distances in order to gather the proper materials required for conducting a particular procedure (Hines & Rich, 1997).

2.2.1 Lean Health Care

TPS contain seven types of waste (Mudas) that can be modified and applied within health care as well (Jimmerson, 2009). Thus, the seven wastes in health care are referred to as: confusion, motion/conveyance, waiting, overprocessing, inventory, defects and overproduction (Visich, Wicks & Zalila, 2010). For instance, confusion might erupt when information or instructions for conducting various processes remain unclear. Motion redundancy occurs when for example necessary items needed to perform a procedure are not close at hand. Delays in health care can cause waste in terms of time spent doing nothing of value, such as waiting for a physician’s order to be given. Using a mutual form of IT software across departments to record patient history eliminates redundant work or overprocessing, and in turn creates freed up time for health professionals to focus more on the actual treatment of patients (Jimmerson, 2009).

Lean health care has been increasingly discussed as a means to reform health care institutions (de Souza & Pidd, 2011; Waring & Bishop, 2010). For instance, standardization and re-regulation of clinical work have been increasingly observed (Harrison, 2002; Timmermans & Berg, 2003) as well as the reduction of professional boundaries and provision of more patient-centered services (Martin, Currie & Finn, 2009). Especially in a service organization such as health care, the ways of working are necessarily not a result of deliberate strategies but comes from traditions, routines and established hierarchical structures, which are difficult to change. However, lean methodologies are not meant to reduce the professionals’ power or interfere with patient care, but rather it is practiced to do more for patients with fewer resources (Weinstock, 2008).

Numerous studies have shown the opportunities of implementing lean methodologies in health care to improve patient care (Waring & Bishop, 2010; Fillingham, 2007; Joosten, Bongers & Janssen, 2009). Simultaneously, other studies have shown obstacles of implementation, such as lack of supportive leadership, no organizational readiness, and no availability of communication systems and resources. There is also a high risk of resistance from working professionals whom fret using manufacturing techniques in patient care as well as they may experience a loss of their authority and personal skills (Radnor & Boaden, 2008; Waring & Bishop, 2010; de Souza & Pidd, 2011).

Since health care institutions’ main goal is to provide good care for patients, opponents to lean are concerned about losing the human touch and treat patients as a piece of material (de Souza & Pidd, 2011; Radnor & Walley, 2008). However, some researchers believe that the reduction of NVA activities in health care are mostly coupled with administrative activities, which would even give clinicians’ additional time for patient care. The idea is not that all patients should be treated identically, but that a holistic view of parallel patient
pathways should be implemented in order to consider the interactions between all flows and create synergies (de Souza & Pidd, 2011).

Furthermore, standardized work is by some clinicians believed to lessen the flexibility that is needed in patient care (de Souza & Pidd, 2011). However, it has been observed that standardization leads to an increased clarity of job processes, which in turn allows for variations from the standard to be easily detected and errors prevented in time. Arguably, lean is not translated to health care without difficulties and it must be adapted to the organizational needs (Radnor & Walley, 2008). Similarly, implementing a process-based approach in the service sector needs special caution, time, and resources. Reorganization of occupational and departmental boundaries is required, and such reshaping of health care may be helpful to improve the overall service (Waring & Bishop, 2010).

Thus, the success of lean implementation rests on the ability for health care professionals to manage and integrate complex change processes over various departments (Mazzocato, Savage, Brommels, Aronsson & Thor, 2010). Further, an aim to reduce patient waiting times and enable a faster room turnover is required (Weinstock, 2008). Therefore, a holistic and system-wide approach is needed, however it may be problematic as hospitals are usually made up of departmental and occupational silos (Fillingham, 2007). That is why it is especially difficult to detect error and causes of waste.

2.3 Leagile Health Care

While a lean strategy is advantageous in environments with predictable demands, longer life cycles and low variability, it may not always work beneficially by itself in a highly volatile hospital setting (Rahimnia & Moghadasian, 2010). Agility in contrast, has in manufacturing settings proven to be an advantageous application in volatile, high variety circumstances. Hence, its applicability to health care services seems to be interesting to explore, however, the use of agility in services and particular in health care has been rare (Aronsson, Abrahamsson & Spens 2011).

Due to the high degree of variability in health care services, such as varying degrees of treatment complexities and durations of care, complete standardization of processes is not possible (Aronsson et al., 2011). Hence, it is challenging to integrate the various parallel value streams and their subsequent personnel in a joint process. Thus, a strategy in order to cope with the uncertainties, the lack of an interactive way of operating as well as the relatively small and varying volumes of services, all raise the need for more agile processes. An agile organization responds quickly to changes in demand and uses proactive innovation to customize demands. In effect, a hospital’s supply chain should involve both lean and agile process strategies in order to be cost-efficient and quality focused, as well as flexible and responsive to the volatile demand. Such a hybrid approach is known as “leagility” and consists of the appropriate use of both lean and agile strategies when they are most suitable (Aronsson et al., 2011).

In many cases, it is found that lean strategies are more suitable “upstream” in the value chain, when demand is planned based on forecasts, and it is used to avoid queues by hold-
ing stock (Rahimnia & Moghadasian, 2010). The agile processes are suitable “downstream” in the value chain when actual demand is identified and are used to improve the flexibility capacity. These streams are separated by the decoupling point, which is the point when the demand of a product or service is connected to a specific customer order. The location of this point depends on the certain setting and when lean and agile processes are most suitable (Rahimnia & Moghadasian, 2010). In health care, a fixed decoupling point can be difficult to determine due to the patient being part of the entire service, since each service differs greatly (Aronsson et al., 2011). For instance, the combination of lean and agile strategies should be adapted to each specific customer or patient segment in a way that parallel patient flows do not interfere with one another. A correct use of a leagile strategy can hence reach benefits through standardization as well as it allows for high assortment variability. This would provide a seamless value stream in health care, improve patient throughput and flexibility, as well as create cost-efficient processes. Furthermore, economies of scale can be reached as an outcome of the integrated process efforts (Aronsson et al., 2011).

2.4 Business Process Reengineering

Business processes can be defined as series of events composed to develop a product or service from one step of completion to another (Hunt, 1996). In other words, they illustrate how firms operate and therefore have a significant impact on organizational performance (Van Looy, De Bocker, Poels & Snoeck, 2013). Moreover, a business process can be seen as a contributor to the entire value chain, since each step should enhance value to the preceding step in the production and distribution of a product or service (Hunt, 1996). Every process should also have an assigned process owner that controls the planning, ensures that the right work is performed, communicates to all involved parties, and certifies that quality standards and goals are met (Harmon, 2007).

Business Process Reengineering (BPR) was popularly practiced from the early 1990’s as a business management strategy that challenged managers to think differently (Stoddard, 2013). Radical changes were desired in order to achieve extensive improvements in business performance. When implementing BPR, some business processes need to be obliterated and reengineered from start to achieve improvements of magnitude. BPR separates itself from other change programs in that a holistic and cross-functional view over the organization is taken. It stresses a fundamental rethinking of the business, intends to break down functional silos and improve process efficiency, service, cost quality and innovation progress (Stoddard, 2013; Gunasekaran & Nath, 1997). Although an abundance of BPR studies are focused on the manufacturing and engineering industry, the method is as applicable in other industries, such as service-organizations (Earl, Jeffrey, Sampler & Short, 1995). However, BPR is very time-consuming which is why some organizations, regardless of the industry, are still hesitant to go through the entire process (Stoddard, 2013).

Motiwalla and Thompson (2012) recommend the following steps to undertake a successful BPR. Initially, organization goals and wanted outcomes need to be identified. Second, current ‘as is’ processes should be described and studied in order to understand problems and concerns of each process. Next, the processes are reengineered into ‘to be” processes that
should fit the desired goals. Ultimately, processes should be tested and implemented and continuously re-evaluated for further improvements.

2.5 Process Mapping

To effectively examine an organization’s business processes a management tool called process mapping can be used to either optimize existing processes, or assist in the creation and implementation of an entirely new process structure through the use of a process map (Hunt, 1996).

2.5.1 Detailed Mapping

Process activity mapping (PAM) is one of the seven value stream mapping tools used to detect VA and NVA activities that occur in an organization’s business processes (Hines & Rich, 1997). PAM has its origins in industrial engineering and is particularly useful for detecting waste in terms of waiting time, excessive transportation, inappropriate processing and unnecessary motions at micro level of a firm (Hines, Rich, Bicheno, Brunt & Taylor, 1998). This is in contrast to the other value stream mapping tools depicted in table 1, which do not display as high of a correlation with such particular types of waste.

Table 1. The Seven Value Stream Mapping Tools (Hines & Rich, 1997)

<table>
<thead>
<tr>
<th>Wastes/structure</th>
<th>Process activity mapping</th>
<th>Supply chain response matrix</th>
<th>Production variety funnel</th>
<th>Quality filtering mapping</th>
<th>Demand amplification mapping</th>
<th>Decision point analysis</th>
<th>Physical Structure (a) volume (b) value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overproduction</td>
<td>L</td>
<td>M</td>
<td>L</td>
<td>M</td>
<td>M</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Waiting</td>
<td>H</td>
<td>H</td>
<td>L</td>
<td>M</td>
<td>M</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transportation</td>
<td>H</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inappropriate processing</td>
<td>H</td>
<td>M</td>
<td>L</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unnecessary inventory</td>
<td>M</td>
<td>H</td>
<td>M</td>
<td>H</td>
<td>M</td>
<td>L</td>
<td></td>
</tr>
<tr>
<td>Unnecessary motion</td>
<td>H</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Defects</td>
<td>L</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall structure</td>
<td>L</td>
<td>L</td>
<td>M</td>
<td>L</td>
<td>H</td>
<td>M</td>
<td>H</td>
</tr>
</tbody>
</table>

Notes: H=High correlation and usefulness
M=Medium correlation and usefulness
L=Low correlation and usefulness

Therefore, the purpose of PAM is to capture the inputs and outputs of every step in a process or a sub-process of a firm (Hines & Rich, 1997). PAM is essentially a table where every activity is categorized in one of the assigned columns (Hines & Taylor, 2000). A few simple steps need to be followed in order to conduct PAM. First, an initial analysis of the
process in question needs to be conducted (Jones, Hines & Rich, 1997). Thereafter a more
detailed reporting of all the inputs required during each step is formalized, which results in
a PAM map for the considered process (Hines & Rich, 1997). When filling out the columns
of the PAM map, each step of the process should be assigned a number, an activity, and a
flow. Furthermore, areas where the activities occur, the distances moved, time spent and
people involved in each step should be documented as well (Jones et al., 1997). There are
four types of flows that have been identified by Hines and Taylor (2000):

1. Operation (O): essentially all value adding activities required to conduct a process.
2. Transportation (T): all movements around a facility or between sites involved in a
   process.
3. Inspection (I): various checks of quality or quantity of a product or information
   provided during an operation.
4. Delay (or storage) (D): are all instances where there is no activity happening. In
   other words, where a product or information is waiting to be of use.

Moreover, when information flows are included in a process it is useful to add another cat-
egory called communication (C). This category contains various manners in which infor-
mation is transmitted within a process (Hines & Taylor, 2000). The finished map can later
on be used as a basis for further examination and action planning for process reengineering
(Hines & Rich, 1997).

Headings used in a processes activity map (Hines & Taylor, 2000).

<table>
<thead>
<tr>
<th>Number</th>
<th>Activity</th>
<th>Flow</th>
<th>Area</th>
<th>Distance (meters)</th>
<th>Time (minutes)</th>
<th>People</th>
<th>Comments</th>
</tr>
</thead>
</table>

2.6 **Hygiene Standards and Working Environment**

2.6.1 **Cleaning Guidelines**

Clinical guidelines have increasingly become a natural part of medical practice at hospitals
around the world since they provide reliable instructions to follow when dealing with pa-
tient care. Moreover, formally written guidelines are viewed as tools for making the treat-
ment of patients more standardized and efficient, in order to narrow the gap between how
health professionals perform and what scientific evidence actually supports (Woolf, Grol,
Hutchinson, Eccles & Grimshaw, 1999).

Health care institutions in Sweden are no different, thus the Swedish institution known as
SFVH formulated national guidelines for the cleaning of health care facilities in 2012 as an
attempt to provide optional basal hygiene standards (Svensk Förening för Vårdhygien,
2012). According to the health care law constituted in 2006, medical organizations are
obliged to offer excellent hygiene standards. Sweden applies Nordic cleaning standards,
which explain appropriate systems for cleaning and why these standards are needed. The
providers of health care organizations are themselves responsible to take the required
measures. In order to reduce infections, health care personnel must possess sufficient knowledge about various infections and viruses. Moreover, monitoring and testing are necessary to evaluate current cleaning procedures in order to improve the current cleaning rituals. At the minimum, visual controls after cleaning should be part of the procedure to ensure that the area is visually disinfected.

Moreover, in-depth controls such as checks with UV-lights and other instrumental tools should be used regularly in the cleaning routine to ensure a good quality (Svensk Förening för Vårdhygien, 2012). Health care personnel responsible for the cleaning should also possess appropriate education and training before practicing. According to SFVH (2012), the patient wards, including the beds and all other equipment near the patient zone, are seen as a high-risk area for infections and contaminations to spread. Thus, this high-risk area is of vital importance to clean flawlessly. Desirably, the personnel should have fixed local cleaning guidelines and checklists to follow. More rigorous cleaning of the wards may in fact help to decrease the rate of HAIs. When it comes to the final cleaning, which takes place whenever a patient is moved to another department, is discharged or dies, it is of critical importance to completely decontaminate the room (Svensk Förening för Vårdhygien, 2012).

2.6.2 Health Professional Working Environment

The challenges that give rise to a stressful working environment for health care personnel are mainly tied to issues such as organizational restructuring, cost constraints and the downsizing of staff (Hertting, Nilsson, Theorell, & Larsson, 2002). Therefore, it is safe to argue that nurses around the world at times experience frustration in their line of work and many decide to leave their profession as a consequence of a heavy workload, work-related stress and feelings of burnout (Sveinsdóttir, Biering & Ramel, 2006). Moreover, as discussed by Hallin and Danielson (2007), the different factors causing a stressful working environment for nurses are for instance demands from both patients and colleagues to constantly deliver high quality care. Thus, interruptions during various procedures are proven to be especially frustrating for nurses to cope with since it forces them to frequently switch between various urgent duties.

Furthermore, feelings of being inadequate and unsure of oneself are affected by a heavy workload in combination with delays, which may lead to shortcuts when performing daily procedures due to a lack of time to attain appropriate knowledge. Moreover, a heavy patient turnover and demands for constant documentation of daily work might lead to insufficient contact with patients that in turn effects the quality of care provided. Thus, solutions are needed to support nurses in their daily work to overcome such factors of stress and assist them to focus on more stimulating tasks such as the actual treatment, support and follow-up on patients (Hallin & Danielson, 2007).
2.7 Working Conceptual Model

Below is an overview of the theories incorporated in this thesis that will be used to analyze the empirical findings. The theories consist of logistics tools and philosophies together with technology, which are represented on the left side of the model. The combination of them is assumed to influence how effectively the bed management operates and, in turn, generate improvements for health care institutions. The central part of the model is thus the bed management, which can be either decentralized or centralized and manual or mechanical. The right side of the model depicts the final objective, improved health care, which is defined by the enhanced working environment for health professionals and a reduction in transmissions of HAIs. Furthermore, a consolidation of these theories is believed to provide new insights for Swedish health care providers.

Figure 1. Working Conceptual Model. Source: Authors’ own illustration.
3 Methodology

This chapter will outline how the authors conducted the research and the motivation of the chosen method will be presented. Finally, a discussion will evaluate the quality of the research in terms of trustworthiness and credibility. Furthermore, the limitations of the study will be acknowledged.

3.1 Research Philosophy

This research is based on the perceptions of a critical realist meaning that our knowledge and experiences of reality is understood through social conditioning (Easton, 2010). Furthermore, a critical realist needs to add theory such as practical and theoretical processes to research in order to reduce the risk of subjective interpretations and evaluate social phenomena objectively (Saunders, Lewis & Thornhill, 2012). As this thesis intends to explore a particular phenomenon in a social setting while at the same time adding theory, the critical realist stance appears fitting, supposing that appropriate theory is used objectively to analyze specified research questions and purpose. Furthermore, as process mapping requires the use of theory to critically analyze the empirical findings, the critical realist view becomes even more applicable to this study.

3.2 Research Approach

According to Saunders et al., (2012), three main approaches to conducting research projects exist which are deductive, inductive and abductive. A deductive approach begins with a hypothesis discovered in existing theory that is later on evaluated through appropriate data collection techniques. An abductive approach on the other hand starts out with a surprising observation where a reasonable explanation is given that is later on tested to see whether the explanation upholds (Kovács & Spens, 2005). However, in this particular research an inductive approach becomes applicable since we began with the collection of data to explore the topic of interest. This was done with an attempt to add to existing theory within lean services in health care. Moreover, this approach is considered since we wish to gain a deeper understanding of the issue at hand from the hospital’s perspective through various data collection techniques that will be analyzed and subsequently used to formulate theory. In other words, “[...] theory would follow data, rather than vice versa [...]” (Saunders et al., 2012, p.146). Furthermore, according to Blombäck (2005), elements of both deductive and inductive nature can be present in a research regardless of its choice of method. Thus, contemporary theory in this thesis is analyzed in order to guide the authors to contribute to existing theory.

3.3 Research Design

3.3.1 Method

Research design provides a general direction on how to execute the study and answer the research questions (Saunders et al., 2012). Further, the design should be deliberately chosen in order to generate a logic relationship between research questions and the data collection method (Yin, 2013). One aspect of the research design involves the choice of method. This specifically means choosing a qualitative or quantitative design, or a combination of the
two. Due to the nature of our purpose, and the inductive approach, we have chosen to investigate the research questions through the use of a qualitative study.

