Production control in hospital departments

Improving coordination through better optimization of IT-support tools at Astrid Lindgren Children’s Hospital, a Case Study at the Pediatric Oncology department

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Abstract
A challenge for healthcare organizations is that operational efficiency suffers from variation in production. This is because variation in healthcare is hard to predict and the methods and IT-support tools for handling variation are suboptimal. The concept of production control can be used to describe the coordination of activities so that healthcare can be delivered on time, of adequate quality and at a reasonable cost, and thus includes the use of IT-support tools to handle variation.

The objective of this report is to suggest improvements for production control in hospital departments through the development of a prototype for a new IT-support tool. In order to achieve this, a case study was conducted at the pediatric oncology department at Karolinska University Hospital (KS). The case study includes observations and interviews to investigate production control at department Q84, as well as associated roles and IT-support tools.

Four IT-support tools were identified at the department, two of which were used interchangeably. Due to lack of integration between these systems and the fact that one system contained data manually synchronized from the other, handling changes required double labor. An improvement suggestion is therefore presented, consisting of a prototype which demonstrates that production control can be improved by automating the maintenance of a system at the department while fulfilling the organization’s information security policy. The development of the prototype was aligned with the lean philosophy which KS strives to adopt.

Through an investigation of the production system, a role for production control and associated IT-support tools at a hospital department can be identified and analyzed and through the prototyping of an IT-support tool for production control, improvements and optimizations can be made.

Keywords: Production, Production control, healthcare, hospital departments, Lean, IT, IT-support tools
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1. Introduction

In this chapter the background to this project is introduced, including an introduction to the problem with variation in healthcare and why the concept production control can be applied to the healthcare industry. This is followed by the problem formulation, research objective and the research questions which go deeper into associated functions and methods for production control. Delimitations and report structure are also presented in the end of this chapter.

1.1 Background

A great challenge many healthcare organizations face today, is that operational efficiency is adversely affected due to variation in the production process. This is based on that variation in demand can be hard to predict and that the methods for handling variation can be suboptimal (Scheutz et al., 2014). To handle variation in a production process and to ensure that production plans are carried out, production control can be used (Francis, 2012; Slack et al., 2010). Production control is often facilitated by a role tasked with ensuring that production flows without incident and reacting to problems that occur in the process (Easley, 2014; McKay & Wiers, 2004), which can be achieved through the use of IT-support tools (Olhager & Wikner, 2000; Butler et al., 1996).

The term production is perhaps not the most associated description of the work performed by doctors and nurses at hospitals and healthcare organizations. However, looking at the term of production, it can be perceived in at least three different ways: as a process converting inputs to outputs, or as a flow of materials and information through time and space, or as a process of generating value for customers (Ballard, 2000). Health can be recognized as the general condition of an individual’s body (Health, 2014), and as health depends on a number of factors, which some can be influenced by the individual, it can be produced (Machado, 2014). Hence, healthcare delivered by hospitals can be categorized using the concept of production.

Healthcare is one of the largest service industries in the world, and is facing increasing challenges linked to economical sustainability due to increasing societal healthcare costs. These costs are derived mainly from areas such as: the aging of population and related healthcare needs, an increase in chronic disease among the population, as well as high costs for developing new technology in combination with the population’s increasing expectation on the quality level of healthcare (Boone, 2012; Mohrman & Shani, 2012; Zhang et al., 2010).

To respond to the negative transformation pressure coming from these increasing needs, costs and expectations, organizations in healthcare have used various philosophies, strategies and tools to increase their operational efficiency, the quality of the medical care, as well as cutting costs (Källberg, 2013). For example, New Public Management (NPM) emerged in the early 1990’s and was applied to healthcare to improve quality and patient safety and empowerment, as well as to reduce costs (Anell et al., 2012). Another concept that was introduced around the same time was Total Quality Management (TQM), mainly to increase the quality level of delivered care (Lim & Tang, 2014). Business Process Reengineering (BPR) is another example of an improvement initiative taken (Källberg, 2013). Further, many of the healthcare organizations today use Lean as a source of inspiration for
increasing the quality of healthcare as well as increasing efficiency (Teich & Faddoul, 2013). This is done by lowering waste and improving the flow efficiency of the organization while at the same time handling the tradeoff between high resource utilization and high flow efficiency (Modig & Åhlström, 2012; Berwick & Hackbarth, 2012).

Working with efficiency in healthcare presents challenges, and employees sometimes interpret the efforts as detrimental to the quality of their services and patient security (Källberg, 2013). Another challenge comes from the fact that healthcare cannot be produced and stocked up on shelves to be delivered when it is later requested, it needs to be produced and delivered on demand when a person needs it. Thus, one essential function required to successfully deliver healthcare is the systematic coordination and directing of activities to ensure that delivery occurs on time, of adequate quality and at a reasonable cost, i.e. efficient production control (Production control, 2014). Production control is carried out by a role dedicated to production control, and the responsibilities include acting as an information hub and real-time problem solving (McKay & Wiers, 2004).

The research on production control within healthcare is in an immature state where focus lies on detailed methods including implementations of complex standardized resource planning systems, which is inconsistent with the needs of healthcare organizations (Plantin & Johansson, 2012). It has been demonstrated that it is possible to align production control with the needs in healthcare through simplified models and a focus on understanding the scheduling and planning process (ibid).