### 3.3.2 Nature of Research Design

The nature of a research design can be classified into three specific categories: exploratory, descriptive and explanatory. The manners in which the research questions are formulated combined with the purpose of the study are the main determinants that involve the research in one particular category (Saunders et al., 2012). Hence, while conducting an exploratory research we wish to attain a deeper understanding of a topic of interest. Moreover, the use of a descriptive research as a forerunner to the exploratory will demonstrate a clear picture of the phenomenon in question (Saunders et al., 2012). Thus, the first research question implies a descriptive purpose as it aims to map out a current process at Länssjukhuset Ryhov. Although the nature of the second and third research questions remain exploratory since they seek to find out benefits and drawbacks, as well as design a prospective logistics flow of hospital beds when implementing an automatic bed disinfection system.

### 3.3.3 Research Strategy

Various examples of research strategies exist and serve as a plan of action in order to accomplish the research project’s questions and purpose (Saunders et al., 2012). A case study research strategy is normally used in exploratory qualitative research since it explores a phenomenon within one or several real-life settings in order to produce a rich understanding of them (Saunders et al., 2012). Furthermore, the case study strategy is suitable to generate answers to questions “why” and “how”, which are the focus of our study (Yin, 2009). Moreover, a case study strategy can be further divided into single case and multiple case designs, where a single case design exemplifies for instance a unique, critical, or typical case rationale (Ellram, 1996). A ‘typical case’ rationale is normally preferred when an opportunity arises to observe and analyze a topic that few researchers have previously considered, which can be done by examining the context of an everyday situation (Saunders et al., 2012).

Thus, the choice of research questions in this thesis implies a case study strategy, more specifically a single case study with a ‘typical case’ rationale. The use of a single case might not provide strong arguments to generalize, however the findings from the use of a typical case will still be compelling and informative to other interested parties (Yin, 2009). Additionally a single case study allows for a more in-depth investigation of Länssjukhuset Ryhov, how it operates, and defines its bed cleaning procedure.

However, it is worth mentioning that a single case study faces the challenge of potential misinterpretation of data compared to a multiple case study, where several experiments reveal how different real life settings affect the results of a particular topic of interest. Therefore, a higher amount of data collection and background preparation is necessary to reduce the possibility of misinterpreting the data of a single case study (Ellram, 1996). In other words, we could have chosen to conduct a multiple case study in order to produce similar or contrasting results that would be easier to generalize. However, the use of a single case study was preferred since the explored machine is relatively new on the marketplace and
there is yet a hospital in Sweden that has decided to implement it. Furthermore, the relatively high HAI rate in this country essentially motivated Länssjukhuset Ryhov to consider implementing the automatic bed disinfection system from SEMI-STAAL, since they have the financial means to invest in such a machine. Thus, the choice of conducting a single case study over a multiple one became an obvious choice due to the fact that not too many hospitals in Sweden are yet planning to make such a large investment.

Additionally, what makes this single case study even more interesting is the hospital’s location, since it is an acute hospital serving the whole Jönköping region, which makes it the top medical institution in the county. Furthermore, Länssjukhuset Ryhov is also a good typical case due to it being awarded as the best medium sized hospital in Sweden three years in a row, implying that it constantly searches for novel ways of improving its healthcare services and patient care. Additionally, the geographic proximity of the hospital combined with our initial contact with the hospital director allowed for an interesting thesis collaboration and topic to explore.

3.3.4 Time Horizon

For this research study, the time constraints and the characteristics of the study proposed a cross-sectional time horizon (Saunders et al., 2012). A cross-sectional study is generally chosen when a particular, delimited case is explored that can be perceived as a ‘snapshot’ taken at a certain time. Thus, cross-sectional studies are appropriate for single case studies, since such cases focus on a very specific setting.

3.3.5 Data Collection

Data can be obtained either by the collection of primary or secondary data, or by a mix of both (Saunders et al., 2012). An appropriate use of data collection techniques may significantly affect how relevant, accurate, and credible the empirical findings are. The secondary data used for this study consist of material collected online from company and official hospital websites. In addition, information has been collected from brochures and reports from our contacts at Länssjukhuset Ryhov, SEMI-STAAL and the Danish technical institute FORCE Technology, as can be seen in evaluation figures 2 and 3. Primary data in this thesis consist of material collected through interviews and observations listed in table 2 and table 3.

3.3.5.1 Observations

The interviews and observations were scheduled with the assistance of our contacts at Länssjukhuset Ryhov and the hospital’s head nurse who forwarded us to appropriate informants and interviewees at the clinic of interest. Thereby approval was given to make observations inside the hospital. The observations were undertaken with the aim to explore how exactly the hospital’s bed cleaning process is currently performed and by whom. In other words, the observations were assumed with the purpose to answer our first research question and also to be used as a basis for the investigation of the third research question. Since the observations were conducted before the interviews, they proved helpful to expand our knowledge of the daily activities as well as raised additional key questions for the interviews (Stuart, McCutcheon, Handfield, McLachlin & Samson, 2002). Thus, the results
from the observations guided the authors through the interviews, in which the results were further evaluated and possible misunderstandings could be averted.

Our role as complete observers led to a pure observation of the bed cleaning process (Saunders et al., 2012). Moreover, the informants were not informed of our underlying purpose nor were they aware of the various time measurements that were conducted. Thus, the participants only knew that we wished to monitor the entire bed cleaning procedure. Hence, we experienced the activity in its natural setting and were able to explore the behaviors and meanings of the informants that conducted the bed cleaning process, without interference. Observations were performed at each department of the medical clinic at Länssjukhuset Ryhov. The choice was made since this clinic involves departments with regular patient admittances and discharges as well as a major, consistent flow of patients. Since the procedure is a routine activity performed at the hospital, it is conducted similarly at every department and only a few actions differ. Thus, we believe that the findings from four departments were sufficient to find patterns and similarities through the medical clinic, and we chose to bring attention to this one only.

Since the observations at the hospital were expected to contain sensitive and confidential information, video recordings or pictures could not be taken. Thus, time sequences and notes were attentively taken for each step in the process in order to obtain information for the scheming of the PAM maps.

Table 2. List of Observations

<table>
<thead>
<tr>
<th>Place</th>
<th>Informant</th>
<th>Date</th>
<th>Duration</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ryhov</td>
<td>Assistant Nurse, Medical A</td>
<td>2015-03-27</td>
<td>16:30 min</td>
<td>Jönköping, Sweden</td>
</tr>
<tr>
<td>Ryhov</td>
<td>Assistant Nurse, Medical B</td>
<td>2015-03-16</td>
<td>14:07 min</td>
<td>Jönköping, Sweden</td>
</tr>
<tr>
<td>Ryhov</td>
<td>Assistant Nurse, Medical C</td>
<td>2015-03-18</td>
<td>12:33 min</td>
<td>Jönköping, Sweden</td>
</tr>
<tr>
<td>Ryhov</td>
<td>Assistant Nurse, Medical E</td>
<td>2015-03-18</td>
<td>13:51 min</td>
<td>Jönköping, Sweden</td>
</tr>
</tbody>
</table>

3.3.5.2 Interviews

According to Ghauri and Grønhaug (2010), the best qualitative data collection technique is interviews, since they have the ability to generate unpretentious and comprehensive findings. Thus, in order to explore the data collected through observations, semi-structured interviews were conducted to find underlying meanings, implications, and extensive answers. All interviews were conducted face-to-face to establish a level of comfort and observe visual expressions that could be explored further (Yin, 2009). The questions comprised of both open and probing questions that encouraged more expressive and extensive answers, which is more suitable for exploratory studies (Saunders et al., 2012). Some specific/closed ques-
tions were also used to obtain detailed information of the observed activity. These questions can be viewed in the interview guides attached in Appendix 6. Furthermore, ideas for the interview questions were grounded in the literature study, but adjusted to each interviewee.

An interview typically aims to establish rapport between the participants by asking appropriate, unambiguous questions that are relevant to the research questions (Saunders et al., 2012). The purpose with the interviews was to develop knowledge in an area relatively unexplored and bring forward any matters that may have been overlooked previously. The semi-structured interview, which is a mix between unstructured and structured interviews, was chosen since the research setting was still fairly unknown for the researchers and misinterpretations or assumptions could thus be avoided. Since hospitals are complex and dynamic in nature, flexibility was required in order to collect relevant data. Thus, themes and key questions were chosen and directed the entire interview in a desired way. However, the questions were adapted for each respondent to allow for further exploration of each individual case (Saunders et al., 2012).

All interviewees were contacted via email, without conveying the underlying purpose of the research. Furthermore, a few general questions were asked in order to obtain organizational information and routines to prepare for the interviews. This was conceivable because of our already established contact with the head nurse who gave approval for keeping interviews with the health professionals. Hence, consent was given. Emails were sent out to all head of departments to set up dates for interviews. All interviews were conducted directly after the observation at each department, in order to follow up with questions right after each activity. Since hospital patients were always within hearing distance it seemed appropriate to conduct the interviews in a private room. Furthermore, all interviewees had the chance to remain anonymous, since the topic involves sensitive information about cleaning standards at the hospital wards. The interviews were voice recorded with the approval of the interviewees and were subsequently transcribed and coded as preparation for the analysis.

Eight interviews were conducted at the medical clinic at Länssjukhuset Ryhov, with assistant nurses and heads or vice heads of each department. The respondents were chosen according to their profession and knowledge, first the assistant nurses that take care of the manual cleaning process on a regular basis and consequently, the head of the departments that possess the overall insight over the whole department. Eventually, similar to the observations, these interviews resulted in similar answers with only slight differences, which gave the impression that sufficient information was collected from one clinic. The assistant nurses’ response were further validated by the heads of each department.

After collecting the empirical findings from the hospital departments, we followed up with further interviews with the development manager at Länssjukhuset Ryhov as well as with their manufacturer of interest, SEMI-STAAL that has recently developed a new, one of a kind, automatic bed disinfection system. These interviews gathered data concerning the general objectives, concerns, and requirements of implementing the system, in order to explore our second and third research question. In addition, several attempts were made to
contact Hvidovre Hospital in Denmark, the only hospital that has yet implemented this specific system, for further comparisons. However, due to time constraints of the decision makers at the Danish hospital, no contact was established despite our several attempts to develop rapport via email and phone calls. Nevertheless, we consider the remaining interviews to have obtained sufficient data to answer the research questions. Especially since the manufacturer of the bed disinfection system has been directly involved in its implementation at the Danish hospital, thus possessing rich knowledge of its application. Due to the difficulties in reaching Hvidovre Hospital itself, information and experiment results from the outcome of the machine were therefore retrieved from the manufacturer. Additionally, a visit by the management at Länssjukhuset Ryhov’s was recently conducted at Hvidovre Hospital to inspect the machine in its natural setting and obtain further information to validate the previous findings.

Table 3. List of Interviews

<table>
<thead>
<tr>
<th>Name</th>
<th>Occupation</th>
<th>Date</th>
<th>Duration</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Miriam Gadmar</td>
<td>Vice Head of medical department A</td>
<td>2015-03-26</td>
<td>16:00 min</td>
<td>Ryhov Jönköping, Sweden</td>
</tr>
<tr>
<td>Assistant nurse A</td>
<td>Medical department A</td>
<td>2015-03-27</td>
<td>8:30 min</td>
<td>Ryhov Jönköping, Sweden</td>
</tr>
<tr>
<td>Carin Alm</td>
<td>Head of medical department B</td>
<td>2015-03-16</td>
<td>21:00 min</td>
<td>Ryhov, Jönköping, Sweden</td>
</tr>
<tr>
<td>Assistant nurse B</td>
<td>Medical department B</td>
<td>2015-03-16</td>
<td>12:31 min</td>
<td>Ryhov, Jönköping, Sweden</td>
</tr>
<tr>
<td>Anette Elmquist</td>
<td>Head of medical department C</td>
<td>2015-03-24</td>
<td>14:00 min</td>
<td>Ryhov, Jönköping, Sweden</td>
</tr>
<tr>
<td>Assistant nurse C</td>
<td>Medical department C</td>
<td>2015-03-18</td>
<td>10:31 min</td>
<td>Ryhov Jönköping, Sweden</td>
</tr>
<tr>
<td>Carina Ambré</td>
<td>Head of medical department E</td>
<td>2015-03-18</td>
<td>14:00 min</td>
<td>Ryhov Jönköping, Sweden</td>
</tr>
</tbody>
</table>
In addition to observations and interviews, several discussions with the development manager and technical department involved in the restructuring plans of Länssjukhuset Ryhov led to an investigation of a potential location for a bed disinfection system at the hospital. After receiving information that a future bed central would be preferably placed at level two of the hospital, we conducted further studies inside the hospital building. Assisted by maps of the hospital facilities, an overview of each floor was provided and a suitable location with the fundamental conditions to host a bed central was detected. With this location as a foundation, time and distance records were documented through walking from the entrance at various departments at the hospital to the chosen location at level 2.

The five departments were chosen according to their location at the hospital, as we strived to document the distance and time from departments spread out both close by and far away. This allocation proved to be helpful as various data were provided and through this spread, many other departments were covered as most of them lay between the investigated points. The chosen departments can be viewed in table 6, whereof three of them are the major and busiest departments at Länssjukhuset Ryhov and possess a high rate of patient turnover that relies on an efficient flow of beds. Based on time and distance records and the maps of the floor levels of the hospital, it was possible to compile prospective flow maps for the bed transportation through the Microsoft Office program Visio.

### 3.4 Qualitative Data Analysis

In case study research, data analysis is ideally carried out parallel with the data collection (Yin, 2009). Furthermore, the propositions presented in the theoretical framework provide a basis of reference for each part of the analysis. One should identify main variables, themes, and issues in the theoretical propositions and use these to explain the empirical findings. In this thesis, an inductive approach will guide the researchers through the exploration of the topic. Hence, starting with the research questions and moving forward to data collection and findings drives the development of new perspectives that will consequently be connected to theory in order to make a proper analysis, and in turn contribute to existing theory (Yin, 2009).

The first section will refer to the current state of operations at Länssjukhuset Ryhov, taking various participants and management perspectives into consideration. Consequently, the advantages and disadvantages will be identified and analyzed to expand the current
knowledge of the topic at hand and suggest solutions for prospective bed management. Furthermore, a revised version of the conceptual model that combines our theoretical framework with our findings will be suggested after a comprehensive analysis.

Yin (2009) states that transcribing data is a time-consuming process and needs to be considered several times from various angles for complete analysis. Therefore, the authors recorded each interview and transcribed and translated them directly after each meeting. After the transcription of the interview findings, the authors studied them together and summarized the most important parts in order to select important quotes and key themes. From our empirical findings, several themes were found through the use of color coding schemes in order to gather groups of answers from our various interviews (Saunders et al., 2012).

### 3.5 Qualitative Validity

Validity in research covers various procedures that intend to confirm that the outcomes of a study can be stated with confidence (Flint & Mentzer, 1997). Consequently, Lincoln and Guba (1985) argue that the validity of a qualitative research can be examined through various elements of trustworthiness. These consist of criteria such as credibility, transferability, dependability, and conformability (Lincoln & Guba, 1985). Furthermore, these four criteria are correspondingly present in Yin’s clarifications concerning qualitative validity in the form of internal validity, external validity, construct validity and reliability (Yin, 2009).

Internal validity or credibility is related to whether or not the findings portray a real-life context in an accurate manner in order to reach proper inferences from data (Ellram, 1996; Yin, 2009). The findings need to be credible and realistic since internal validity certifies if a relationship between two variables is causal (Flint & Mentzer, 1997). Moreover, the validity of the research requires a confirmation by the respondents to reinforce the credibility of the study (Shenton, 2004). While this study aims to understand and analyze data through an objective lens, the possibility of retrieving biased answers during data collection cannot be neglected (Saunders et al., 2012). During interviews, responses from interviewees risk being subjective to some extent, since they are raised from individual experiences and opinions. However, attempts to overcome such bias have been made by validating the information from each assistant nurse with the response from the heads of departments. Trustworthiness was further established by giving each respondent the possibility to verify the interview findings by reading through and commenting on transcribed summaries. The mapping of processes in several departments also ensured that issues and other aspects were not overlooked. Hence, the maps of current activities and prospective flows are assumed to give an objective view and conform to the reality of the situation.

External validity or transferability is linked to the extent to which the results of the study can be further generalized into other research settings or case studies (Lincoln & Guba, 1985; Yin, 2009). Case study research, especially the single case study, is often restricted to the observed organization and typically lacks the potential of generalization (Shenton, 2004). Therefore the authors do not aim to generalize this single case study to a larger degree, however since Länssjukhuset Ryhov is regarded to be a typical case, this information
can tap the construct of interest for other health institutions and it has the potential of being replicated in other studies.

Thereafter, dependability refers to the repeatability of the study and demonstrates that the data collection method outcome provides reliable findings (Ellram, 1996; Yin, 2009). More specifically, it is crucial that the research methods and findings are consistent throughout the explored study so it can be replicated (Flint & Mentzer, 1997). As such, we decided to thoroughly document the data collection methods so that future researchers can arrive at the same findings and conclusions by simply imitating our techniques.

The degree of conformability in a study is linked with construct validity and ascertains that the authors are neutral in their research (Lincoln & Guba, 1985; Yin, 2009). Subjectivity and bias should be avoided by ensuring that enough data is collected to provide an objective stance. In this thesis, we aim for an objective stance by incorporating empirical findings and documents from multiple sources of evidence such as several departments at Länssjukhuset Ryhov, Hvidovre Hospital, SEMI-STAAL, and supplementary documented research (Yin, 2009). Additionally, all interviewees were offered the option to remain anonymous to increase the chance of truthful answers. Therefore, the authors argue that sufficient findings, to fully understand the entirety of the topic, have been retrieved in order to achieve the desired level of objectivity. Furthermore, the information obtained from the manufacturer may create bias due to their willingness to sell their machine. However, such bias was accounted for and minimized by the incorporation of the information that Länssjukhuset Ryhov’s confirmed during its visit at Hvidovre Hospital. Thus, supporting the philosophical stance of a critical realist by making sure that the topic of interest is objectively analyzed in its natural setting. Moreover, after several observations and semi-structured interviews, the authors were able to develop an extensive knowledge into a previously unfamiliar area of research.

3.6 Limitations

This study is limited in the fact that no concrete restructuring plans have been determined by Länssjukhuset Ryhov, thus no detailed facility plans or resource conditions for the future have been developed yet. Therefore, the authors can only give suggestions for a prospective state based on the current hospital layout and the authors’ own investigations at the hospital. Hence, the authors’ can only provide important considerations that need to be devised for such a transition and examples on how the prospective bed management may appear in an optimal scenario. Due to the qualitative nature of this study and the authors’ knowledge base, own evaluations of microbiological analysis measures could not be performed at the explored hospital, since the required resources for such testing are not possessed. Furthermore, due to the uniqueness of the investigated automatic bed disinfection system, further information, and evaluations could not be collected from additional sources than the manufacturer and Hvidovre Hospital, which so far remains the only medical institution in possession of it. For further comparison, it would have been interesting to include other hospitals undergoing a similar transition. However, since such transitions are not so common for Swedish hospitals yet and this machine only exists in one medical institution, a comparative study could not be conducted.
4 Empirical Findings

This chapter presents the chosen case study with a brief organizational background along with the information gathered from observations and interviews from the participants of the research. The collected raw data is categorized according to identified themes and only the relevant findings are provided. These will shape the foundation for the analysis in the following chapter.

4.1 Länssjukhuset Ryhov

Länssjukhuset Ryhov is an acute hospital in Jönköping, Sweden, providing health care in Region Jönköping’s län (Region Jönköpings lään, 2015b). Region Jönköping’s län is responsible for the county’s health care among other public services for its 341 000 inhabitants, and is divided in three health care areas. Of these, the Jönköping area is the biggest one and Länssjukhuset Ryhov covers 149 000 of its inhabitants. It was established in 1988 and consists of 22 clinics, of which the medical department is the major one, and a total of 34 departments that together offer 500 care places. 3300 employees work at the hospital, of which most are nurses, assistant nurses and doctors. Länssjukhuset Ryhov is engaged in educational purposes around Sweden and it collaborates with several universities and high schools (Region Jönköpings Län, 2015b). With a growing population in need of care, the hospital is pressed with budget constraints and is in constant need of creating cost-efficiencies. In reaction to that, Länssjukhuset Ryhov was the first hospital in the county to employ logisticians in order to generate a more cost-efficient health care.

The hospital is hence constantly striving to improve their patient care, which for instance has been demonstrated in their honorary awards (Region Jönköpings Län, 2015a). For the third year in a row, Länssjukhuset Ryhov has been awarded as the best middle-sized hospital of the year in Sweden. Nevertheless, the hospital realizes that there is further room for improvements. Being an acute hospital, it is especially important to be prepared for unexpected increases of inpatients and to have a steady and constant flow of patients and beds that can handle excess demand (L. Ljungkvist, personal communication, 2015-03-31). In response to these requirement needs, Länssjukhuset Ryhov is presently planning a major restructuring of the hospital that will take place during the next 5 to 10 years. For instance, new buildings are planned for to expand the hospital. Some bottom line objectives are to develop and secure a better care for patients and offer an improved hospital environment, for instance through reducing HAI’s which is one of the major threats for hospitals (L. Ljungkvist, personal communication, 2015-03-31). As part of the new plans, the implementation of an automatic bed and mattress disinfection system is considered and the potential for such an implementation is herein analyzed in order to assist Länssjukhuset Ryhov with its restructuring plans. Specifically, the hospital was concerned by the bed logistics as this is seen as an urgent factor to investigate before such an implementation can be initiated.

4.1.1 Current State of Bed Management at Länssjukhuset Ryhov

All of the findings in this section are directly obtained from the observations and interviews at the medical clinic at Länssjukhuset Ryhov. Furthermore, a summary of the most relevant findings from the interviews will be provided in table 4 and discussed in the sections that follow.
4.1.1.1 Bed Cleaning Process

Länsjukhuset Ryhov is presently using a decentralized method for its hospital bed cleaning process. In other words, all beds are washed manually in the patient wards by the nurses or more commonly the assistant nurses working at the different departments of the hospital. Therefore, a cleaning room referred to as “sköljen”, containing various material for cleaning such as laundry bags, detergents, washcloths and dishwashers, can be found at each department of the hospital due to the decentralized bed cleaning method. Through the use of PAM along with observations, the authors could easily document the various activities taken place, personnel and distances involved as well as time measurements during the existing bed cleaning procedure, which can be viewed in appendix 1.

Moreover, it is worth mentioning that a patient being discharged triggers the current bed cleaning process. This information is obtained during the routine medical rounds conducted every morning in each department, where a doctor decides which patients are healthy enough to end treatment and leave the hospital. Therefore, the nurses that accompany the doctors during a medical round verbally inform the assistant nurses which hospital bed is in need of cleaning. The nurses and assistant nurses cooperate in teams of two and are responsible for specific patient wards at the department where they work. Furthermore, the bed cleaning process is typically conducted right after the patient vacates the ward and the assistant nurse can begin with the cleaning procedure. However, no written guidelines exist in the hospital on how to properly clean a hospital bed. The assistant nurses are trained on how to clean a bed during their formal education as well as with a mentor during the first couple of weeks during their employment.

The entire cleaning procedure entails not only the hospital beds, but also the accompanying bed tables and patient wardrobes. The whole process takes approximately 10-15 minutes to perform including the waiting time for the beds and mattresses to properly dry up before the bed linen can be put on. The material used in the cleaning procedure varies between different nurses and departments. Some nurses may use microfiber washcloths, while others may use paper towels or paper washcloths to wipe off the beds. Furthermore, the type of detergent might vary as well, however in case of a non-infectious bed being cleaned the use of the detergents called “Ytidesinfektion” and “Storfix” are regularly applied. Nevertheless, strict guidelines exist for which type of detergents to use when a bed is contaminated with a certain type of infection due to the previous patient occupying it. Those guidelines are normally found written down on a document in the cleaning room, “sköljen”. Moreover, the specific steps or activities taken place during the bed cleaning process differ in terms of the order in which they were performed. Thus, the assistant nurses essentially perform the same cleaning procedure, but in a different order and occasionally some activities are left out.
### Table 4. Summarized Opinions Concerning the Current Bed Cleaning Process

<table>
<thead>
<tr>
<th>Questions</th>
<th>Opinions</th>
</tr>
</thead>
<tbody>
<tr>
<td>What kind of results should be accomplished from the current bed cleaning process?</td>
<td>“It should be clean, there should not be any visible dirt or stains left on the bed” (assistant nurse Med. B, personal communication, 2015-03-16).</td>
</tr>
<tr>
<td>Does the outcome of the current bed cleaning process reach a desired level of quality?</td>
<td>“The quality level is sufficient, because I do not believe that there are any consequences like infections or so spreading because of it” (M. Gadmar, personal communication, 2015-03-26).</td>
</tr>
<tr>
<td></td>
<td>“Certain times, and hopefully a majority of the times, the cleaning process is satisfactory. However, at other times it might not be as good, due to the human factor involved” (C. Alm, personal communication, 2015-03-16).</td>
</tr>
<tr>
<td></td>
<td>“I believe that the bed cleaning process that I witness and the one I conduct myself is sufficient enough. Since we clean everything that patients might possibly come in contact with.” (assistant nurse Med. C, personal communication, 2015-03-18).</td>
</tr>
<tr>
<td></td>
<td>“I believe that it could be done better. Since we only wipe off the beds, miniscule areas and spaces cannot be reached” (assistant nurse Med. A, personal communication, 2015-03-27).</td>
</tr>
<tr>
<td>Are there any evaluations conducted concerning the quality of the current bed cleaning process?</td>
<td>“No such measurements are performed” (C. Ambré, personal communication, 2015-03-18).</td>
</tr>
<tr>
<td>Does the current bed cleaning process produce any physical side effects?</td>
<td>“The working position is not optimal when one needs to crawl down on the floor to reach underneath the bed” (A. Elmquist, personal communication, 2015-03-24).</td>
</tr>
<tr>
<td></td>
<td>“I do not believe that the working activates that require active movements are harmful. It is more the inactive type of work, for instance holding your shoulders in the same position for quite some time, which is more harmful. But just the fact that one moves and bends underneath the bed, I do not perceive this as</td>
</tr>
<tr>
<td></td>
<td>“One does feel some pain in the back and shoulders now after having worked for so long, so yes it is a bit messy to crawl underneath the bed” (assistant nurse Med. A, personal communication, 2015-03-27).</td>
</tr>
<tr>
<td></td>
<td>“It is clear that as long as one feels healthy and does not have any physical limitations, there is no danger of any negative effects from the bed cleaning process (assistant nurse Med. C, personal communication, 2015-03-18).</td>
</tr>
</tbody>
</table>
Does the current bed cleaning process become a stressful event in the every-day working environment?

“ [...] some days are quite hectic, one has barely time to sit down before something happens. Thus, in those cases when it’s hectic at the department, the act of cleaning the beds becomes stressful” (assistant nurse Med. C, personal communication, 2015-03-18).

“No, it depends on how important it is to clean, but one needs to be flexible in this line of work. I can do anything and still be interrupted” (assistant nurse Med. E, personal communication, 2015-03-18).

Outcome of the Bed Cleaning Process

The assistant nurses were initially enquired whether they understand what kind of results they should achieve from the existing bed cleaning procedure. The findings reveal that the assistant nurses’ answers remain unanimous in all four interviews. They maintain that the outcome of the bed cleaning process should be as clean as possible, meaning that there should not be any visible stains or dirt on the bed or mattress that can be detected by the naked eye.

Perceived Quality of the Bed Cleaning Process

When the assistant nurses were asked if the outcome of the current bed cleaning process reaches a desired quality level, the opinions remain split. In half of the cases the assistant nurses declare that a desired level of quality is reached. In other words, proclaiming that the existing procedure is sufficient and that there is no risk of laying in one of the cleaned hospital beds. However, the other half of the assistant nurses maintain that the current bed cleaning process could be further improved. The main reason being that one simply cannot access all the nooks and crannies of the bed, thus it cannot be completely clean.

Furthermore, the various heads of the departments were also asked to discuss their thoughts concerning the outcome of the cleaning process and whether it reaches a desired quality level. Once again, the views remain split. In half of the cases, the heads of the departments state that a desired quality level is reached. This means that the existing procedure is sufficient since the opinion remains that there are no infections spreading as a consequence of it. Although, in the remaining two cases the opinions remain different since
they stress the importance of the human factor that is constantly involved in the process. Moreover, they also state that the bed cleaning procedure could have been better if professional cleaning personnel handled it through the use of a machine that reaches all surfaces of the bed.

Additionally, the different heads of the departments were asked whether they perform any measurements on the quality of the current bed cleaning process, in terms of how well it is performed and to which extent it eliminates HAIs and other dirt on the bed. The answers proved to be unanimous; they all mentioned that no such evaluations were presently conducted.

**Perceived Working Environment of the Bed Cleaning Process**

In terms of the issue of ergonomics, the assistant nurses were asked if they perceive that the physical aspect of the manual bed cleaning process affects them in any way. The opinions once again remain split on this issue as well. For instance, half of the nurses proclaim that the procedure can hurt the back and shoulders when one needs to bend down on one’s knees to properly reach underneath the bed. On the other hand, some nurses state that the physical aspect does not affect them negatively in any way. However, they still maintain that the manual bed cleaning process does become harder if a person attains any physical limitations, such as pains in back and shoulders during their working experience.

The different heads of the departments were asked a similar question concerning the physical aspect of the manual bed cleaning process, and whether it has any effects on their staff. The findings reveal that in half of the cases the heads of the departments assure that they do not believe that it bares any negative effects. Thus, the physical aspect of the manual bed cleaning process is not considered as a big issue since static work is believed to inflict more damage than mobile. However, some heads of the departments verify that the working position is not optimal, since the nurses need to for instance clean the area around the wheels, thus the posture can become uncomfortable.

When the assistant nurses were enquired if they feel that the manual cleaning process is a stressful event in their everyday working life, the answers were unanimous in three out of four cases. Thus, the majority states that it is not unusual that one becomes interrupted when cleaning the bed at times when it is hectic at the department. One assistant nurse on the other hand stresses the fact that it is essential to be flexible in this line of work since interruptions may occur at any time during the day, not only while cleaning. However, they all maintain that the current bed cleaning process takes time away from more valuable tasks, such as the treatment of patients.

**4.1.1.2 Bed Logistics**

The following sections are based on interviews with the Development Manager at Länssjukhuset Ryhov, heads of hospital departments and records from the authors’ visit at the hospital’s culverts.

During 2014, Länssjukhuset Ryhov had a total of 32 712 discharged patients from all the hospital’s departments, which resulted in an average of 90 discharges per day (L.
Ljungkvist, personal communication, 2015-03-31). The bed occupancy rate, the intakes of patients towards the total amount of available care places, amounted to an average of 83.1%. Assuming at least every discharged patient releases an unclean bed, 90 beds at the minimum per day are in need of cleaning. The hospital has a variety of different bed types, of which most stay at their respective department. A couple of years ago, Länssjukhuset Ryhov started to purchase new electrical beds that they have introduced successively throughout the hospital. As of today, it has 685 hospital beds whereof 310 are electrical and 30 beds in stock in the cellar or in the attic. 250 of the electrical beds belong to the recent acquisition and they are certified with an IP 66 qualification.

Currently, the hospital beds belong to specific departments and should preferably always return to their specific location. Since health care personnel at the departments manually clean the beds, there is no constant transportation of beds except for when patients for various reasons are being transferred to other departments. In order to track and control the hospital beds, the head of departments maintain that every bed should be marked with a specific number and what department it belongs to. However, the observations at the medical departments showed that many of the beds still lack labels or inscriptions. Every department had different systems for tracking beds and in most cases relied on the nurses to remember displaced beds and pick them up themselves, while one department had a flow board to keep track of missing beds.

“We have no IT-system or barcodes for beds, so the regulation of beds is not excellent. The bed and mattress should be marked with our department, however, I am aware that this is not always the case and this is not an optimal situation.” (M. Gadmar, personal communication, 2015-03-26).

Länssjukhuset Ryhov has expanded greatly since its establishment and that has resulted in an overcrowded hospital with many departments sharing inadequate areas. Hence, space is a scarce resource and none of the departments could think of any space to use as additional collection point for unclean beds to ease the burden of having unclean beds standing in the wards.

“We are so overcrowded and we are not allowed to stock beds in the hallways because of safety regulations. We always need to be prepared for new inpatients with a clean bed.” (C. Alm, personal communication, 2015-03-16).

### 4.1.1.3 Medical Clinic

Table 5 represents the medical clinic’s capacity in numbers. As one of the major and busiest clinics at the hospital, its patient turnover is large in relation to other clinics. It receives many critical patients directly from the emergency department, and therefore the hospital was especially curious to investigate the bed logistics surrounding this clinic.
Table 5. Länssjukhuset Ryhov Medical Clinic in Numbers

<table>
<thead>
<tr>
<th>Hospital Department</th>
<th>Average patient discharges per week</th>
<th>Care places</th>
<th>Number of health care personnel</th>
<th>Busiest time for discharges</th>
<th>Busiest hours for bed cleaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medical A</td>
<td>&gt;10</td>
<td>&gt;27</td>
<td>40-50</td>
<td>Just after lunch</td>
<td>09:00-18:00</td>
</tr>
<tr>
<td>Medical B</td>
<td>25</td>
<td>22</td>
<td>40</td>
<td>Just after lunch</td>
<td>10:00-18:00</td>
</tr>
<tr>
<td>Medical C</td>
<td>8</td>
<td>21</td>
<td>52</td>
<td>In between 11:00-18:00</td>
<td>Entire day and night</td>
</tr>
<tr>
<td>Medical E</td>
<td>&gt;=48</td>
<td>33</td>
<td>65, 10-12 per working shift</td>
<td>Just after lunch, 12:00, and some during afternoon</td>
<td>09:00-18:00</td>
</tr>
</tbody>
</table>

According to the development manager Ljungkvist, and as observed in table 5, the majority of patient discharges at the entire hospital take place during 10:00 and 16:00. After that discharges only occur sporadically if it is especially requested. Certain routines apply to the discharge process of patients and at all of the medical clinic’s departments, the decision to discharge patients takes place during the medical rounds. After that, usually after lunchtime, the administrative discharge of the patient ensues whereby the patient leaves the hospital and the bed is prepared for the next patient in line. However, all of the departments pursue to be flexible and discharge patients at any time of the day.

“Since our department has such a big turnover of patients every day, we try to stay open to discharge patients at all times. At our intensive care unit with a high patient turnover, patients come and go randomly so we need to stay flexible and always be ready to prepare the beds.” (C. Ambré, personal communication, 2015-03-18).

Concerning the shortage of care places, the head of departments and assistant nurses maintain that it is a severe issue that significantly affects patients and it prolongs waiting times. As discussed by Gadmar (personal communication, 2015-03-26), “[…]there is a constant quest for care places[…]” since most of the departments are constantly crowded, and the personnel seldom can foresee when patients will be admitted. If an urgently ill patient arrives, an available bed has to be found immediately. However, sudden admittances sometimes need to wait in a temporary hospital gurney until another patient is discharged. In the worst case, patients that feel better are placed in the dining hall instead until their pick-up arrives. The situation today is far from optimal, Gadmar claims, since so much additional responsibility and stress is laid on personnel.
4.1.1.4 Manual versus Mechanical Bed Cleaning

In the search for far more optimal logistics flows and bed management, Länssjukhuset Ryhov attempts to think innovatively and rearrange the bed management by introducing technologies, says Ljungkvist. Introducing the idea of an automatic bed and mattress disinfection system to the health care personnel resulted in unanimous attitudes.