One of Scandinavia's premier healthcare facilities is Karolinska University Hospital (KS) (About Karolinska, 2014). KS has had success in working with lean initiatives during recent years, and the organization is undergoing changes in the operations of their departments (Lean healthcare, 2014). At KS there are many departments with specialized care that often have a limited amount of beds and a lot of variation in production activities. These departments often have a role for coordination which is tasked with handling these activities on a daily basis, shouldered by a nurse at the department using numerous IT-support tools and systems. Specifically, the department for childhood cancer, the Pediatric Oncology department (Q84), has a limited capacity of 8 beds, with overcrowding possibilities of 2 extra beds. The department also has issues due to the large amount of variation that comes from the stochastic nature of cancer treatments. This, in combination with suboptimal IT-support tools, results in inefficient and problematic scheduling and creates a stressful environment for the coordination role at the department (Scheutz et al., 2014).

1.2 Problem formulation
In all types of production a common challenge is to handle variation while delivering high quality on time and at a reasonable cost, and it can be problematic to handle the tradeoff between high resource utilization and high flow efficiency. At department Q84, the pediatric oncology department, there is a situation with limited capacity and a lot of variation which is problematic due to suboptimal IT-support tools. The effects manifest themselves in stress for the coordinators, reduced flow efficiency as well as a perceived risk that patient security is affected.
1.3 Objective
The objective of this project is to suggest improvements for production control in hospital departments through the development of a prototype for a new IT-support tool aligned with the Lean philosophy that the organization strives to adopt.

1.4 Research questions
To understand how to improve production control in hospital departments, the current methods for production control must be identified. Further, roles and IT-support tools used for production control must be identified as well. This identification enables the formulation of improvement suggestions regarding the IT-support tools. In order to achieve this, three research questions are formulated:

- How are roles for production control in hospital departments specified?

In order to answer this question a greater understanding of the concept of production control is necessary. This is achieved through a literature review of the concept area and through interviews at the department, as well as complimentary interviews at other departments. After answering the question of how a role for production control can be specified, the IT-support tools used by the role must also be identified. This leads to the second research question:

- What IT-support tools exist today and what needs do they fulfill?

This question is answered through observations of the daily activities of the coordinator at department Q84, as well as interviews at the department and complimentary interviews at other departments. The answer to this question creates an understanding of the current situation which is required in order to answer the third research question which is:

- How can the IT-support tools be optimized?

This question is answered through combining interviews at department Q84 and complimentary interviews at other departments with an understanding of the existing literature on the subject. The answer to this question leads to a specification of requirements for a functional prototype.

1.5 Delimitations
The time frame of this project is 20 weeks, and a case study is conducted during 16 weeks at KS in Solna at the pediatric oncology department (Q84). The observations are delimited to department Q84 and the IT-systems related to production control.

Production control is often associated with production planning, however the decision horizons differ as production control is more about day-to-day activities while production planning is more about forecasting and prediction. Hence this project is more focused on production control.

Within the concept of production control exists complex resource planning systems that can be implemented, such as Material Requirements Planning (MRP I/II) and Enterprise Resource Planning (ERP) systems. These will not be investigated in this
project since initial research show that healthcare can benefit more from an understanding of the concept and the usage of simplified methods.

1.6 Report structure
The rest of the report is structured as such: a walkthrough of the methodological approach taken in this project is accounted for in chapter 2, which includes details on chosen methods. A theoretical framework serves as a knowledge base for the argumentation and is presented in chapter 3. In chapter 4 follows a presentation of the case study conducted in this project. The case study is then analyzed in chapter 5 in order to form a basis for discussion and conclusions on the subject. Chapter 6 includes a discussion regarding the project, including managerial implications and suggestions for future research. Finally, chapter 7 presents the conclusions drawn from this project. An illustration of the disposition of the chapters is presented below in figure 1.

![Figure 1: Report disposition](image-url)
2. Methodology
This chapter introduces the methodology chosen when performing this research. In order to identify current methods for production control in hospital departments, associated roles and IT-support tools, as well as to suggest improvements, a case study divided in two phases was conducted at department Q84. The case study is based on the interpretivist paradigm, focusing on the collection of qualitative data. The data was gathered through observations and interviews, and is analyzed in relation to a theoretical framework which consists of relevant concepts to the area of production control. The research can be considered applied research since the results included the development of a functional prototype, intended for implementation at department Q84 (Collis & Hussey 2009).

2.2 Theoretical Framework
To build a strong foundation for the research, a theoretical framework was created through a literature review of the subject area. The theoretical framework consists of relevant theories and models applicable to the research areas used in this report, and is based on literature found using the KTH library search engine Primo as well as Google Scholar. During the literature review the following keywords or phrases were combined and used when searching for literature: Healthcare, lean, production, production control, variation, IT.

2.3 Case study
The case study was conducted at department Q84 and spanned over a period of four months from January to May 2014. The time frame of the case study enabled the use of observations and interviews, as well as informal encounters with employees at department Q84.

2.3.1 Phase one - investigation
Phase one of the case study included an investigation of the current methods and tools for production control at department Q84. Since production control includes the systematic coordination and directing of activities, the role of coordinators at department Q84 has been chosen as the unit of investigation to specify a role for production control.