"An automated cleaning would be great since it is very difficult to reach all areas of the bed and it is not easy to reach under the bed and around the wheels and pipes, it is not possible to clean those parts entirely." (assistant nurse Med. A, personal communication, 2015-03-27).

All head of departments and assistant nurses seem optimistic about such a change, since it will result in improved hygiene standards as well as released time for the health professionals. A standardized machine that reaches unattainable areas will most likely improve the whole process and guarantee higher cleanliness, says Ambré. Moreover, a common concern is found through the interviews, namely the question of how to organize the transportation of the beds to the central point of cleaning. The opinions are that centralized cleaning is only feasible if another professional group carries out the transportation and cleaning so the health care personnel can focus on their patient.

"If the bed central was located close to our department it would be perfect, but if it is located further away, then perhaps it has to work differently with new routines. But I still think it will take less time than when we clean them manually." (assistant nurse Med. E, personal communication, 2015-03-18).

A concern from the assistant nurse at Med. C follows that in the case of more traffic of beds,

"[...]the bed still needs to come back to our department so there has to be a system to control the beds or that we all use the same bed."

Furthermore, she states that their cleaning responsibilities may not disappear completely since the rest of the ward equipment still needs to be cleaned. Another topic brought up during the interviews was the increased amount of transportation in hospital hallways, however this is not perceived as a noteworthy issue.

"Of course it would be more traffic here and since we have a major patient turnover it would be a lot[...] but still with the benefits it would produce, it would not be a problem." (C. Ambré, personal communication, 2015-03-18).

4.1.1.5 Time and Distance Studies

After several discussions with the development manager and technical department at the hospital and the studying of the hospital’s facility plan and maps, the authors visited the hospital’s culvert and connecting floors to find a potential location for the bed central.
By walking from the chosen departments medical E, the emergency department, medical B, the infection department and the oncology department down to the culvert at floor level two, the authors became familiar with the shortest and quickest routes through the central hallways and bed elevators. Time and distance records were taken from the departments and through the most central passages at the hospital. Based on that, a central location was detected in the current electricity central. Moreover, the location has good access to main bed elevators and spacious hallways from various departments, with only short distances to walk from the elevators. Simultaneously, this location is directly next to the bed and wheelchair workshops. The time and distance details from the simulation walks through the hospital are noted in table 6 and illustrate an optimal scenario where no disturbances or waiting times for elevators are included. The cycle time of the bed cleaning procedure in this table involves the time the hospital bed is in movement. In other words, the transportation time from the hospital department to the bed central, the disinfection process time in the bed central (02:30 min) and the transportation time back to the same department. Consequently, these figures will provide the basis for the prospective bed flow maps in appendix 3 and is also part of the prospective PAM map in appendix 2.

Table 6. Time and Distance Records at Länssjukhuset Ryhov

<table>
<thead>
<tr>
<th>From Hospital Department</th>
<th>Time toward bed central (min)</th>
<th>Time return from bed central (min)</th>
<th>Cycle time (min) (including time for cleaning the bed and mattress)</th>
<th>Distance round-trip (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medical Department B</td>
<td>03:45</td>
<td>03:45</td>
<td>10:00</td>
<td>420</td>
</tr>
<tr>
<td>Medical Department E</td>
<td>03:29</td>
<td>03:29</td>
<td>09:28</td>
<td>370</td>
</tr>
<tr>
<td>Emergency Department</td>
<td>02:48</td>
<td>02:48</td>
<td>08:06</td>
<td>280</td>
</tr>
<tr>
<td>Oncology Department</td>
<td>03:50</td>
<td>03:50</td>
<td>10:10</td>
<td>460</td>
</tr>
<tr>
<td>Infection Department, Section 1</td>
<td>03:56</td>
<td>03:56</td>
<td>10:22</td>
<td>420</td>
</tr>
</tbody>
</table>
4.2  SEMI-STAAL

4.2.1  Background

SEMI-STAAL is a family owned company from Denmark with over 40 years of experience in the development and manufacturing of various washing, disinfecting and logistics solutions in both the hospital and food industry alike. The company recognized a need for more advanced cleaning solutions in health care institutions with the ambition of improving hygiene standards for hospital beds and their accompanying mattresses (SEMI-STAAL, 2015). Thus, the company’s overall vision and goals with the automatic bed and mattress disinfection system is to heighten the quality of cleaning, reduce the rate of HAIs, as well as improving the working environment for health professionals (H. Bugge-Hansen, personal communication, 2015-03-30). There is currently only one automatic bed and mattress disinfection system from SEMI-STAAL on the market, and it is located in Hvidovre Hospital in Denmark since 2013. SEMI-STAAL was initially approached by the hospital that requested a collaboration with the firm since it was interested in implementing a centralized bed cleaning procedure.

The cooperation with Hvidovre led to a custom made machine that was directly installed in the hospital consisting of only an automatic bed disinfection system part at first (H. Bugge-Hansen, personal communication, 2015-03-30). Thus, Hvidovre quickly realized that it needed to wash its bed mattresses in an effective manner as well. Therefore, the hospital contacted SEMI-STAAL once again requesting an innovative cleaning solution for its bed mattresses as a complement to the existing machine. SEMI-STAAL in turn recognized an opportunity to contact the Danish technical institute called FORCE Technology. Together with the technical institute’s SonoSteam technology, SEMI-STAAL was able to produce an automatic bed mattress disinfection system, which proved to be a satisfying solution for Hvidovre Hospital (H. Bugge-Hansen, personal communication, 2015-03-30).

4.2.2  SEMI-STAAL Automatic Bed and Mattress Disinfection System

The system is divided up into two parts. The first part is the automatic bed disinfection system, which is currently the fastest bed washing system on the market (SEMI-STAAL, 2015). It consists of a fully automated system for washing, disinfecting and drying hospital beds. The machine looks like a tunnel and can be best described as a “carwash” that separates clean and dirty zones in order to prevent cross-contamination of hospital beds. Furthermore, the machine has a capacity of handling three hospital beds at the same time. While one is waiting in the automatic infeed to be washed, the second one is being washed and the third one is simultaneously drying (H. Bugge-Hansen, personal communication, 2015-03-30). The total washing cycle of the beds is divided up into five parts and takes approximately 2 minutes per bed to conduct (SEMI-STAAL, 2015). A detailed description of the bed disinfection procedure can be found in Appendix 4.

The second part is the automatic disinfection system for mattresses that uses SonoSteam technology in combination with ultrasound and steam from regular drinking water to accomplish rapid disinfection on the surface of the mattresses. Thus, making the technology completely free of any chemicals in its cleaning procedure. It is also worth mentioning that
the SonoSteam technology gets rid of all aerobic bacteria (mainly bacteria but also molds and yeasts) and reduces the enterobacteriaceae (a group of intestinal bacteria) below detection limit (SEMI-STAAL, 2015). The total washing cycle of the mattresses is divided into five parts and takes approximately 30 seconds per mattress to conduct (SEMI-STAAL, 2015). A detailed description of the mattress disinfection procedure can be found in Appendix 4.

Thus, the total cleaning process with hospital bed and mattress combined takes approximately 02:30 minutes. In other words, the machine has a capacity of washing 25 beds per hour and up to 90 mattresses per hour. Furthermore, the operating costs for the automatic bed washing system are calculated as below € 1 per bed and only 7 cents per mattress (SEMI-STAAL, 2015). Not to mention the environmental aspect by the use of minimal chemistry and water consumption, only 15 liters of water per bed that is regularly recycled through reverse osmosis. As for the personnel working with this machine, it is rather simple to master and requires minimal handling, thus it creates an optimal ergonomic working environment (SEMI-STAAL, 2015).

4.2.3 Evaluation of SEMI-STAAL's Automatic Bed and Mattress Disinfection System

An experiment was conducted by the Danish technical institute called FORCE Technology on the SEMI-STAAL's automatic bed and mattress disinfection system implemented at Hvidovre Hospital. This was done in order to estimate the level of cleaning quality on hospital beds and mattresses. Testing was performed on nine mattresses and nine beds using swabbing methods and contact agar plates (petri dishes) before and after the use of the automatic disinfection system (FORCE Technology, 2015).

1. Contact agar plates-specific areas
   - Mattresses: the contact agar plates were chosen to determine the levels of contamination on specific areas of the mattresses. This particular technique is designed to detect levels of contamination on very small surfaces, but is on the other hand very useful in evaluating what reductions are achieved on visibly contaminated areas.
   - Hospital beds: Contact agar plates were applied on remotes, frames and rails, which are usually areas that patients come into contact with the most.

2. Cloth swabbing-large areas
   - Mattresses: Sterile swabbing cloths were used to swab a large area along one side of the mattress as well as a large squared section in the middle of the mattress.
   - Hospital beds: Visibly contaminated areas of the beds were swabbed with a sterile cloth such as rails, wheels and rails underneath the bed amongst others.

3. ATP analysis-cotton swabs
   - Mattresses and beds: An ATP analysis utilizes cotton swabs that are specifically designed to be read by the ATP Clean-Trace Luminometer by 3M. ATP is essentially a molecule found in and around living cells and gives a direct indication of biological concentration and health. The ATP testing was performed separately on surfaces on the sides and across the middle of the mattress. In terms of the beds, the
ATP analysis was conducted on different critical and visible areas where contaminations are normally located.

The results of the microbial analysis illustrate a successful bacterial reduction on both mattresses and hospital beds (FORCE Technology, 2015). The numbers in figure 2 demonstrate an average of both nine beds and mattresses analyzed in this experiment.

Figure 2. Microbial Analysis Prior To and Post SEMI-STAAL’s Automatic Bed and Mattress Disinfection System Treatment. Source: FORCE Technology, 2015.

As can be seen from figure 2, the different types of bacteria that were completely eliminated after the use of the automatic disinfection system were *Enterococcus* (a type of intestinal bacteria), *E. coli* (a type of intestinal bacteria) and *MRSA* (a bacteria found on the skin and mucous membranes), indicating a 100% reduction rate post treatment. Furthermore, *Staphylococcus* (a bacteria found on the skin, hair and mucous membranes), *Streptococcus* (a bacteria found in the oral cavity, nasal cavity and upper respiratory tract), *Clostridium difficile* (a type of intestinal bacteria) indicate a 97-99% reduction rate of bacterial counts post treatment. Moreover, *TVC* (total viable count), meaning the total number of living microorganism
such as bacteria, molds and yeasts species were all successfully reduced by 89-100% on visible contaminated areas and underneath the beds after the use of the automatic disinfection system on both mattresses and hospital beds alike. In other words, demonstrating a high quality cleaning (FORCE Technology, 2015).

4.3 Hvidovre Hospital

Hvidovre Hospital near Copenhagen, Denmark, is a large acute hospital that officially opened in 1976 (Hvidovre Hospital, 2015). The hospital holds four main buildings at an area of 300,000 m², has 35 hospital departments, a catchment-area of 500,000 people and a capacity of 670 care places in total. A bed central has been used at the hospital since many years, however, with at least 250 out of 800 beds circulating in their hospital every day, there was a need for a more efficient system with the capability to clean more beds per hour. Due to the large size of Hvidovre Hospital, long transportation times for hospital beds from the wards to the bed central belong to the daily routines (H. Bugge-Hansen, personal communication, 2015-03-30). Since its earlier experience from an implementation of the system in question, the authors were curious to explore how its logistics processes concerning the hospital beds operate. Thus, this hospital was used as precedent case for this study since it deals with similar circumstances. From email conversations with a contact person at Hvidovre Hospital, it was explained that the automatic bed disinfection system cleans 250 beds and 150 other types of equipment every day.

The Sales Manager, Helle Bugge-Hansen at SEMI-STAAL has been actively involved in the implementation at Hvidovre Hospital so due to her close relationship with them, her experiences offered valuable insights to the findings of this research.

SEMI-STAAL’s system was implemented at Hvidovre Hospital during 2013 and was set in operation in the beginning of 2014. Since a bed central had already been implemented before, a location was already at place and not many reconstructions had to be made. The bed central has a surface area of 2000 m² spread over two floors. Bugge-Hansen and Hvidovre Hospital’s employees maintain that such huge area is not required, and hospitals with less space can host this system without problems. The automatic bed and mattress disinfection system itself needs approximately 50 m², according to Bugge-Hansen. Except for that, there must be two rooms divided by a wall that the system connects to, one clean room and one unclean to separate the beds and guarantee superior hygiene standards. Furthermore, the bed central also needs to be isolated to reduce the noise level produced by the system, says Bugge-Hansen. Since hospitals vary significantly in sizes and needs, it is essentially up to the hospital in question to decide what is required.

Bugge-Hansen states some important factors that should be considered when choosing a location for the bed central, namely that it is helpful to have a bed workshop, bed linen wash and similar services in close connection to the cleaning process. One also needs to count for additional space inside and around the bed central since the hospital beds need space for movement and maneuvering. Furthermore, the bed central is optimally located with good connections to hallways and bed elevators for a smooth flow in the hospital.
4.3.1 Current State of Bed Management at Hvidovre Hospital

4.3.1.1 Bed Logistics

Hvidovre Hospital holds a stock of 40 clean beds ready to be used when acute patients arrive. Hence, they have chosen to accumulate a bed pool in close connection to the bed central. When the bed central closes overnight, these beds are used instead to cover for the unclean beds. However, Bugge-Hansen argues that it is not necessary to have a large stock since the bed cleaning is so quick, and it is possible to have constant flow of beds without any opening and closing times if wanted.

“The optimal scenario would be when a porter comes to collect the bed directly after a patient has been discharged, transports it to the bed central and when it comes out at the clean side it is transported back right away.” (H. Bugge-Hansen, personal communication, 2015-03-30).

In addition, Hvidovre Hospital outsources the transportation of hospital beds to another professional group, porters, that carries out diverse assistance at the hospital. As soon as a patient is discharged, the porters are informed and they bring the beds to the bed central and back to the department. In order to control and track the beds, an RFID system has been installed. The RFID system has not been difficult to introduce as it can easily be connected with the IT-system that already exists in the bed washing machine. To simplify the process, a software is applied and all the details about the hospital beds can be viewed on the screens in the bed central.

“With RFID everyone can see directly in the software that there is an unclean bed on its way, and connected to our system you can also see when the bed was cleaned last, with what temperature and so on.” (H. Bugge-Hansen, personal communication, 2015-03-30).

The first year of operation with SEMI-STAAL’s system has resulted in positive feedbacks from employees, the logistics flow has worked well, and more beds per hour are reprocessed, Bugge-Hansen says. With the current amount of beds in circulation, one machine is enough to serve the hospital’s daily bed flow of 250 beds without disruptions. The health care personnel were only optimistic about the machine’s outcome, as found out during Länssjukhuset Ryhov’s visit at the hospital.

4.3.1.2 Bed Central Management

At Hvidovre Hospital, the bed central is open from 06:00-21:00, which is divided up into two shifts with five people working on each shift. However, Bugge-Hansen does not think it is necessary to have that many personnel, it would be enough with one person working on each side. All cleaning at the ward is outsourced to cleaning staff so that health care personnel can care only for patients. Porters transport the unclean beds to a designated area where unclean bed linen are disposed by cleaning staff, and thereafter continues to the bed central. Workers on the unclean side receive the beds and place them and the mattresses into the machines. Subsequently, the workers on the clean side receive the clean beds, con-
nect them with the mattresses, and apply bed linen. Finally, the beds are covered in plastic while they are stored or brought back to the departments.

4.3.1.3 Benefits and Challenges of SEMI-STAAL’s Bed and Mattress Disinfection System

Several benefits from the automated bed and mattress disinfection system are observed, according to the personnel at Hvidovre hospital. The standardized cleaning produces the same results every time, which guarantees a certain hygiene standard and economies of scale are realized by the centralizing of both bed and mattress cleaning as well as bed linen handling. Furthermore, the specialization of personnel has resulted in gained efficiencies. While the unclean beds leave the wards directly and make room for a clean bed, a smooth patient flow and efficient patient turnover is enabled. It has also offered great value-adding effects at Hvidovre Hospital since the health care personnel experience released time to focus solely on patients. However, the personnel at Hvidovre Hospital point out that the development of a good communication system, a transportation flow and management system for the bed logistics are important. Some calculations at Hvidovre Hospital showed that a manual cleaning in general takes 15 minutes. The automatic process is much shorter and although transportation time needs to be accounted for, the process is still significantly faster and the released time for personnel is even more valuable (H. Bugge-Hansen, personal communication, 2015-03-30).

In regard to the challenges of the implementation of the system, one obstacle caused disruptions for Hvidovre Hospital and delayed the introduction of the system:

“\[In order to be run in the system, the beds need to have this IP 66 qualification. But also, they must not have any holes in the beds, because if there are, water comes in and you have rust that breaks the beds and bacteria likes to grow there. Hvidovre bought new beds but they still had holes in them that they had to seal before they could operate the bed disinfection system.\]” (H. Bugge-Hansen, personal communication, 2015-03-30).

Otherwise, no issues with the machine itself have been noticed and SEMI-STAAL attempts to overcome such problems by educating the technical department at the hospital on how to fix and avoid technical difficulties.

4.3.1.4 An Evaluation from the Department of Clinical Microbiology at Hvidovre Hospital

Furthermore, a study concerning manual bed cleaning was also conducted by the department of clinical microbiology at Hvidovre Hospital demonstrating the level of manual cleaning quality. The study consisted of 50 different samples and as can be seen in figure 3 numerous fluctuations in cleaning quality exist ranging from as high as 3,5 cfu/cm² to as low as 1,5 cfu/cm². These numbers indicate a colonization of bacteria per square centimeter, where the desired level is 0 cfu/cm². Additionally, figure 3 further reveals that a significantly greater proportion of the studied cases show contamination levels of 2,5 cfu/cm² or higher after manual bed cleaning is performed (Mikkelsen, Klingenberg, Kristoffersen, Slotsbjerg, 2012).
Figure 3. Fluctuations in Disinfection Quality for Manual Cleaning of Hospital Beds. Beds. Source: Mikkelsen et al., 2012.
5 Analysis

In this chapter the empirical findings will be analyzed against the theoretical framework, using this as a structure for answering the research questions presented earlier in this thesis. In the beginning the current process is analyzed followed by the potential of a prospective one. Several themes are addressed and the combination of them will subsequently lead to the desired outcome of this thesis. Conclusively, a revised conceptual model will be provided.

5.1 Current State of Bed Management at Länssjukhuset Ryhov

The task of mapping out the current bed cleaning process at Länssjukhuset Ryhov is not as simple as one first might expect. Especially conducting a detailed mapping process such as a PAM map along with observations requires a more thorough investigation of all the inputs and outputs required to perform the activities involved in each step of the procedure (Hines & Rich, 1997). However, it is necessary for an organization to identify its business processes for two major reasons, one is to ensure that the right work is done and that the specific requirements to perform the business process are fulfilled (Harmon, 2007). The second one is to discover if any necessary improvements need to be made in order to optimize the existing process or assist in the creation and application of an entirely new process structure (Hunt, 1996). Therefore, the current bed cleaning process will now be discussed in greater detail using both empirical findings and theory provided in previous chapters with an emphasis on lean thinking in health care.

5.1.1 Process Owner

As the empirical findings suggest, Länssjukhuset Ryhov utilizes a decentralized method of cleaning its hospital beds. Meaning that beds are cleaned manually by assistant nurses at all departments of the health care institution. The nurse working together with the assistant nurse in teams of two is responsible for making sure that a hospital bed is cleaned, whereas the assistant nurse is the one that actually executes the bed cleaning process. Thus, in effect making the nurse the process owner that makes sure that the work is done by informing the assistant nurse which patient is going to be discharged and what bed is in need of cleaning (Harmon, 2007). The entire bed cleaning process was rigorously documented by the authors in a PAM map, seen in appendix 1, which makes the process more clear to comprehend. The material used during the cleaning procedure can be viewed as an input and the output in this case is a clean bed for the benefit of the patients according to the standards of the hospital (Hines & Rich, 1997).

5.1.2 Current State Process Activity Map

When observing the bed cleaning process at Länssjukhuset Ryhov, the authors recognized that it is triggered when a patient is discharged and vacates the bed. Moreover, it involves several activities that consist of various movements that create waste as well as idle time that creates waste between activities in the process. Furthermore, the different wastes detected during the observations through the use of a PAM map can be connected to the seven wastes within health care. Due to the fact that the PAM map is highly useful in de-
tecting wastes in terms of waiting time and unnecessary motion in a process (Hines et al., 1998; Hines & Rich, 1997). Therefore, the detailed process mapping tool became an obvious choice for the authors since it can be easily linked to the seven wastes within health care as argued by both Jimmerson (2009) and Visich et al. (2010). Examples of such waste are the movements between the cleaning room “sköjljen” and the patient ward. It creates waste in terms of time spent moving with materials back and forth, thus motion redundancy is created since various items required to perform the procedure are not nearby (Visich et al, 2010). This is a typical example of a NNVA, since the motion of moving back and forth does not directly contribute with value to the bed being cleaned (Hines & Rich, 1997). However, the activity is still necessary for the existing procedure to function, but nonetheless is also a wasteful activity where the motion redundancy should be largely reduced. Furthermore, the time spent waiting for the bed and more specifically the mattress to properly dry up is a waste in itself since time is spent for the assistant nurse doing nothing of value (Jimmerson, 2009). Waiting time is a prime example of a NVA and should preferably be removed (Hines & Rich, 1997).

5.1.3 Non-Standardized Bed Cleaning Process

In regard to the various activities taken place throughout the current bed cleaning process, the authors noticed during the observations that all of the assistant nurses were performing the activities in their own order and at times omitting some activities from the procedure. Additionally, in terms of the material being used for the cleaning of the beds, the authors further noticed that three different washcloths were utilized as well as two diverse detergents for exactly the same type of procedure (See appendix 1). Thus, exhibiting that the manner in which the existing bed cleaning process is conducted remains exclusively non-standardized. Therefore, through a lean perspective, the current bed cleaning procedure is not optimally performed. This is in line with the arguments of Plsek (2013), who claims that a standardization of processes combined with best practices creates efficient coordination of various flows of an organization. Consequently, developing flows by pursuing perfection and limiting disruptions seems perfectly suitable for health care institutions, since the organizational operations need to run seamlessly and without errors to offer excellent service for patients.

Essentially, there are no formal guidelines written down to support the assistant nurses in the bed cleaning process and only few weeks of mentoring in the beginning of their employment. This leads to a more individual way of conducting the bed cleaning procedure. Evidently, no human being is another alike in their behaviors or ways of operating, as can be observed from the four process activity maps in appendix 1. Thus, the lack of standardization in the current bed cleaning process can create fluctuations in the quality of the cleaning as discovered by the department of clinical microbiology at Hvidovre Hospital (Mikkelsen et al., 2012).

5.1.4 Quality Standards

During the interviews with the health care personnel at Länsjukhuset Ryhov, different reasons as to why fluctuations in bed cleaning quality might occur were mentioned. The issue
of the human factor was repeatedly pointed out since some individuals are more thorough than others in terms of cleaning. Moreover, a lack of time to properly conduct the bed cleaning process when it is hectic at the department or when one becomes interrupted during the procedure, are also contributors to a possible lack of quality. In other words, a stressful working environment caused by a heavy workload in combination with a rapid patient turnover creates less time spent with patients, which essentially reduces the quality of care provided as discussed by Hallin and Danielson (2007).

Moreover, a majority of the interviewees declares that the quality of the current bed cleaning process could be improved, by more standardized methods such as machines or professionals that clean for a living since miniscule areas and spaces of the bed prove hard for the health professionals to reach. In other words, one might argue that the authors’ findings are in line with the reasoning of the study performed by the department of clinical microbiology at Hvidovre Hospital in Denmark. The study reveals that when individuals are present in a process, fluctuations are bound to occur due to the human factor involved. Thus, further supporting the statements made during the interviews with the health care personnel at Länssjukhuset Ryhov. Therefore, a standardization of the current bed cleaning process becomes imperative for a desired quality level to be reached and fluctuations overcome.

### 5.1.5 Cleaning Guidelines

In terms of the aspect of formally written cleaning guidelines, the authors have discovered that Länssjukhuset Ryhov is missing such instructions for health professionals to follow. Thus, there are no local cleaning guidelines that the assistant nurses can use to lead them in their bed cleaning procedure when necessary. Therefore, the authors have decided to incorporate national cleaning guidelines in this analysis as a standard to follow as suggested by SFVH (2012). Moreover, the authors have further discovered that the different heads of the departments in this research do not seem to be aware of the national cleaning guidelines, or they simply do not incorporate these instructions in their daily work. The national cleaning guidelines were constructed as a supportive tool by the Swedish institution known as SFVH for health care providers across the nation. Even though these guidelines are not compulsory, SFVH still recognized a need for them to be constructed since the knowledge of how to properly clean health care facilities is often inadequate. According to SFVH (2012), providers of health care organizations are responsible to conduct regular evaluations of different clinical procedures. The current bed cleaning process at Länssjukhuset Ryhov falls into that description. However, from the interviews conducted with the various heads of the departments at the hospital, they all mention that no monitoring or testing is currently undertaken. In other words, there are no evaluations made concerning the quality of the bed cleaning process currently performed at the hospital.

Furthermore, the national cleaning guidelines from SFVH state that hospital beds are a high-risk area for infections to spread from patients to health professionals and vice versa. Thus, the importance of cleaning the hospital beds carefully should be of utmost concern for all health care institutions. If nothing else, there should be a checklist of some sorts or formal guidelines that the personnel cleaning the beds can follow in order to avoid mis-
takes and reduce the transmissions of HAI s (Svensk Förening för Vårdhygien, 2012). Through the observations of the current bed cleaning process at Länssjukhuset Ryhov, the authors noticed that a majority of the assistant nurses performed the procedure carefully and made sure to conduct the various activities in an appropriate manner in order to avoid mistakes as much as possible. Nevertheless, there is still room for improvement in the current bed cleaning process, in order to make sure that all assistant nurses follow the same cleaning standard. Therefore, according to SFVH, guidelines are highly recommended but usually not implemented, which is evident in the example of Länssjukhuset Ryhov. Thus, since such instructions are not implemented the current bed cleaning procedure is not optimally performed since best practice methods are not applied. This statement is supported by the unanimous opinions from the various heads of the explored departments of the hospital.

5.2 Prospective State of Bed Management at Länssjukhuset Ryhov

5.2.1 Bed Management

The overcrowding at the hospital departments is highly noticeable at Länssjukhuset Ryhov, which is why it is so crucial with a functioning bed management system, as argued by Proudlove et al. (2003). Furthermore, the continuous matching of supply and demand of beds suggested by Winkelmann et al. (2008) is seemingly disposed to limits due to the fact that the beds belong to different hospital departments and are bound to their original position. Through the current decentralized bed management process, mismatches and bed blockages are likely to occur, which affects the patient throughput negatively (Gorunescu et al., 2002). As a result, an excess supply of beds may develop, and a waste of resources when the beds have been cleaned and wait for a patient to arrive, rather than being brought to a place where a patient is in urgent need of one. In contrast, it may also be that an unplanned patient comes to the department when there is no bed available because of the shortage of care places. This system causes wasteful waiting times and prolongs the care time since the patient needs to stay in a temporary hospital gurney until another patient is discharged, or wait for personnel to prepare a bed. Arguably, such wastes count as NVA activities that should be eliminated according to lean thinking (Hines & Rich, 1997).

The bed pool of 30 beds may help the hospital to cover for mismatches however, this pool is only used on occasion and is not responsive enough to cover for urgent unavailability of beds. Since the hospital beds consist of a variety of different sorts, the bed pool becomes less responsive if a specific type of bed is out of stock. Arguably, the flow of beds would become significantly improved with one bed type for the entire hospital. Thus, existing parallel bed flows can be reduced into a single flow to standardize and streamline processes further, following Womack and Jones (2003).

Accordingly, it seems appropriate to have a responsive flow of beds and apply a leagile strategy in order to be prepared for the fluctuating needs. The decoupling point separating the lean and agile strategies as discussed by Aronsson et al. (2011) is in this case most suitably located at the point when a patient is admitted at a hospital department. In case of a
centralized cleaning procedure, a clean bed can be transferred immediately from the bed central to any department as soon as a patient’s need for a clean bed is known. Thus, it will have a responsive function to fill the demand instantly. The lean strategies will accordingly take place before a patient is admitted. Discharges of patients can be forecasted more easily, at least from the moment of the medical rounds when the patient discharge is known. Consequently, the unclean beds route to the bed central would be a planned and standardized action where the first bed in line is cleaned first. Evidently, in this case it is possible to determine a fixed decoupling point even for a health care service setting, which challenges Aronsson et al. (2011) statement.

In order to support a consistent bed flow, Länssjukhuset Ryhov has firstly the choice to make use of a larger stock of clean beds that are ready to fill up the possible gap when an unclean bed is transported to the bed central. This is in line with an agile thinking to hold stock in order to be responsive to demand (Rahimnia & Moghadasian, 2010). Alternatively, it can choose to not use the stock of beds in the daily flow, and rather focus on a constant, joint flow of standard beds throughout the hospital, which would be the lean way of handling the problem. Thus, the beds are picked up directly when a patient is discharged from one department and brought immediately to the bed central without being stored at other collection points in between. In the authors’ opinion, the second alternative would provide an optimal solution. Regardless of the choice, actions needs to be responsive from the time that a new patient arrives at the hospital and the working routines need to be flexible enough to provide an ill patient with a clean bed.

5.2.2 Bed Logistics

While referring back to the definition of logistics by the Council of Supply Chain Management Professionals (2015), this second part of the analysis focuses on the process of planning, implementing, and controlling an efficient and effective forward and reverse flow and storage of the hospital beds at Länssjukhuset Ryhov, for the purpose of meeting patient requirements and providing quality health care. The traditional, departmental view that Mayfield (2009) claims to often be noticed at hospitals, is also evident in several areas of operation at the case study hospital. Each department is primarily looked at as a functional silo with individual resources and practices, whereof many departments operate without any consistent communication or collaboration in between. Although the parallel patient flows often cross several departments during their journey, a holistic process-view is difficult to truly establish. This can be a result of traditions and great variations in specializations due to the highly knowledge-intensive industry, as argued by Lin and Stead (2009). As the authors have experienced from the interviews and visits at the hospital, such sub-optimization of processes may be enforced by a lack of innovative communication systems and efficient logistic systems.

One area where such sub-optimization is evident is in the bed management. The beds are not a shared resource between departments and collaboration mostly occurs when patients are transferred from one department to another. If a cross-functional view were taken, a joint bed flow would be established with the aim to communicate in between the depart-
ments and collaborate with a mutual sharing of beds. In turn, cost- and process efficiencies may be obtained through collaborative forces and new ways of thinking (Stoddard, 2013).

As asserted by Winkelmann et al. (2008), the hospital bed flow is one of the supportive flows that either directly or indirectly affects the patient flow. As noted at Länssjukhuset Ryhov, when there is no available bed in place the patients need to wait, which causes longer hospitalization times and has indirect negative effects on the patients. The importance of effectively managing and allocating hospital beds was revealed by the management at Länssjukhuset Ryhov due to their special interest of investigating the bed logistics required for the future restructuring plans of the hospital. Hence, a prospective PAM map, viewed in appendix 2, was conducted as a basis for the changes that are needed to support the prospective bed management.

5.2.2.1 Prospective Process Activity Map

The transformation from a decentralized bed reprocessing to a centralized one raises the need for fundamental changes in current operations and development of new working processes. BPR may prove to be a valuable program to use for such a radical change, especially since it takes the holistic cross-functional view needed to realize the change implementation throughout the entire hospital (Gunasekaran & Nath, 1997). The bed reprocessing is a part of the patient’s whole value chain, where any improvement will directly or indirectly lead to an improved quality of health care service. Hence, by breaking down the current manual cleaning process to minor activities it was possible to detect and eliminate waste in the activities, and the prospective process activity map could be developed as the ‘to-be’ process, in line with Motiwalla and Thompson’s (2012) BPR steps.

The prospective PAM map was developed from an optimal scenario, meaning that the beds are transported directly from the department to the bed central and back, thus not stored along the way. In the prospective state another personnel group, such as service personnel, are most optimally in charge of the transportation of the beds, since it is no one’s desire at the hospital to offer this responsibility to the assistant nurses. Furthermore, the prospective map also includes the time the service personnel needs to walk to the department and pick up the bed, as well as the duties of the bed central personnel. As a result, the prospective PAM map involves 15 steps instead of the 20-25 steps involved in the current state PAM maps. Several steps such as waiting for the bed to dry up have been eliminated and the fewer steps are a result of a machine taking over the process and standardizing it. However, one also needs to consider that the optimal scenario will not always occur due to possible waiting times for elevators to arrive or other disturbances along the way in the case of more frequent bed transportations.

Importantly, the whole time for the current bed cleaning process, which varied from 12:30 minutes up to 16:30 minutes, is released from the health care personnel. Considering the fact that this process takes place several times per day, the time gains would be noticeable. Additionally, the physical work from manual bed cleaning is released and taken over by a machine instead of any occupational group. As expressed by Van Looy et al. (2013), map-
ping and reorganization of business processes can have a great impact on the organization’s efficiency, when each activity is reconfigured so that it adds to the value chain.

The need to standardize the cleaning process at the hospital is in line with Plsek (2013) lean principles as well as Waring and Bishop’s (2010) statement that an increasing use of standardization in clinical work is gaining increased attention. In this case, standardization is believed to result in improved and reliable hygiene standards for the hospital as a way to provide improved care. In addition, the health care personnel would be able to rely more on the fact that the beds are properly cleaned and they can guarantee their cleanliness, which they cannot today according to the assistant nurses. Concerns about losing the human touch and flexibility in health care due to standardization as argued by de Souza and Pidd (2011), seem not to be realized in this case. Rather the opposite follows since more value-adding resources are in effect released for the patients’ benefit when health care personnel attain freed time, which suggests an increase in flexibility (de Souza & Pidd, 2011). The flexibility in turn will provide a basis for more agile activities, for instance a quicker response for patients’ varying needs and volatile demands as argued by Aronsson et al. (2011). As a result, a more effective use of employee resources as workers can provide an improved patient care with the same resources, which follows Weinstock’s (2008) viewpoint. This also confirms the trend in health care toward a more patient-centered care, as mentioned by Martin et al. (2009).

5.2.3 Elements Affecting the Prospective Bed Management

As found during the authors’ empirical investigations, a transformation from the current decentralized bed reprocessing to a centralized one has several implications for the hospital. The following themes have been detected through the coding scheme of the data analysis, and are important elements to consider for the future rearrangement of the logistics concerning the bed management at Länssjukhuset Rybov and will be discussed subsequently. These will also be analyzed against similar operations at Hvidovre Hospital in order to provide practical recommendations.