To identify a role for production control and relating methods and responsibilities, observations and interviews were conducted with coordinators at the department. Data was used to identify processes and ways of working in relation to existing IT-support tools. Further, the needs of the department in regards of IT-support tools were identified and current IT-support tools were investigated in order to find potential for improvement, as well as to identify potential risks and problems with existing tools and methods. Associated work processes were described in relation to the IT-support tools and thus created an overview of the flow of information in relation to the role for production control. Since phase two involved the development of a prototype for a new IT-support tool, a specification of requirements for the prototype was formulated based on the findings from phase one.
**Observations**
Observations were carried out in a natural setting at the department in order to be able to identify a role for production control and investigate its associated problems in the context where they normally exist (Zikmund et al., 2010). Due to the stressful nature of the coordinators at the department and to preserve the natural behavior of the one carrying out the work, observations were made without participation. This also served to minimize impact on the observed individual by the observers. As the observations were performed in a hospital environment, recordings were prohibited. In order to increase validity of the observations, investigator triangulation was used, which is the use of more than one investigator while performing the observations (Guion et al., 2011; Thurmond, 2001). The investigators observed individually and compared notes and experiences from the situation afterwards, which lends greater credibility to the findings from the observations (Thurmond, 2001). This type of investigator triangulation minimizes bias and contributes to understanding the observed phenomenon (ibid). One potential disadvantage of triangulation can be that it is time-consuming and requires more extensive planning. However, considering the scale and time-span of this project, the benefits were considered to outweigh the potential disadvantages (ibid).

By conducting observations in this manner, the researchers were able to gain insights into aspects which can be difficult to articulate (Zikmund et al., 2010). The observations comprised two full days of observation conducted on 20 and 21 January 2014. As the observation data was collected during two days, the data might not fully represent the general state of the department and therefore these initial observations were complemented by additional shorter informal observation sessions, as well as follow-up interviews, conducted between January and April 2014.

**Interviews**
In order to identify a role for production control, the results from the initial observations were verified by conducting interviews with the coordinators at department Q84, and crosschecked with theory on how a role is defined. After identifying a role for production control, semi-structured interviews which included open-ended questions were conducted with the employees responsible for shouldering the role. These were centered on themes regarding how they perceived the usefulness of IT-support tools, and how they experienced associated work processes. The main advantage of this approach compared to more structured interviews was the ability to address more specific issues through follow-up questions based on the responses as well as the insights gained from the initial observations (Cohen & Crabtree, 2006). Also, the researchers’ experiences from the observations were presented and discussed during these interviews, where the coordinators could supplement the information and verify or deny observed details regarding the work processes, thus increasing validity (Zikmund et al., 2010). The persons interviewed in this project can be seen in table 1 below. The interviewee titles will be used to refer to the interviews in the text.
Table 1: Persons interviewed in the project

<table>
<thead>
<tr>
<th>Interviewee title</th>
<th>Date(s) and location</th>
<th>Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nurse A</td>
<td>16 January 2014, Solna, Sweden</td>
<td>Nursing assistant and IT-administrator at department Q84</td>
</tr>
<tr>
<td>Nurse B</td>
<td>14 January 2014, Solna, Sweden</td>
<td>Nurse and coordinator at department Q84</td>
</tr>
<tr>
<td></td>
<td>29 January 2014, Solna, Sweden</td>
<td></td>
</tr>
<tr>
<td></td>
<td>17 February 2014, Solna, Sweden</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4 April 2014, Solna, Sweden</td>
<td></td>
</tr>
<tr>
<td>Nurse C</td>
<td>27 January 2014, Solna, Sweden</td>
<td>Nurse and coordinator at department Q84</td>
</tr>
<tr>
<td></td>
<td>5 February 2014, Solna, Sweden</td>
<td></td>
</tr>
<tr>
<td></td>
<td>12 February 2014, Solna, Sweden</td>
<td></td>
</tr>
<tr>
<td>Doctor A</td>
<td>5 February 2014, Stockholm, Sweden</td>
<td>Doctor at Center for Technology in Medicine and Health (CTMH)</td>
</tr>
<tr>
<td>Business Developer A</td>
<td>5 February 2014, Solna, Sweden</td>
<td>Strategic Business Development at KS</td>
</tr>
<tr>
<td></td>
<td>6 May 2014, Solna, Sweden</td>
<td></td>
</tr>
<tr>
<td>Business Developer B</td>
<td>5 February 2014, Solna, Sweden</td>
<td>Strategic Business Development at KS</td>
</tr>
<tr>
<td>Information Security Coordinator A</td>
<td>21 February 2014, Solna, Sweden</td>
<td>Information Security Coordinator at KS</td>
</tr>
<tr>
<td>Information System Developer A</td>
<td>26 March 2014, Stockholm, Sweden</td>
<td>Enterprise Information Systems at KS</td>
</tr>
<tr>
<td>Information System Developer B</td>
<td>26 March 2014, Stockholm, Sweden</td>
<td>Enterprise Information Systems at KS</td>
</tr>
</tbody>
</table>

The interviewees were selected based on their competence in relation to the subject of the project. The nursing assistant was selected because of his role as IT-administrator, which meant that he had the overall responsibility for IT-support tools at the department. The nurses were selected because they were the ones shouldering the role which had been chosen as the unit of investigation for identifying a role for production control, and they were the ones most actively using the IT-support tools. They are also the ones that are affected the most by the outcomes of this project. A doctor was interviewed to help the researchers gain a better understanding of the treatment process at hospital departments, patient flow, as well as specifics that relate to the daily operations at department Q84. The members of the department for Strategic Business Development at KS were interviewed because they have been working on developing IT-support tools inside the organization of KS and makes sure they are aligned with lean. The information security coordinator has a large role of coordinating efforts to improve information.
security and was therefore interviewed for his experience in IT-projects at KS. The Enterprise Information Systems department is responsible for the systems handling all types of patient data at KS and will therefore need to participate in the implementation of the prototype.

**Process mapping**

To investigate daily operations and identify processes and tasks relating to the role for production control, process mapping was used. Process mapping is a way of visualizing the steps in a process so that problems and possibilities for improvement become visible. Process mapping is not to be considered an improvement tool by itself (Carlsson, 2004), but rather it’s a way to visualize and propose changes that might improve processes. Data from observations and follow up interviews was used for mapping processes relating to the role, and the aim was to fully understand the performance and flexibility of the processes, as well as to identify bottlenecks and non value-adding steps. Background research is crucial in order to gain the information required to correctly map a process. The individuals involved in working with the process are the ones with the greatest knowledge of its performance and quirks, implying that good process mapping begin with the practitioners of the process (ibid).

Process mapping consists of five major parts: process identification, data gathering, interviewing and map generation, analyzing the data, and presentation (Jacka & Keller, 2009). These steps have guided the process mapping and identification of the tasks and responsibilities of the role for production control.

**Complementary interviews**

Interviews with head nurses from the department for kidneys, livers and bone marrow transplantation (B78) and from the department for acute care (Q80) at KS were used for comparison, to show how other departments deal with production control. These interviews also serve to show how broad the applicability of the prototype is, since if possible, the prototype should fulfill the needs of more departments than just Q84 and be flexible enough to be further developed in the future to serve additional needs and departments. The complementary interviews are shown in table 2 below, and their respective titles will be used to refer to the interviews in the text.

**Table 2: Complementary interviews**

<table>
<thead>
<tr>
<th>Complementary title</th>
<th>Date(s) and location</th>
<th>Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head Nurse A</td>
<td>20 March 2014, Huddinge, Sweden</td>
<td>Head nurse at the department for kidneys, livers and bone marrow transplantation (B78)</td>
</tr>
<tr>
<td>Head Nurse B</td>
<td>16 April 2014, Solna, Sweden</td>
<td>Head nurse at the department for acute care (Q80)</td>
</tr>
</tbody>
</table>
Prototype requirements specification
In order to facilitate the development and implementation of the prototype, the findings from phase one of the case study were analyzed and summarized into a specification of the requirements on the prototype. The specification was further discussed during interviews with the coordinators at department Q84 to validate the requirements. Further interviews were conducted with the departments for Information Security, Strategic Business Development and Enterprise Information Systems at KS in order to ensure that the development of the prototype would be sustainable and aligned with common practice at the organization. These interviews also served to enable early identification of issues that relate to the development of the prototype.

2.3.2 Phase two - development
Phase two of the case study included the realization of potential improvements in relation to the role and IT-support tools for production control identified in phase one. Knowing the needs of the department and having a clear picture of the responsibilities and activities of the role, changes are ensured to fulfill an actual need. The second phase included the development of a functional prototype of an IT-support tool which was to be implemented at department Q84 after the project was finalized.

End user involvement
Interviews have been conducted continuously during the project, also overlapping into phase two. These interviews have been of different length and varying in structure, but the main theme is that interviews have been semi-structured and focused on elaborating on the experiences of the interviewee with the goal of understanding what demands will be placed on the prototype. Through these interactions, ideas that surfaced during development could be discussed and quickly implemented or rejected. By involving the intended user(s) of the prototype in the development, significant benefits in terms of increased quality, delivery reliability and innovation speed can be gained (Carbonell et al., 2009; Feng et al., 2010), and end user involvement was therefore a continuous theme in the development of the prototype.
3. Theoretical framework

In order to build a solid base for analysis and argumentation, a literature study is conducted, consisting of books and articles relating to the subject areas of production control and associated concepts. This chapter presents the major findings from the literature and elaborates on factors that will influence the case study in this project. The concept of lean is presented and its implications for roles for production control are discussed. Further, in order to understand the production control methods and its associated IT-support tools that are investigated in the case study, concepts and theories on production control are presented, and implications for successful production control in hospital departments are discussed. Also, the concept of variation in production and its implications for production control in healthcare organizations are discussed. The theoretical framework ends with an extensive summary pinpointing the most important aspects of the concepts presented with the purpose of facilitating the analysis in this project.

3.1 Lean

According to the department for Strategic Business Development at KS, the organization has had success in working with lean initiatives during recent years, and the organization has undergone extensive changes, introducing new ways of working and new ways of thinking based on continuous improvements and flow processes according to the lean methodology (Business Developer B; Lean healthcare, 2014). As this project will provide suggestions for improvement, it is important to cover the basics of lean and ensure that the project outcome is aligned with current practices and policies in the organization. Characteristics of Lean initiatives at KS are reflected in the book by Modig and Åhlström (2012), “This is Lean” (Business Developer B), and the book will therefore form the basis for the Lean part of the theoretical framework.

Lean as a concept has as many interpretations as there are implementations, effectively making it difficult to realize. However, the main principles of lean are well established: continuous improvement, waste removal and increasing flow efficiency of operations (Modig & Åhlström, 2012), and these align with the goals of implementing lean at KS according to the department for Strategic Business Development (Business Developer B). Continuous improvement is an important aspect of lean, as whether an organization “is lean” can only be seen by looking at the organization at two different points in time (Modig & Åhlström, 2012). This importance can be exemplified with a quote by a legendary manager at Toyota. When visiting a European engineering company he was asked whether the organization was lean or not. To this he simply answered “it is impossible for me to say, I wasn’t here yesterday” (Modig & Åhlström, 2012, p. 149). Further, realizing a lean operations strategy is about creating an organization that continuously improves, increases its flow efficiency and reduces its waste. Reducing waste is mainly a means for achieving higher flow efficiency, as wasteful work hinders efficient production flow (McKay & Wiers, 2004).