**Transition Elements**
- Bed Transportation
- Information Technology
- Bed Qualification
- Time and Distance Studies
- Bed Central Location
- Bed Central Opening Hours

Figure 4. Transition Elements. Source: Author’s Own Illustration
5.2.3.1 Bed Transportation

An element to consider for hospitals looking to centralize operations is the higher frequency of bed transportations, according to Winkelmann et al. (2008). This has been confirmed by the authors’ findings since a much higher frequency of bed transportations take place at Hvidovre Hospital in relation to Länssjukhuset Ryhov. The amount of bed transportations has not bothered the employees at Hvidovre Hospital, although the fact that they have had a centralized bed cleaning procedure for many years may contribute to their adaptation to this. However, as discovered from the interviews with the health care personnel at Länssjukhuset Ryhov, they did not appear to have concerns over an increased traffic of beds either. Obstacles in change programs mentioned by Radnor and Boaden (2008) such as no organizational readiness and resistance to change can be averted by communicating new, clear job descriptions. Resistance from employees has however not been evident in any of the conducted interviews, rather the majority of the employees seem positive about the changes since they believe it will result in better working conditions and patient care. This is in line with Weinstock (2008) that claims that lean methodologies are not meant to reduce health professionals’ power and interfere with the delivery of patient care, but rather give them more power and authority to provide improved health care.

The employees’ only concerns were if people would be let off because of such changes, or who would be responsible for the bed transportations, since they themselves would not desire to exert time on bed transportations. Both theoretical and empirical findings in this research point to the fact that health care personnel are extremely busy and stressed as it is, and that it would be highly appreciated if they could save time from tasks that do not belong to their immediate responsibilities. As follows, handing over the responsibility of bed transportation to another professional group, similar to the porters at Hvidovre Hospital, is an imperative resolution to this concern. The specialization of tasks that occurs when one specific group focuses on one task further increases the chance of obtaining the process-and cost-efficiencies that hospitals are in need of (Waring & Bishop, 2010).

5.2.3.2 Technology

In order to control the bed flow a profound system for tracking and tracing the hospital beds is required, hence the use of IT systems is highly recommended (Kumar et al., 2008). Since the use of technology in patient care is greatly used already as claimed by Lin and Stead (2009), new systems that can support the logistics of the secondary flows such as the hospital beds, would be the next step in line to advance the organizational efficiencies. This statement is supported by Hvidovre Hospital that recently acknowledged the need to add a RFID tracking system to its bed central system, since the resulting real-time information about every bed is a required tool for an efficient bed management.

At Länssjukhuset Ryhov it is difficult to track and trace the hospital beds since they often lack identification labels and are not connected to any software system. According to Gadmar, it is often the nurses’ responsibility to remember bringing the beds back and this only creates another work task for the personnel. Without a rigorous system, this task is more vulnerable for misunderstandings and may result in waste of time and resources. Primarily, it needs to be ensured that all beds are inscribed with an identification of some
sort when they are transferred to various places inside the hospital. However, the beds need to be identified quicker and hence an IT-system that can provide real-time information is required to control the beds even outside of their respective ward. For this cause, an RFID system would be suitable due to the consistent and reliable information provided (Tzeng et al., 2008). With such technology support, the scheduling of bed cleaning in the bed central could be more accurate with less risk of bed blockages and misallocation of beds. Furthermore, since SEMI-STAAL’s automatic bed disinfection system is equipped to handle an RFID system as a complement to the existing system features, such an implementation does not need to be very time-consuming according to Helle-Bugge. Meanwhile, the already existing software in the automatic bed disinfection system can provide detailed information about the cleaning itself, which further reduce the risk of misunderstandings and errors in the bed management process.

5.2.3.3 Bed Qualifications

In regard to the quality of the hospital beds it is detected that only 250 of the beds at Länssjukhuset Ryhov have the IP 66 qualification that is required for them to be mechanically cleaned. Additionally, many of Länssjukhuset Ryhov’s beds have holes and cavities that may harm the beds if they are run in the automatic disinfection system. This unforeseen factor was discovered by Hvidovre Hospital after the implementation began, and it needs to be planned for future implementations. A precondition for an implementation of SEMI-STAAL’s system is therefore additional purchases of the same sort of beds with the IP 66 qualification at Länssjukhuset Ryhov. Furthermore, a solution for sealing the holes in the beds needs to be figured out before any of the beds can tolerate a mechanical cleaning. This fact will increase the investment costs of the implementation and needs to be calculated for in future cost analyzes. This is furthermore in line with a system-wide approach and that such a practice within health care may need special caution, time, and resources as mentioned by Radnor and Walley (2008).

5.2.3.4 Bed Central Location

Another element that needs to be carefully considered is where to strategically place the prospective bed central at the hospital. This may be difficult in many cases due to the often mentioned overcrowding at hospitals, where additional surfaces for new equipment do not exist. One has to also consider that the budget constraints, reconstructions, and new buildings are not always an option either. Hence, the most economical choice is obviously to choose a location that already exists. While de Vries and Huijsman (2011) maintain that a centralized cleaning process is reliant on sound and flexible logistics systems, the location of the bed central will greatly affect how efficient and flexible the bed logistics and the process operates. Appropriately, the bed central location is easily reached from all departments at the hospital, however this is difficult to fulfill, as some departments will always have a more uncomfortable distance. Most importantly, the bed central should be located so that the major departments with high patient turnovers, such as the emergency department and alike, have good access to the mechanical cleaning.

As aforementioned, such a central place was detected during the authors visit at the hospital and has been chosen as the center of location in the illustrations of our prospective flow.
maps in appendix 3. It has a central place of the hospital building at floor level two, the logistics culvert. Many benefits add to this location due to the proximity of bed elevators, spacious hallways and the bed workshop, which are the most important factors to consider according to SEMI-STAAL and Hvidovre Hospital. The hallways connecting the bed central to bed elevators comprised adequate surface for up to two beds passing each other. There was also sufficient area around elevators and the bed central location for the maneuvering of beds. Arguably, with such a central location the opportunity of developing efficient and responsive bed flows from various departments at the hospital seems conceivable without many changes in the current hospital facilities.

5.2.3.5 Time and Distance Studies

A centralized bed reprocessing necessitates longer time due to the increased transportation time to the bed central, according to Winkelmann et al. (2008). However, this research’s findings have shown that this is not always the case. Hvidovre Hospital conducted comparative studies of the manual and mechanical cleaning and noticed that the times did not differ significantly. Sometimes the entire mechanical process, including transportation, was even shorter, as revealed by Bugge-Hansen. The transportation time naturally depends on the size of the hospital, where the bed central is located, and how well the hospital’s hallways and bed elevators can support the bed flows. The shorter the cycle-time, the more responsive is the bed supply for new patients, which may heighten the patient turnover due to the bed flows’ indirect effect on the patient flows (Villa et al., 2009). An optimization of the bed cleaning time thus requires a leagile strategy that could act responsively towards the volatile demand of patients, as suggested by Aronsson et al. (2011). Through a responsive bed reprocessing with flexibility for rapid decisions, a clean bed may be rerouted directly to a department where a patient needs it quicker than it takes to wait for a departmental bound bed to be cleaned by nurses.

From the authors’ time and distance records at Länsjukhuset Rybov in table 6 it was concluded that the cycle times for an automatic cleaning at the authors’ suggested location, was oftentimes shorter than the manual process. It generally took between 8 and 10 minutes in total for the entire centralized process. These times include the transportation of a bed from the department entrance to the bed central entrance, machine cleaning time, and transportation back to the same department. Thus, only when the bed is in movement. The distances varied from 280 m to 460 m, counting the round-trip from departments either in close connection to the possible bed central or furthest away. Therefore, it can be assumed that the time and distances measurements from departments not covered in this research are also within these frames. All the investigated departments were closely located to bed elevators with direct access to the bed central level and the routes seem conceivable to allow for more frequent traffic. Thus, in terms of the bed transportation no issues are presented by this preliminary investigation.

The time and distance measurements consequently provided a foundation for the prospective bed flow maps illustrated in appendix 3, which give an idea of how the bed logistics may look like from the authors’ suggestions. The prospective flows illustrate the entire bed flow from the department entrance down to the bed central at level two, and suggest which
routes and elevators to optimally use. Due to the central location, it was viable to find efficient and quick routes even from departments at the opposite side of the hospital. In line with this, one may assume that similar use of the main hallways and elevators would be suggested for a major part of the unexplored hospital departments as well.

Importantly to note is that one needs to expect variations of these time records due to other disturbances that may occur in the case of a higher frequency of bed transportations in a future scenario. However, the flow maps demonstrate that the cycle times of manual versus mechanical cleaning do not deviate significantly from each other. Nevertheless, as experienced through the interviews at Länssjukhuset Ryhov even a slightly longer bed reprocessing time can be dealt with in light of the many additional gains provided by the automatic bed disinfection system.

5.2.3.6 Bed Central Opening Hours

Another strategic decision to make, concerns the opening hours of the bed central. The opening hours should be determined with consideration to how many beds are in need of cleaning during various hours of the day, and the average cycle-time for the whole process. The first decision is to decide whether to have the bed central closed at all, since it can operationally run at all times. However, running the machine during the night would result in increased costs and use of resources, and in Länssjukhuset Ryhov’s case, this is not worthwhile since only few beds are cleaned during the evening and nighttime. The authors found that the desired opening times of the health professionals at Länssjukhuset Ryhov would be between 09:00-17:00, since the majority of patient discharges occur during these hours. In that case, a stock of beds needs to be in proximity to the bed central, ready to be utilized during the closing times.

An important finding was that several of the major hospital departments have most of their patient discharges just before or after lunchtime. If this is the case for the majority of the departments, it implies a major traffic to the bed central during these hours. This can be a concern that needs to be planned for beforehand, for instance by increasing use of the bed pool during this time to avoid bed blockages, which also fits the agile strategy mentioned by Aronsson et al. (2011). However, as previously mentioned SEMI-STAAL’s automatic bed and mattress disinfection system has a capacity of cleaning 25 beds and 90 mattresses per hour (SEMI-STAAL, 2015). With an average of 90 discharges per day, this means that the system still has the capability of handling all of these if they would all be discharged during the two hours before and after lunchtime.

5.2.4 Manual versus Mechanical Cleaning

In Länssjukhuset Ryhov’s case, the decentralized bed reprocessing has been solved by manual cleaning while the prospective centralized bed reprocessing will preferably be mechanical. As noted before, the differences between these procedures are significant and the results from a mechanical cleaning has through several tests proven much more reliable as can be discovered from the study by Hopman et al., (2015). In comparison, the manual handling involves less investment costs but consumes more health care personnel resources that could be used in more valuable ways. A mechanical handling implicates higher initial
investment costs, especially when there is a need for reconstructions and purchasing of supplementary products such as IT-systems and hospital beds. However, the consequent operational costs for each bed and mattress cleaning are not significant and can be compared to the costs of material and resources for manual cleaning (SEMI-STAAL, 2015). Thereof, the benefits of the improved cleanliness results from mechanical cleaning need to be weighed towards the low investment costs of the manual cleaning.

In terms of the quality aspect of the cleaning, mechanical cleaning has been proved to reduce the amount of biological contamination far better than manual cleaning procedures, even with the use of best practice methods for enhancing manual cleaning (Hopman et al., 2015). Thereof, one major advantage of mechanical cleaning is that all hospital beds and mattresses are more carefully disinfected after every patient discharge. As can be seen from figure 2 where SEMI-STAAL’s automatic bed and mattress disinfection system is evaluated, the amount of microorganisms has been successfully reduced by a 100% in half of the cases, and in the other half the bacterial count has been reduced below detection limit. Consequently, accumulation and transmission of bacteria is minimized, which are the contributors to the spread of HAIs. Since the mechanical cleaning displays less fluctuation in cleaning results combined with consistently lower levels of biological contamination, arguably the quality of mechanical cleaning is superior to manual. However, it is worth mentioning that technology and machines are not without error, as such, maintenance and repairs should be accounted for in the course of operations. Moreover, as the findings reveal, Hvidovre Hospital has not yet experienced any major operational errors with SEMI-STAAL’s system. Additionally, the system will arguably consume higher amounts of water and energy in comparison to the manual handling. In regard to the noise level of the system, the bed central needs to be isolated as a part of the reconstruction of the hospital facilities, says Bugge-Hansen.

Concerning the ergonomic aspect, manual-handling injuries within health care are still highly prevalent, therefore counteracting measures need to be conducted (Owen et.al. 2002). SEMI-STAAL’s system requires minimal human handling and is easy to master (SEMI-STAAL, 2015). Therefore, whoever handles the machine no longer needs to bear the physical burden of manually cleaning a hospital bed and incurring back and shoulder aches. Additionally, the health care personnel can let go of one more task to handle during their daily responsibilities. Thus, the highly desired patient-centered care can be provided due to released time for more value adding tasks for the benefit of the patients (Martin et al., 2009). According to the statements from the interviewees, the ergonomic aspect of the manual cleaning is not a big issue until someone attains physical limitations. Therefore, the implementation of a mechanical cleaning procedure has the possibility of limiting such risks.

For Länssjukhuset Ryhov, the objective is to provide a high quality care by reducing the current spread of infections, and improving the working environment for its employees, thus mechanical cleaning seems to be the appropriate choice. The entire process as the health care personnel conducts it today can arguably be seen as a waste in itself, since it is a NNVA, which does not directly add value for the patients (Hines & Rich, 1997). Since even a best practice manual cleaning cannot match the quality provided by mechanical
cleaning, an even larger portion of medical institutions in Sweden should consider a transition towards such a standardized method. Conclusively, an implementation of an automatic disinfection system has many advantages but also some disadvantages to consider, which are summarized in Table 7.

**Table 7. Advantages and Disadvantages of Implementing an Automatic Bed Disinfection System**

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Responsive bed management due to a joint flow</td>
<td>High initial investment cost of implementing the system</td>
</tr>
<tr>
<td>Standardized bed cleaning process with fewer activities involved</td>
<td>More rigorous bed qualifications requires all beds to comply with the IP66 standard</td>
</tr>
<tr>
<td>Released time for health professionals to focus on the patient treatment (improved patient-centered care)</td>
<td>Higher water and energy consumption in comparison to manual cleaning</td>
</tr>
<tr>
<td>Ergonomic benefits due to a minimum manual handling of beds for all personnel</td>
<td>Regular maintenance of the machine</td>
</tr>
<tr>
<td>Improved patient safety due to a reduction of biological contamination levels, and in turn minimized transmissions of HAIs</td>
<td>Possibility of system or technological errors to occur</td>
</tr>
<tr>
<td>Reliable hygiene standards due to consistent cleaning results</td>
<td>Higher noise level in the bed central if not properly isolated</td>
</tr>
<tr>
<td>Higher cleaning capacity (25 beds per hour)</td>
<td>Time and resource efforts for the reconstruction of existing hospital facilities</td>
</tr>
<tr>
<td>Able to clean a variety of hospital equipment</td>
<td></td>
</tr>
</tbody>
</table>

The authors conclude that the advantages appear to outweigh the disadvantages of the implementation of an automatic bed disinfection system at Länssjukhuset Ryhov. This statement is based on the fact that the advantages will improve health care both in a short-term and long-term aspect and outweigh the initial investment costs and resources needed for the implementation. Due to the exceeding advantages, an implementation of a centralized mechanical bed cleaning procedure is highly advisable.
5.3 Revised Conceptual Model

The empirical findings have led to alterations of the conceptual model illustrated in the theoretical framework chapter. This revised model illustrates the prospective transition from a decentralized manual bed cleaning to a centralized mechanical one. The transition elements that the authors detected through the empirical findings were subsequently analyzed through the theories on the left side of the model, therefore the link between theories and empirical findings is evident. The elements provide necessary guidance in such a transition process. Furthermore, the use of logistic tools such as PAM, allowed the authors to explore how the current bed cleaning process is undertaken. The incorporation of lean thinking and BPR further supported the configuration of a prospective map by detecting and reducing wasteful activities.

Additionally, the outcome of the transition elements toward a centralized mechanical cleaning procedure by the support of logistics and technology, arguably result in a reduction of HAIs and improved working environment for health professionals. This leads to the final objective of improved health care at the far right side of the model. This revised model may be of use for other health care providers considering such a transition. In using the model presented below, hospitals could take the first steps towards making extended use of logistics and technology to undergo a similar transition process.

Figure 5. Revised Conceptual Model. Source: Authors' Own Illustration
6 Conclusion

This chapter focuses on reflecting back on the purpose of the research and concluding the most relevant findings of the analysis.

The purpose of this thesis was to explore how a central automatic bed disinfection system could be implemented at a hospital in Sweden. In this research, we chose to examine Länssjukhuset Ryhov in order to improve its patient safety, and enhance the working environment for health professionals. The use of PAM maps allowed the authors to identify the activities involved in the current bed cleaning procedure. This resulted in the development of a prospective solution for the bed cleaning process by a combination of logistics and technology. The utilization of such theories proved significant in order to exploit the possible practical, managerial, and theoretical contributions for a health care setting, where such concepts have yet been rare (Portioli-Staudacher, 2012).

Due to the fact that health care institutions in Sweden are increasingly challenged by societal and environmental factors and the spread of HAIs, new and innovative methods have to be adopted in order to improve the current quality of health care (Sveriges Kommuner och Landsting, 2010). Länssjukhuset Ryhov has since several years been at the forefront of medical practice and shown a constant strive for advancements in their patient care (Region Jönköpings Län, 2015a). Thus, their initiative to combat the issue of HAIs and reduce the current rate may provide useful insights for the Swedish health care industry.

The current manual bed cleaning procedure at Länssjukhuset Ryhov requires extensive nurse resources and results in a non-standardized way of cleaning. This leads to fluctuations in the quality of the cleaning output, and is not a desirable outcome for medical institutions. This research reveals that introducing a mechanical cleaning procedure can provide advantages in terms of a standardized manner of cleaning, released time from health professionals, and consistent cleaning results that reduce transmissions of HAIs. These advantages seem to outweigh the disadvantages such as high initial investment costs and resource efforts required for the restructuring and maintenance of the system.

Before a transition from a decentralized to a centralized bed reprocessing can be initiated, several transition elements have to be considered. When these elements have been devised, the implementation of a centralized automatic bed disinfection system becomes conceivable. Recommendations of the concrete steps that have to be performed at Länssjukhuset Ryhov are provided in appendix 5.