3.1.1 Resource efficiency and flow efficiency

The reasoning behind resource efficiency is that if an organization spends money on acquiring a resource, it should be utilized as much as possible (Modig & Åhlström, 2012). Resource efficiency can be measured by how much a resource is used in relation to a specific time frame. If a resource is utilized all the time, it will be
considered 100% resource efficient. Economically it is easy to rationalize a focus on resource efficiency, due to opportunity costs. Opportunity costs occur when a resource is standing still and thus not being utilized to the fullest (ibid).

According to Modig and Åhlström (2012), flow efficiency contradicts the traditional focus on efficient utilization of resources, by focusing on the flow unit which is processed in the organization. In manufacturing, the flow unit could be a product consisting of different parts that are handled at different stages to become the final product. In services it is often the customer which flows through the production processes of an organization, and in healthcare it is the patient. Flow efficiency can be measured by how large portion of the time spent in the process the flow unit receives value. This type of efficiency is completely focused on the flow unit and the main factor is how much time out of the total time is value adding for the flow unit. The reasoning is that flow units should pass smoothly through the processes in the organization and receive value during as much of the time as possible (ibid).

For traditional reasons many organizations today focus on resource efficiency over flow efficiency whether they are aware of it or not (ibid). The goal is often to utilize all available capacity, which from an economic standpoint is sound, but it creates other problems and side-effects which can be detrimental to customers as well as the organization and its employees (ibid). Keeping a resource utilized 100% of the time leaves no margin to handle problems that can occur, which in the long run leads to secondary needs (ibid). One example of how these secondary needs can manifest themselves is if for example a patient has to wait for a treatment, he or she may need additional treatments to handle complications that appear as a direct result of the wait. Also, in the case of the resource being a person, that person has no time to reflect on performance and how to improve. Since lean is about continuous improvement, it inherently requires a drop in resource efficiency to facilitate improvements in flow efficiency.

3.2 Production in healthcare
According to Machado (2014), health can be produced. Since it can be produced, it can be considered the result of the production process in hospitals and healthcare organizations, which is healthcare. Because of this, the concept of production and surrounding concepts can be used when categorizing and studying healthcare. Production is carried out in the context of the organization which can be described as the production system. Thus, in order to understand implications for production, the production system must be described.

3.2.1 Production systems
A healthcare facility uses a different production system than a factory which for example manufactures small plastic parts (Segerstedt, 2001). The major difference between production systems in different organizations is the degree to which the production or material flows through the organization. While flow is something that can be improved through for example lean initiatives (Modig & Åhlström, 2012), it is also a basic inherent characteristic of a production system. The levels of inherent flow can be graded as follows (Segerstedt, 2001):

- Continuous production (high flow rate)
- Constantly repeating series of production
- Rarely recurring series of production
• One or a few units rarely recurring (low flow rate)

Continuous production is when the finished output is made from the organizations input sources in a continuous process without interruptions (Continuous production, 2014). The other extreme where one or a few units are rarely recurring implies a customization aspect of production where all production is customized and tailored to the customer, thus creating a more discontinuous flow of production (Segerstedt, 2001).

According to Segerstedt (2001), production systems can be further characterized based on whether production is considered divergent or convergent. Divergent production is most easily described as when the organization has one main input source for materials or clients, from which it creates several output products or services, such as in sawmills producing several types of planks. Convergent production on the other hand is when the organization puts several input sources such as materials or components together to result in one main output product or service (such as in car manufacturing). Convergent production requires timing in order to have required resources available in the order they are needed and at the correct time.

Layout of production can also be used to characterize and describe the production system (ibid). Organizations utilizing a process layout focus on the utilization of resources used in the production process, leading to grouping of resources and that the unit in process is transported to the resources for further processing. Conversely, with a product layout the unit “flows” through the production system and is continuously processed from input to output product or service. In contrast to a process layout, a product layout tends to lead to positioning of resources in a sequence which promotes the continuous value adding while processing the unit. Organizations striving for high flow efficiency will try to combine the benefits of process and product layout to achieve high resource utilization while still continuously adding value to the unit in process (ibid).

3.3 Variation in production

When striving to improve flow in a production system, one important characteristic of the system is how variation affects it as there can never be two identical actions resulting in the exact same outcome. Thus, variation is inherent in all forms of production, whether it is healthcare or manufacturing (Variation, 2014). Variation is the changes that occur either to the product or to the process of production and being unprepared for variation, or simply identifying the wrong source of variation, can lead to situations where the scheduling and planning of the production becomes detrimental to production (Litvak & Long, 2007).

Predicting or forecasting the variation in a process within set limits can be accomplished through statistical measures of the process over time (Variation, 2014). However even when the behavior of a process can be predicted with a certain amount of precision, it is necessary to be prepared to handle emergencies when unexpected variation occurs. Such is the case in healthcare, where one cannot say that a treatment failed because variation was outside the expected boundaries, and that the patient has to accept this. Instead, statistical measures to predict variation can be useful, and being prepared to handle variation instantly is necessary in order to deliver healthcare with high quality (ibid). In order to be prepared for this kind
of variation, or foreseen uncertainty, resources must be available to handle the
effects of the variation.

In healthcare, foreseen uncertainty is common: patients who suffer from the same
disease can react differently to treatments and thus require different kinds of
treatments. They can also arrive at the decision to seek care at different stages of
their disease and thus arrival times differ. Clinics must be prepared to deal with
these two types of variation on a daily basis in order to convert the largely varying
inflow of sick patients to a stable outflow of patients with a clean bill of health
(Litvak & Long, 2007).