Furthermore, the research findings have led to the conclusion that introducing a central automatic bed disinfection system may improve patient safety and the working environment for health care personnel. Arguably, more consistent hygiene standards and an improved cleaning quality will lead to an augmented minimization of transmissions of HAIs. This may result in desired cost-efficiencies due to a reduction in patient length of stay. Moreover, the cleaning capacity of the machine has the potential to increase patient throughput and in turn assist hospitals to treat more patients more attentively.
7 Discussion

In this final chapter, the theoretical, practical, and managerial contributions will be expressed. Furthermore, suggestions for future research will be delivered.

7.1 Contributions

This thesis was initiated in order to assist Länssjukhuset Ryhov with practical logistic solutions for their future restructuring plans. Observably through extensive exploration of academic literature, the authors recognized that the topic of concern has not been given much credit in Swedish hospitals up to this date. Therefore, the authors intend to fill the gap in this area of research by providing examples on how to incorporate logistics and technology in health care services, which may increase managers’ awareness of such methods and provide new insights on how to improve the quality of health care. In other words, assisting providers of Swedish health care institutions in the decision of transitioning from a decentralized to a centralized cleaning procedure, since no such evidence is currently available.

In terms of theoretical contributions, logistics and lean methods have been used in this thesis in order to find innovative ways of using such techniques within the health care industry. As found during the course of this thesis, logistics philosophies and tools may both standardize organizational processes while also generating actions that are more responsive. This seems highly suitable for the volatile and unpredictable demand in health care services, since such rarely applied techniques may produce the desired cost-efficiencies and patient-centered care that are sought for. For instance, PAM maps that have been of limited use in health care studies previously, proved to be a vital tool in this research.

As observed, the combination of the theories and transition elements in the revised conceptual model creates a theoretical contribution due to their application in a health care setting. However, the detected elements developed to ease a transition from decentralized to centralized bed reprocessing are a practical contribution in themselves. Since they are practical steps designed to assist health care providers in the reengineering of an entirely new bed cleaning process. The practical steps recommended to support Länssjukhuset Ryhov in such a transition are provided in appendix 5, and might as well be of interest for other hospitals considering a similar transition process. Furthermore, prospective bed flows that illustrate how exactly the beds would be transported through the hospital in the most efficient way, are provided in appendix 3.

7.2 Future Research

There is an emergent need of making medical institutions in Sweden more efficient and placing them in the forefront of global health care (Anell et al., 2012). Hence, Swedish health care providers need to look beyond the national borders and embrace novel practices utilized in more forward thinking nations in this respect. Thus, further research is needed to address the combination of logistics and technology for advancements within Swedish health care, in order to strengthen the contributions of this research project. Furthermore, a follow-up study of the prospective implementation at Länssjukhuset Ryhov is needed in order to justify the validity of the authors’ recommendations. Further evaluations
of the outcome of mechanical cleaning for SEMI-STAALs system as well as other systems would be of interest for decision-makers. Moreover, this study could be performed through quantitative methods to measure to what extent the HAI rate would be further reduced, and in turn how the patient safety and employee working environment would be affected after the implementation of the system.

Additionally, since this research does not aim to generalize, it would be interesting to explore other cases of Swedish hospitals that consider implementing a central automatic bed disinfection system and what factors they consider as important for a smooth transition beyond the ones detected for Länssjukhuset Ryhov. Moreover, the economic feasibility of a mechanical cleaning procedure versus a manual one could also be a subject for further investigation, since financial considerations have not been central to this research. For Länssjukhuset Ryhov, further investigations are needed that cover how all hospital departments are affected by the implementation of a central automatic bed disinfection system in consideration of the future facility plans design and conditions.
List of references


Appendix 1

Current State Process Activity Maps

In this section, four process activity maps illustrate the current bed cleaning procedure. A patient being discharged triggers the current bed cleaning process.

Assistant nurse medical clinic department A

<table>
<thead>
<tr>
<th>Number</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Getting the laundry bag</td>
</tr>
<tr>
<td>2</td>
<td>Putting on disposable gloves and apron</td>
</tr>
<tr>
<td>3</td>
<td>Getting material for cleaning (detergent in a spray bottle and paper washcloths)</td>
</tr>
<tr>
<td>4</td>
<td>Rising the bed to a more comfortable cleaning position</td>
</tr>
<tr>
<td>5</td>
<td>Removing the bed linen</td>
</tr>
<tr>
<td>6</td>
<td>Starting with cleaning the crane above the bed</td>
</tr>
<tr>
<td>7</td>
<td>Spraying on detergent to clean the bed, pillow and mattress</td>
</tr>
<tr>
<td>8</td>
<td>Cleaning the reusable pillow</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number</th>
<th>Activity</th>
<th>Flow</th>
<th>Area</th>
<th>Distance (meters)</th>
<th>Time (minutes)</th>
<th>People</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Getting the laundry bag</td>
<td>T</td>
<td>“Sköljen” (room for cleaning)</td>
<td>4m away from the ward</td>
<td>0:45 min</td>
<td>1</td>
<td>Assistant nurse duty begins!</td>
</tr>
<tr>
<td>2</td>
<td>Putting on disposable gloves and apron</td>
<td>T</td>
<td>Department hallway</td>
<td>1 m outside the ward</td>
<td>0:31 min</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Getting material for cleaning (detergent in a spray bottle and paper washcloths)</td>
<td>T</td>
<td>In the wardrobes outside of the hospital ward</td>
<td>2 m</td>
<td>0:37 min</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Rising the bed to a more comfortable cleaning position</td>
<td>O</td>
<td>In the hospital ward</td>
<td>0 m</td>
<td>0:26 min</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Removing the bed linen</td>
<td>O</td>
<td>In the hospital ward</td>
<td>0 m</td>
<td>0:44 min</td>
<td>1</td>
<td></td>
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<tr>
<td>6</td>
<td>Starting with cleaning the crane above the bed</td>
<td>O</td>
<td>In the hospital ward</td>
<td>0 m</td>
<td>0:36 min</td>
<td>1</td>
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<tr>
<td>7</td>
<td>Spraying on detergent to clean the bed, pillow and mattress</td>
<td>O</td>
<td>In the hospital ward</td>
<td>0 m</td>
<td>0:22 min</td>
<td>1</td>
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<tr>
<td>8</td>
<td>Cleaning the reusable pillow</td>
<td>O</td>
<td>In the hospital ward</td>
<td>0 m</td>
<td>0:23 min</td>
<td>1</td>
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<tr>
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<td>Time</td>
<td>Duration</td>
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<td>----------</td>
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<td></td>
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</tr>
<tr>
<td>9</td>
<td>Cleaning the top part of the mattress</td>
<td>In the hospital ward</td>
<td>0 m</td>
<td>0:36 min</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>10</td>
<td>Flipping the mattress over on one side and cleaning the bottom part</td>
<td>In the hospital ward</td>
<td>0 m</td>
<td>0:18 min</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Flipping the mattress over on the other side and cleaning the bottom part</td>
<td>In the hospital ward</td>
<td>0 m</td>
<td>0:16 min</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Cleaning the headboard and the footboard</td>
<td>In the hospital ward</td>
<td>0 m</td>
<td>0:27 min</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Lifting up and cleaning the bed rail on one side of the bed</td>
<td>In the hospital ward</td>
<td>0 m</td>
<td>0:37 min</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>14</td>
<td>Cleaning the undercarriage on one side of the bed</td>
<td>In the hospital ward</td>
<td>0 m</td>
<td>0:48 min</td>
<td></td>
<td></td>
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<td>15</td>
<td>Lifting up and cleaning the bed rail on the other side of the bed</td>
<td>In the hospital ward</td>
<td>0 m</td>
<td>0:36 min</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>16</td>
<td>Cleaning the undercarriage on the other side of the bed</td>
<td>In the hospital ward</td>
<td>0 m</td>
<td>0:50 min</td>
<td></td>
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</tr>
<tr>
<td>17</td>
<td>Taking down the bed rails on both sides</td>
<td>In the hospital ward</td>
<td>0 m</td>
<td>0:10 min</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
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<td>Location</td>
<td>Time</td>
<td>Notes</td>
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<tr>
<td>18</td>
<td>Removing all loose items off the bed table</td>
<td>In the hospital ward</td>
<td>0 min</td>
<td>0:30 min</td>
<td>1</td>
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</tr>
<tr>
<td>19</td>
<td>Spraying detergent and wiping off the bed table and draws</td>
<td>In the hospital ward</td>
<td>0 min</td>
<td>1:07 min</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Cleaning all of the electrical equipment (radio, alarm button etc.)</td>
<td>In the hospital ward</td>
<td>0 min</td>
<td>0:25 min</td>
<td>1</td>
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</tr>
<tr>
<td>21</td>
<td>Cleaning the patient wardrobe next to the bed</td>
<td>In the hospital ward</td>
<td>0 min</td>
<td>1:06 min</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>Removing the dirty apron and gloves, and washing hands</td>
<td>In the hospital ward</td>
<td>0 min</td>
<td>0:16 min</td>
<td>1</td>
<td></td>
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</tr>
<tr>
<td>23</td>
<td>Waiting for the bed and mattress to dry</td>
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<td>0 min</td>
<td>2:00 min</td>
<td>1</td>
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<tr>
<td>24</td>
<td>Getting clean bed linen from the wardrobe</td>
<td>Outside of the hospital ward</td>
<td>2 min</td>
<td>0:17 min</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>Making the bed</td>
<td>In the hospital ward</td>
<td>0 min</td>
<td>1:47 min</td>
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**Total bed cleaning time: 16:30 min**
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<th>Time (minutes)</th>
<th>People</th>
<th>Comments</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>Getting the laundry bag and cleaning material for the bed (detergent in a bucket with water and washcloth)</td>
<td>T</td>
<td>“Sköljen” (room for cleaning)</td>
<td>6m away from the hospital ward</td>
<td>0:57 min</td>
<td>1</td>
<td>Assistant nurse duty begins!</td>
</tr>
<tr>
<td>2</td>
<td>Putting on disposable gloves and apron</td>
<td>T</td>
<td>Department hallway</td>
<td>1 m outside the hospital ward</td>
<td>0:23 min</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Starting the cleaning process by removing bed linen off the bed, and loose items off the bed table</td>
<td>O</td>
<td>In the hospital ward</td>
<td>0 m</td>
<td>1:16 min</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Using detergent and wiping off the bed table and accompanying draws with washcloth</td>
<td>O</td>
<td>In the hospital ward</td>
<td>0 m</td>
<td>0:56 min</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Cleaning all of the electrical equipment (radio, alarm button etc.)</td>
<td>O</td>
<td>In the hospital ward</td>
<td>0 m</td>
<td>0:30 min</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Rising the bed to a more comfortable cleaning position</td>
<td>O</td>
<td>In the hospital ward</td>
<td>0 m</td>
<td>0:22 min</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Cleaning the reusable pil-</td>
<td>O</td>
<td>In the hospital ward</td>
<td>0 m</td>
<td>0:24 min</td>
<td>1</td>
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</tr>
<tr>
<td>Step</td>
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<td>Time</td>
<td>Code</td>
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<td>------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Cleaning the top part of the mattress</td>
<td>In the hospital ward</td>
<td>0 min</td>
<td>0:38 min</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Flipping the mattress over on one side and cleaning the bottom part</td>
<td>In the hospital ward</td>
<td>0 min</td>
<td>0:15 min</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Flipping the mattress over on the other side and cleaning the bottom part</td>
<td>In the hospital ward</td>
<td>0 min</td>
<td>0:18 min</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Cleaning the headboard and the footboard</td>
<td>In the hospital ward</td>
<td>0 min</td>
<td>0:31 min</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Lifting up and cleaning the bed rail on one side of the bed</td>
<td>In the hospital ward</td>
<td>0 min</td>
<td>0:26 min</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Cleaning the undercarriage on one side of the bed</td>
<td>In the hospital ward</td>
<td>0 min</td>
<td>0:35 min</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Lifting up and cleaning the bed rail on the other side of the bed</td>
<td>In the hospital ward</td>
<td>0 min</td>
<td>0:25 min</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Cleaning the undercarriage on the other side of the bed</td>
<td>In the hospital ward</td>
<td>0 min</td>
<td>0:39 min</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Taking down the bed rails on both sides</td>
<td>In the hospital ward</td>
<td>0 min</td>
<td>0:12 min</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Cleaning the headboard and the footboard</td>
<td>In the hospital ward</td>
<td>0 min</td>
<td>1:15 min</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
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<td>---</td>
<td>---</td>
<td>---</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>patient wardrobe next to the bed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Removing the dirty apron and gloves, and washing hands</td>
<td>O</td>
<td>In the hospital ward</td>
<td>0 m</td>
<td>0:12 min</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Waiting for the bed and mattress to dry</td>
<td>D</td>
<td>In the hospital ward</td>
<td>0 m</td>
<td>2:00 min</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Getting clean bed linen from the wardrobe</td>
<td>T</td>
<td>Outside of the hospital ward</td>
<td>2 m</td>
<td>0:22 min</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>Making the bed</td>
<td>O</td>
<td>In the hospital ward</td>
<td>0 m</td>
<td>1:31</td>
<td>1</td>
<td>Assistant nurse duty ends!</td>
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Total bed cleaning time: 14:07 min
## Assistant nurse medical clinic department C

<table>
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<tr>
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<th>Area</th>
<th>Distance (meters)</th>
<th>Time (minutes)</th>
<th>People</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Getting the laundry bag and cleaning material for the bed (detergent in a spray bottle and paper washcloths)</td>
<td>T</td>
<td>“Sköljen” (room for cleaning)</td>
<td>3m away from the hospital ward</td>
<td>0:38 min</td>
<td>1</td>
<td>Assistant nurse duty begins!</td>
</tr>
<tr>
<td>2</td>
<td>Putting on disposable gloves and apron</td>
<td>T</td>
<td>Department hallway</td>
<td>1 m outside the hospital ward</td>
<td>0:15 min</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Starting the cleaning process by removing bed linen off the bed, and loose items off the bed table</td>
<td>O</td>
<td>In the hospital ward</td>
<td>0 m</td>
<td>1:06 min</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Rising the bed to a more comfortable cleaning position</td>
<td>O</td>
<td>In the hospital ward</td>
<td>0 m</td>
<td>0:20 min</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Starting with cleaning the crane above the bed</td>
<td>O</td>
<td>In the hospital ward</td>
<td>0 m</td>
<td>0:33 min</td>
<td>1</td>
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</tr>
<tr>
<td>6</td>
<td>Spraying on detergent to clean the bed, pillow and mattress</td>
<td>O</td>
<td>In the hospital ward</td>
<td>0 m</td>
<td>0:28 min</td>
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</tr>
<tr>
<td>7</td>
<td>Cleaning the reusable pillow case</td>
<td>In the hospital ward</td>
<td>0 m</td>
<td>0:18 min</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Cleaning the top part of the mattress</td>
<td>In the hospital ward</td>
<td>0 m</td>
<td>0:44 min</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Cleaning the headboard and the footboard</td>
<td>In the hospital ward</td>
<td>0 m</td>
<td>0:24 min</td>
<td>1</td>
<td></td>
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</tr>
<tr>
<td>10</td>
<td>Lifting up and cleaning the bed rail on one side of the bed</td>
<td>In the hospital ward</td>
<td>0 m</td>
<td>0:31 min</td>
<td>1</td>
<td></td>
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</tr>
<tr>
<td>11</td>
<td>Lifting up and cleaning the bed rail on the other side of the bed</td>
<td>In the hospital ward</td>
<td>0 m</td>
<td>0:33 min</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Taking down the bed rails on both sides</td>
<td>In the hospital ward</td>
<td>0 m</td>
<td>0:10 min</td>
<td>1</td>
<td></td>
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</tr>
<tr>
<td>13</td>
<td>Spraying detergent and wiping off the bed table and draws</td>
<td>In the hospital ward</td>
<td>0 m</td>
<td>0:56 min</td>
<td>1</td>
<td></td>
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</tr>
<tr>
<td>14</td>
<td>Cleaning all of the electrical equipment (radio, alarm button etc.)</td>
<td>In the hospital ward</td>
<td>0 m</td>
<td>0:23 min</td>
<td>1</td>
<td></td>
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</tr>
<tr>
<td>15</td>
<td>Cleaning the patient wardrobe next to the</td>
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<td>0 m</td>
<td>0:58 min</td>
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<td></td>
</tr>
<tr>
<td>16</td>
<td>Removing the dirty apron and gloves, and washing hands</td>
<td>In the hospital ward</td>
<td>0:15 min</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Waiting for the bed and mattress to dry</td>
<td>In the hospital ward</td>
<td>2:00 min</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Getting clean bed linen from the wardrobe</td>
<td>Outside of the hospital ward</td>
<td>0:18 min</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Making the bed</td>
<td>In the hospital ward</td>
<td>1:43 min</td>
<td>Assistant nurse duty ends!</td>
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**Total bed cleaning time: 12:33 min**
### Assistant nurse medical clinic department E

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<th>Time (minutes)</th>
<th>People</th>
<th>Comments</th>
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<td>“Sköljen” (room for cleaning)</td>
<td>4m away from the ward</td>
<td>0:39 min</td>
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<td>Assistant nurse duty begins!</td>
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<tr>
<td>2</td>
<td>Putting on disposable apron</td>
<td>T</td>
<td>Department hallway</td>
<td>1 m outside the ward</td>
<td>0.23 min</td>
<td>1</td>
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</tr>
<tr>
<td>3</td>
<td>Getting material for cleaning</td>
<td>T</td>
<td>In the wardrobes outside of the hospital ward</td>
<td>2 m</td>
<td>0:48 min</td>
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<tr>
<td>4</td>
<td>Rising the bed to a more</td>
<td>O</td>
<td>In the hospital ward</td>
<td>0 m</td>
<td>0:22 min</td>
<td>1</td>
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<tr>
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<td>comfortable cleaning position</td>
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</tr>
<tr>
<td>5</td>
<td>Removing the bed linen</td>
<td>O</td>
<td>In the hospital ward</td>
<td>0 m</td>
<td>0:47 min</td>
<td>1</td>
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</tr>
<tr>
<td>6</td>
<td>Cleaning the reusable pillow case</td>
<td>O</td>
<td>In the hospital ward</td>
<td>0 m</td>
<td>0:21 min</td>
<td>1</td>
<td></td>
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<tr>
<td>7</td>
<td>Cleaning the top part of the</td>
<td>O</td>
<td>In the hospital ward</td>
<td>0 m</td>
<td>0:42 min</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>mattress</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>8</td>
<td>Flipping the mattress over on</td>
<td>O</td>
<td>In the hospital ward</td>
<td>0 m</td>
<td>0:21 min</td>
<td>1</td>
<td></td>
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<tr>
<td></td>
<td>one side and cleaning the bottom</td>
<td></td>
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</tr>
<tr>
<td>9</td>
<td>Flipping the mattress over on the</td>
<td>O</td>
<td>In the hospital ward</td>
<td>0 m</td>
<td>0:24 min</td>
<td>1</td>
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<tr>
<td></td>
<td>other side and cleaning the</td>
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<td></td>
<td>bottom part</td>
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<td></td>
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</tr>
<tr>
<td>10</td>
<td>Cleaning the footboard</td>
<td>O</td>
<td>In the hospital ward</td>
<td>0 m</td>
<td>0:10 min</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Activity Description</td>
<td>Location</td>
<td>Duration</td>
<td>Notes</td>
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</tr>
<tr>
<td>11</td>
<td>Lifting up and cleaning the bed rail on one side</td>
<td>In the hospital ward</td>
<td>0 m</td>
<td>0:35 min</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Cleaning the undercarriage on one side of the</td>
<td>In the hospital ward</td>
<td>0 m</td>
<td>0:43 min</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Lifting up and cleaning the bed rail on the</td>
<td>In the hospital ward</td>
<td>0 m</td>
<td>0:37 min</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Cleaning the undercarriage on the other side of</td>
<td>In the hospital ward</td>
<td>0 m</td>
<td>0:49 min</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Taking down the bed rails on both sides</td>
<td>In the hospital ward</td>
<td>0 m</td>
<td>0:12 min</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Removing all loose items off the bed table</td>
<td>In the hospital ward</td>
<td>0 m</td>
<td>0:28 min</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Spraying detergent and wiping off the bed table and accompanying draws with paper</td>
<td>In the hospital ward</td>
<td>0 m</td>
<td>1:19 min</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Cleaning all of the electrical equipment (radio, alarm button etc.)</td>
<td>In the hospital ward</td>
<td>0 m</td>
<td>0:28 min</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Cleaning the patient wardrobe next to the bed</td>
<td>In the hospital ward</td>
<td>0 m</td>
<td>1:13 min</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>Cleaning the lamp above</td>
<td>In the hospital ward</td>
<td>0 m</td>
<td>0:11 min</td>
<td>1</td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>Removing the dirty apron and gloves, and washing hands</td>
<td>O</td>
<td>In the hospital ward</td>
<td>0 m</td>
<td>0:12 min</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>Waiting for the bed and mattress to dry</td>
<td>D</td>
<td>In the hospital ward</td>
<td>0 m</td>
<td>0:00 min</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>Getting clean bed linen from the wardrobe</td>
<td>T</td>
<td>Outside of the hospital ward</td>
<td>2 m</td>
<td>0:22 min</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>Making the bed</td>
<td>O</td>
<td>In the hospital ward</td>
<td>0 m</td>
<td>1:45 min</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

**Total bed cleaning time: 13:51 min**
**Appendix 2**

**Prospective State Process Activity Map - Optimal Scenario**

Example: Medical department B.

Times are based on table 6 and the current state PAM maps together with assumptions of the prospective scenario. A patient being discharged triggers the prospective bed cleaning process.

<table>
<thead>
<tr>
<th>Number</th>
<th>Activity</th>
<th>Flow</th>
<th>Area</th>
<th>Distance (meters)</th>
<th>Time (minutes)</th>
<th>People</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Health care personnel calls bed central personnel to inform that an un-</td>
<td>C</td>
<td>Department B</td>
<td>0 m</td>
<td>00:25 min</td>
<td>1</td>
<td>Nurse or assistant nurse</td>
</tr>
<tr>
<td></td>
<td>clean bed is vacant and needs cleaning.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Bed central personnel informs service personnel</td>
<td>C</td>
<td>Bed central</td>
<td>0 m</td>
<td>00:30 min</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Service personnel walks to depart-ment B from the bed central.</td>
<td>T</td>
<td>Hospital hallways, elevators and department</td>
<td>210 m</td>
<td>03:45 min</td>
<td>1</td>
<td>Service personnel duty begins.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Assuming he/she starts from the bed central.</td>
</tr>
<tr>
<td>4</td>
<td>Service personnel picks up the bed and transports it to the bed central.</td>
<td>T</td>
<td>Ward, hospital hallways, elevators and bed central unclean area.</td>
<td>210 m</td>
<td>03:45 min</td>
<td>1</td>
<td>Service personnel duty ends.</td>
</tr>
<tr>
<td>5</td>
<td>Bed central personnel takes over and removes bed linen off the bed.</td>
<td>O</td>
<td>Bed central unclean area</td>
<td>0 m</td>
<td>01:05 min</td>
<td>1</td>
<td>Bed central personnel unclean ar-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>ea duty begins</td>
</tr>
<tr>
<td></td>
<td>Description</td>
<td>Location</td>
<td>Time</td>
<td>Process</td>
<td>Status</td>
<td></td>
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<td>------------------------------------------------------------------------------</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Bed central personnel transports the bed to the bed mattress disinfection system</td>
<td>T Bed central unclean area</td>
<td>5 m 00:10 min</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>The mattress is lifted up to the tilting table and led into the system.</td>
<td>O Bed central unclean area</td>
<td>0 m 00:15 min</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>The hospital bed is driven into the automatic in-feed of the bed disinfection system</td>
<td>T Bed central unclean area</td>
<td>2 m 00:15 min</td>
<td>1 Bed central personnel unclean area duty ends.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>The bed and mattress in the disinfection process</td>
<td>O In SEMI-STAAAL's system</td>
<td>0 m 02:30 min</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Bed comes out and is moved close to the mattress outfeed</td>
<td>T Bed central clean area</td>
<td>2 m 00:15 min</td>
<td>1 Bed central personnel clean area duty begins</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Clean mattress is flipped over on to the clean bed</td>
<td>O Bed central clean area</td>
<td>0 m 00:15 min</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Bed central personnel collects bed linen from wardrobe.</td>
<td>T Bed central clean area</td>
<td>5 m 00:20 min</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Bed is made</td>
<td>O Bed central clean area</td>
<td>0 m 01:45 min</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Service personnel is in-</td>
<td>O Bed central</td>
<td>0 m 00:25 min</td>
<td>1 Bed central personnel</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
formed that a clean bed can be transported back to department B

<table>
<thead>
<tr>
<th></th>
<th>clean area</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Service personnel collects the bed and transports it to department B and places it in the ward</td>
<td>Hospital hallways, elevators, ward and bed central clean area.</td>
<td>210 m</td>
</tr>
</tbody>
</table>

**Total process time: 19:25 min**
Appendix 3

Prospective Bed Flow Maps
Appendix 4

SEMI-STAAL Automatic Bed and Mattress Disinfection System

The SEMI-STAAL automatic bed and mattress disinfection system is divided up into two parts.

- The automatic bed disinfection system (7,7 m)
- The automatic mattress disinfection system (14 m)

The cleaning procedure of the bed starts with:

1. Automatic infeed system: This is where the hospital beds are rolled onto the infeed or conveyor (lifting) table where the bed continues into the washing cabinet.
2. Washing: Beds are washed in a closed zone (cabinet) with water from a water tank consisting of 1500 liters of water that is recycled and used during approximately a weekly period, thereafter new water is filled up again (H. Bugge-Hansen, personal communication, 2015-03-30). Thus, recycled water together with a chemo thermic disinfection detergent washes the beds at a temperature of + 61°C, which does not damage any electrical components. It is also worth mentioning that the hospital beds are exposed to a mechanical treatment from several nozzles in order to make sure that all areas of the bed are disinfected during the washing cycle.
3. Final rinse: This phase uses 15 liters of demineralized water or reverse osmosis water (recycled water) to rinse the bed at a temperature of + 81°C.
4. Drying: After the final rinse has been conducted the beds are dried with a powerful compressor system. The compressor provides self-heated and filtered air to a set of air knives that dry the bed as it moves through a separate drying chamber of the machine.
5. Automatic outfeed system: When the beds are dry they become automatically transported onto the discharge conveyor that lowers the bed onto the floor level into the clean area of the washing facility.

The cleaning procedure of the mattress starts with:

1. The mattress being placed horizontally on the tilting table where it becomes automatically lifted into a vertical position, and later on transported into the machine.
2. Rough particles get brushed off and the mattress gets sprayed with detergents on both sides while the brushes are working. This needs to be done before the mattress can enter the SonoSteam disinfection chamber.
3. While the bed is in the SonoSteam disinfection chamber the ultrasound activates the laminar layer of the mattress and breaks it up so that the steam can work its way through the microstructure of the PU-membrane and eliminate all bacteria. This part of the cleaning process takes only 25 seconds since microorganisms are small and therefore easy to warm up and kill at a temperature of +130°C. Furthermore,
the steam does not damage the mattress since it only enters a few micrometers into the surface.

4. Afterwards, the mattress gets dry through the use of a compressor system much like the one for the drying of beds.

5. Later on the mattress gets automatically transported to the outfeed, in other words clean area, ready to be matched with the accompanying bed.
Appendix 5

Recommendations for Länssjukhuset Ryhov

In this part, the authors wish to share their ideas and recommendations that were raised through the course of this research with the main party of interest, Länssjukhuset Ryhov. In order to support the hospital’s future transition from a decentralized to a centralized bed reprocessing procedure, solutions for critical elements that concern the bed management will be provided.

As mentioned previously, there are several elements to consider in this change process. Firstly, the future bed central location has to be determined. The authors therefore selected a suitable area that could withhold the automatic bed disinfection system and provide adequate surface for the surrounding clean and unclean zones. The recommended location is situated at floor level two at a central site with a close proximity to bed elevators, spacious hallways, and the hospital’s bed workshop. Nevertheless, restructuring of this location will be needed to suit the implementation of SEMI-STAAL’s automatic bed and mattress disinfection system. For instance, a wall needs to be constructed to separate the clean and unclean zones of the bed central and the whole area needs to be isolated in order to reduce the noise level produced from the machine.

Furthermore, the logistics concerning the beds are reliant upon the opening hours of the bed central. The findings from this study revealed that the busiest hours for patient discharges are between 09:00-17:00. Therefore, the authors recommend that the bed central should be open during this high traffic time during the day. Important to note is that the major traffic hours presumably occur between 10:00-14:00 and therefore an extension of personnel resources and increased used of the bed stock will be necessary.

Concerning the personnel, it is highly advisable to have at least two employees in the bed central working in each zone. In terms of the bed transportations, these will be designated to another professional group currently working at the hospital, this task will most likely be dispersed throughout the existing service personnel workforce. Regarding the future flow of beds, suggestions have been provided in appendix 3 on how such transportations can be performed from five critical departments at the hospital to the bed central. These flow maps further indicate which bed elevators and major hallways that often will be used in the routes from various locations at the hospital. Time and distance measurements disclose that the times for the whole process of cleaning a bed at the bed central do not differ significantly from the time it currently takes to clean the beds manually.

In terms of the hospital beds, the current bed pool is in need of upgrading. Only 250 out of 685 hospital beds are qualified to be handled by SEMI-STAAL’s automatic bed and mattress disinfection system, due to the lack of the IP 66 qualification and the existing holes in the bed frames. Additionally, the entire centralized bed reprocessing would become smoother if all beds were of the same sort. The authors further suggest that the current bed pool should be exploited more during high traffic times or when excess demand occurs.
Otherwise, an optimal flow of the remaining beds should be advocated first hand to allow for one joint, efficient flow.

Concerning the use of technology, the authors recommend Länssjukhuset Ryhov to incorporate an RFID system together with SEMI-STAAL’s automatic bed and mattress disinfection system. A reliable and real-time tracking of the hospital beds is required before an implementation of the system can commence, in order to track each bed and attain detailed information upon request. This will reduce the risk of misunderstanding and misallocation of beds and allow for a more responsive behavior in the patient care.
Appendix 6

Interview Guide

Preparation for all interviews:
- Retrieve background information of the medical clinic’s departments via emails
- Send out interview guides to interviewees
- Tools: smartphone audio recording, notebook

Interview questions - assistant nurses
1. How do you receive information that a bed needs to be cleaned?
2. How long does it take from when a patient vacates the bed until it is cleaned?
3. Is there a person responsible for informing and making sure that the bed cleaning process is properly conducted?
4. How did you learn to perform the bed cleaning procedure?
5. Are there any formally guidelines that you can follow?
6. Do you know what kind of results should be accomplished from the bed cleaning procedure?
7. Does the outcome of the current bed cleaning procedure reach a desired level of quality?
8. How do you perceive the physical aspect of the bed cleaning procedure, does it affect your working environment?
9. Does the current bed cleaning procedure become a stressful event in the everyday working environment, and do you feel like you have time to properly clean the bed without any interruptions?
10. During what hours of the day is the bed cleaning procedure most commonly conducted?
11. In case of a possible implementation of a centralized mechanical cleaning procedure, do you believe that it will contribute to an improved cleaning quality?
12. Do you believe that a standardized cleaning instead of a manual one contributes to fewer HAIs?
13. Furthermore, the implementation of a bed central will result in increased bed transportation throughout the hospital. Do you believe that it would become a disturbing factor for both patients and personnel, or will it contribute to an improved situation?

Interview questions - heads of departments
1. Does the outcome of the current bed cleaning procedure reach a desired level of quality?
2. How does the assistance nurse receive information that a bed needs to be cleaned?
3. Is there a person responsible for informing and making sure that the bed cleaning process is properly conducted?
4. Is there any training or mentoring conducted for nurses at the hospital concerning the bed cleaning procedure?
5. Are there any evaluations conducted concerning the quality of the current bed cleaning procedure?
6. In terms of ergonomics, how do you perceive the physical aspect of the bed cleaning procedure, does it affect the health professionals’ working environment?
7. In case of a possible implementation of a centralized mechanical cleaning procedure, do you believe that it will contribute to an improved cleaning quality?
8. Do you believe that a standardized cleaning instead of a manual one contributes to fewer HAIs?
9. Furthermore, the implementation of a bed central will result in increased bed transportation throughout the hospital. Do you believe that it would become a disturbing factor for both patients and personnel, or will it contribute to an improved situation?
10. During what hours of the day is the bed cleaning procedure most commonly conducted and between what hours do you believe a bed central should be in operation?
11. Does the hospital currently employ any communication or software system to track each department’s beds? Does it occur that the beds are misallocated at other departments?

**Interview questions – Sales Manager at SEMI-STAAL**

1. What is SEMI-STAAL’s vision with the automatic bed and mattress disinfection system?
2. What kind of hospital beds is this machine capable of cleaning? Is there any risk that the water from the system negatively affects electrical components and metal parts of the bed?
3. Should the personnel in charge of the bed central possess any special skills or knowledge in order to handle the system? How many employees are required to maintain the system?
4. What is the surface area required to host the bed washing system?
5. Have you conducted any measurements or evaluations concerning the quality of cleaning comparing the automated cleaning process to the manual cleaning?

**Questions concerning Hvidovre Hospital**

6. When did Hvidovre implement the automatic bed disinfection system?
7. What are the opening hours of the bed central at Hvidovre Hospital?
8. What does Hvidovre do when the bed central is closed and hospital beds are waiting to be cleaned?
9. How many people work in the bed central? Do they use other personnel for the transportation of beds?
10. What kind of tracking, if any, does the hospital use to track the beds?
11. How long time is the overall process from when a hospital bed is vacated until it is clean and back at the department ready for a new patient? (Cycle-time)
12. Has Hvidovre experienced any issues or break-downs concerning the machine during its time at the hospital?
13. Where in the hospital is the bed central located?
14. Is it enough with one bed central for the entire hospital?
15. Has the hospital observed a reduction in health-care associated infections since the implementation of the bed washing system?
16. Does Hvidovre have a pool of hospital beds ready for use in case there is a shortage of beds? Or is the bed flow reliant on the beds in circulation?
17. In terms of the health care personnel, has the system resulted in improved working conditions for them?
18. Are the personnel and the patients affected by the noise level of the automatic bed disinfection system?

**Interview questions – Development Manager at Länssjukhuset Ryhov**

1. What is Länssjukhuset Ryhov’s vision with implementing a centralized mechanical bed cleaning procedure? What objectives does the hospital want to reach?
2. In your opinion, what are the biggest challenges for patient safety at hospitals?
3. What professional group is considered to take charge of the transportation of beds and the bed central?
4. What is the amount of discharges per day/week/month at Länssjukhuset Ryhov?
5. Are there any concrete plans for the future facility layouts and reconstruction of the hospital that we can take part of?
6. Would the hospital’s facility be ready for increased bed transportations and are there sufficient amount of bed elevators capable of supporting a bed flow?
7. What types of hospital beds does the hospital currently utilize and is there a bed pool that can be used as a backup when necessary?
8. During what hours of the day is the bed cleaning procedure most commonly conducted at the hospital and between what hours do you believe a bed central should be in operation?