3.4 Production planning
In order to deal with variation and to deliver products of the right quality at the
lowest possible cost, planning of production is essential. Production planning
determines a long term plan over what is to be produced, where it is to be produced,
by whom it will be produced, as well as how it will be produced (Francis, 2012). The
main purpose of production planning is to avoid problems resulting from variation
in production. However, production plans are not executed successfully without any
follow-up, and thus functions for coordinating and handling errors during
production on a daily basis is necessary. This coordination and error handling
exists in the concept of production control (ibid).

While planning focus on the theoretical long-term aspect of an activity, control
focuses more on the hands-on, applied aspect, ensuring that the plans actually take
place and includes responding when things do not go according to the plan.
Because control involves taking circumstances into account and re-plan, it is
interlinked with planning (Slack et al., 2010).

3.5 Production control
Control, outside the context of production, has meanings that include to dominate,
to command, to check, to verify and to regulate, and has traditionally been
associated with accounting (Ballard, 2000). However, the main activity in control
has been to monitor actual performance and costs, and compare these against set
goals to deduce performance. Negative effects resulting from variation can thus be
mitigated and corrective actions can be taken when problems occur (ibid).

Production control is a common concept in the manufacturing and construction
industries, where detailed methods and systems for production control are used. In
healthcare however, it has been shown that a focus on understanding the
production control process is more important than the implementation of
standardized systems (Patil, 2012; Plantin & Johansson, 2012). Because of this and
the fact that no formal system for production control exists at department Q84
(Nurse A), a discussion on the concept is held instead, and implications for success
and failure in production control are discussed.

Production control can be defined as the systematic coordination and directing of
activities to ensure delivery on time, of adequate quality and at a reasonable cost
(Production control, 2014). Another, more comprehensive definition by McKay and
Wiers (2004) is that production control is the task of predicting, (re-)planning and
scheduling work, taking into account manpower, materials availability and other
capacity restrictions and costs. The purpose is to achieve proper quality and
quantity at the time it is needed and then following up to see that the plan is carried out, using whatever IT-support tools have proven satisfactory for the purpose.

### 3.5.1 Characterizing production control

How production control is executed in different organizations varies greatly, depending on the competence of the managers in the organization as well as to what level production control is even possible in the organization (McKay & Wiers 2004; Patil 2012). McKay & Wiers (2004) characterize three situations in regards to the feasibility and success of production control:

- **Good** - Where the production system is considered healthy and production control methods are used appropriately so that production goes according to plan.
- **Bad** - Where the production system is considered healthy and production control is feasible, but the methods are used in the wrong way.
- **Ugly** - Where the production system is the problem and production control is impossible but still believed to be the cause of the problems.

In order to achieve a state where the organization is successful in production control, it is important to be aware of where problems reside. Thus, when seeking to improve production control, it is important to find out if problems are even related to production control, or if they are simply the result of a sub-optimal production system (McKay & Wiers 2004).

According to McKay & Wiers (2004), flexibility in scheduling and planning processes is necessary in order to be prepared for handling risks, so that negative effects can be mitigated. Choosing production control methods that are aligned with the production system of the organization is important since organizations can differ vastly, for example a factory and a hospital. Everything from the methods and expectations to the required competence can differ. Also, as organizations develop and change, their production control methods will need to change and adapt as well.

### 3.5.2 Responsibilities in production control

As stated above, production control comprises the execution of production plans and associated activities, hence production control requires production planning. According to McKay & Wiers (2004), there are two main paradigms associated with the division of responsibilities for planning and control functions, hierarchical and focused.

The hierarchical paradigm is associated with centralized decision making based on position in the hierarchy. This structure also implies shared resources and support services in the organization. The hierarchical paradigm also consists of aggregated planning functions on the higher levels, and more detailed control functions on the lower levels.

The focused paradigm is distinguished by the fact that the functions in the organizations are considered self-contained businesses with individualized decision making structures, resources and support services. In the focused paradigm, the functions conduct planning and control activities individually. This means that organizations that implement the hierarchical paradigm need to provide planning.
on an organization wide level that can be used by the functions on the lower levels. Organizations implementing the focused paradigm however, allow and require the functions to conduct their own planning, as these responsibilities are transferred to the functions from the organization. The paradigms are illustrated in figure 2 below.

**Figure 2: Hierarchical vs focused paradigm (McKay & Wiers 2004, modified)**

In order to understand the functions and responsibilities for production control in a healthcare organization and to be able to position the role for production control in relation to the functions and responsibilities, a framework by Hans et al. (2011) is studied. The framework is essentially a guide for structuring production control in healthcare organizations specifically. The framework spans over four hierarchical levels of control as well as four managerial areas. The framework is designed to be applicable to healthcare organizations or to individual departments within healthcare organizations. By grouping activities within these managerial areas and hierarchical levels, a greater understanding for the roles that perform the activities can be achieved.

The managerial areas are:

- **Medical planning** - Decisions regarding diagnosis, treatment and medical protocols, including development of new medical treatments by clinicians.
- **Resource capacity planning** - Planning, scheduling, monitoring and dimensioning of renewable resources such as machines, equipment, bed linen and staff.
- **Materials planning** - Planning of consumable resources such as blood, bandages, food, etc.
- **Financial planning** - How the organization manages its costs in relation to the achievement of stated objectives, including investments, budgeting and cost allocation.

And the hierarchical levels are:

- **Strategic level** - Structural decision making, definitions of the organization’s strategy and related decisions to translate the strategy into
daily operations. Long planning horizon and highly aggregated information and forecasts.

- **Offline operational level** - Short-term decisions that relate to the healthcare delivery process. Low flexibility and planning in advance of operations. Detailed coordination of current elective demand.

- **Online operational level** - This is the level on which reactive decision making related to unexpected or acute events occur.

- **Tactical level** - The tactical level can be seen as in between the strategic level and the operational levels. In contrast to the strategic level, the tactical level is more about the organization of operations, which makes it similar to the operational level. However on the tactical level, the planning horizon is shorter than on the strategic level, but longer than on the operational level. Planning is more abstract and flexible on the tactical level than on the operational level, and is based on less certainty and more forecasting.

These managerial areas and hierarchical levels are grouped together and illustrated in figure 3 below, and by using this matrix an understanding of responsibilities of a role for production can be gained.

**Framework for healthcare planning and control**

By describing an organization’s operational policy in terms of functions for production planning and control in relation to the hierarchical and focused paradigms and the framework described above, a base for analysis can be created which can then be used to evaluate the operational policy. It has been argued that in order to achieve successful production control it is important to evaluate operational policy (Butler et al., 1996) as well as to evaluate performance continuously, in order to ensure that the focus of operations is aligned with the organizations strategy (Olhager & Wikner, 2000). This implies a need for a system
for continuous performance evaluation to be available for the roles responsible for production control.

### 3.5.3 Roles for production control
McKay & Wiers (2004) describes roles for production control as information hubs, with a responsibility to gather information on past, current and upcoming activities in order to facilitate effective decision making. The roles also comprises real-time dynamic problem solving as well as making predictions for the future, all while fulfilling both official and unofficial requirements and constraints (ibid).

A role for production control can differ greatly between organizations and centers around very different principles and tasks depending on the operations of the organization. A general and abstract definition of a role for production control which leaves room for differences in the organization, industry or context in which the role operates is a definition by Easley (2014): A role for production control is responsible for ensuring that the production flows without incident. In the event of a problem, these trained employees diagnose and fix the issue and inform the necessary parties about any resulting schedule changes. The employees shouldering the role need to have knowledge of each stage of the production process to effectively organize the necessary workers and to execute a job plan that will keep production running on schedule.

It can be debated whether roles for production control should be focused on scheduling activities or if they should also partake in higher-up activities such as planning and strategy. Butler et al. (1996) argue that hospital performance can be enhanced by having a proactive role involved in strategic planning rather than a reactive role which only handles problems as they occur. To keep track of past, current and upcoming information, whether it is on a longer time horizon for planning or on a more daily basis for control, IT-support tools can be used (Olhager & Wikner, 2000).

### 3.5.2 IT-support tools for production control
Software which aims to aid or facilitate production control can have many purposes, such as determining lead times, help with inventory and forecasting and even provide scheduling algorithms. However, in order to receive any value from these systems, they must be appropriate for their purpose, used in the right way with the necessary education and maintained and upgraded correctly. If the systems do not fulfil these requirements, they will not accomplish what they are supposed to and may even be detrimental to the operations of the organization (Butler et al., 1996; McKay & Wiers, 2004).

What the software should do for an organization depends on the complexity of the necessary scheduling, which also determines what is feasible to accomplish using software. The organization first needs to evaluate and understand what problems exist and then begin with addressing any basic issues before moving on to more sophisticated systems. Butler et al. (1996) suggest that information systems should provide feedback for clinical decision making and that forecasting and evaluation of operational policy promotes competitive decision making.

When developing software for the healthcare industry, it is necessary to ensure usability because of the critical nature of information in healthcare. Ensuring
usability can be achieved through extensive usability testing (Sarnikar & Murphy, 2009). If usability is lacking or the systems are badly aligned with the workflow of clinicians, clinicians often create workarounds to complete critical tasks (Lowry et al., 2014). These workarounds frequently include copying and pasting of information to keep it readily available (ibid).

3.6 Summary
Lean has three main principles, continuous improvement, waste removal and the increasing of flow efficiency in the organization. Organizations with high utilization of resources may need to lower resource efficiency to facilitate increase of flow efficiency. Keeping a resource utilized 100% of the time leaves no room for continuous improvement and can lead to problems in the form of secondary needs.

In order to improve production, organizations need to be aware of the characteristics of their production system, including the inherent level of flow, which is based on what is produced in the system and how much customization is made. Also, knowing whether production is convergent or divergent is important since it can have implications for timing in planning and control. Another important characteristic of a production system is the inherent level of variation, which is the changes that occur either to the product or the production process. Being aware of what kind of variation affects the production system and knowing how to handle it is necessary for production control to be successful. However, even when there are existing functions in place for predicting or forecasting variation, it’s important to be prepared to directly handle unexpected variation, especially when the effects of that variation cannot be ignored.

In order to deliver the right quality at the lowest cost, organizations use production planning to handle variation in a long term plan. However, to achieve the goals of the plan and to handle problems that occur on a daily basis, production control is necessary. Production control is about keeping an eye on production processes and to facilitate production by coordinating information and handling errors that occur, using necessary systems and IT-support tools. When attempting to improve production control, it is important to be aware of whether problems reside in the production system or in the methods for production control or their associated IT-support tools. An organization’s activities in production control in relation to associated planning activities can be described in terms of the adopted paradigm for division of responsibilities. Organizations having their planning tasks occurring on an organizational level adopt the hierarchical paradigm, while organizations where functions in the organization conduct their own planning adopt the focused paradigm. Further, activities in production control can be categorized based on the managerial area and hierarchical level on which they reside. By combining this information, an organization’s operational policy can be evaluated, which is a precondition for successful production control.

Roles for production control act as information hubs, coordinating information and handling problems as they occur. Differentiation of the tasks the roles perform depends on the organization’s operations, but being knowledgeable about the production process is necessary. Whether roles for production control should focus only on day-to-day problem solving or if they should partake in more long-term planning activities and strategy can be debated. However, performance is said to be positively affected if the role is of a more pro-active than reactive nature. It is important for the role for production control to have the necessary IT-support tools
to perform its tasks, and the systems’ functionality must be aligned with the goals of the organization. It has been argued that IT-support tools should provide feedback for decision making, and that ensuring usability is critical as clinicians otherwise create workarounds to complete critical tasks.
4. Case study at Astrid Lindgren children's Hospital

This chapter presents the findings from the case study which was carried out at department Q84. The case study was based on an initiative from Center for Technology in Medicine and Health (CTMH), who carried out a programme called the Clinical Innovation Fellowships during the autumn of 2013. The programme aimed to facilitate innovation in healthcare through working with cross-functional teams to identify the needs of the clinic. One of the needs that were identified was the need to “organize and optimize the role of the nurse responsible for coordination at the clinic”, which is what this case study attempted to accomplish, as well as to provide an empirical basis for analysis in relation to the theoretical framework.

In the beginning of this chapter the case context and situation at department Q84 is presented based on findings from phase one of the case study, including a description of the system and role for coordination at the department as well as associated IT-support tools. Following this, phase two is then presented which includes the requirements specified for the prototype which was developed in this project as well as a short description of the development process.

4.1 Case context

CTMH is a cooperation between Karolinska Institutet, the Royal Institute of Technology and Stockholms County Council with the purpose of developing the Stockholm region into a world-class center for medical technology unique to Sweden. CTMH acts as a portal for contact between academia, industry and healthcare. The organization also works to initiate research and education within technology in medicine and health and contributes to processes for facilitating the creation of new products, services and organizations (Vision, 2014).

The Clinical Innovation Fellowships is a yearly programme arranged by CTMH and stretching over eight months. The programme aims to facilitate innovation in healthcare through a method called the Biodesign method (Zenios et al., 2010), which was developed at Stanford University in the United States. The programme combines the competences of four individuals from different backgrounds in a project where they work together to improve workflow and medical technology at a hospital department. The current iteration of the programme is the fourth in order (Scheutz et al., 2014).

Healthcare and other welfare services in Sweden are considered a public responsibility and the responsibility is divided between the state, county councils (or regions) and municipalities (Anell et al., 2102). KS is one of Scandinavia’s premier health facilities and together with one of the world’s leading medical universities, Karolinska Institutet, they are considered leaders in medical breakthroughs in Sweden. KS is fully owned by Stockholm County Council, and managed under a corporate structure (About Karolinska, 2014).

Within the organization of KS is Astrid Lindgren Children’s Hospital, which was founded in 1998 through a merger by Stockholm County Council of the three pediatric departments of KS, Saint Göran Hospital and Danderyds Hospital, and focus on the treatment of children. Astrid Lindgren Children’s Hospital is together with the Children’s Hospital in Huddinge part of the child-division at KS. At Astrid Lindgren Children’s Hospital there are departments for all kinds of treatment.
From a production perspective, departments can be seen as having their own production system, as patients are divided based on their category of disease so that they can receive appropriate care at the department specializing in their particular ailment. One department is Q84, where children arrive when diagnosed with cancer. Department Q84 is divided into the outpatient clinic, where patients come for short day visits, and the ward where patients are treated, usually with chemotherapy.

Roughly four out of five children diagnosed with cancer survives and recovers from the illness (Childhood cancer survival statistics, 2014). However, this process is often lengthy and extensive, and generally ranges from six months to two and a half years according to the interviewed doctor (Doctor A). During this process patients regularly come to the department for treatments varying from a single day visit to several weeks of chemotherapy. These visits all need scheduling, medicine ordering and coordination in order for the proper treatment to be delivered. As treatments mainly consist of chemotherapy, there is inherently a lot of variation as the medicine(s) affect not only cancer cells but also normal cells of a treated patient which cause various health impairing side effects (Corrie, 2008). Chemotherapy treatments can only start if the patient’s body is in a state where it can handle the treatment, and thus treatments are often delayed due to other health factors according to both the interviewed nurse and doctor (Nurse B; Doctor A). This puts a lot of strain on the coordinating role, as treatments need to be rescheduled frequently.

Within the Clinical Innovation Fellowships programme 2013-2014 a total of 400 improvement needs were identified at department Q84. These needs have then through the programme been evaluated and validated by a control group consisting of different kinds of medical professionals as well as managers and strategic advisors, to connect and combine different needs to find areas for possible improvement. These have been summarized in the report Clinical Innovation Fellowships - Observations at the Pediatric Oncology department by Scheutz et al. (2014). This case study was centered on one of these areas found to have the greatest potential, namely to organize and optimize the role of the nurse responsible for coordination at the clinic. The reason for this was that the role for coordination at the department was heavily dependent on many different IT-systems that were poorly adapted to the needs of the clinic, meaning that a lot of time was wasted on these systems and therefore the responsibilities and duties of the role were considered inefficient (ibid).

4.2 Production at department Q84
To understand the coordination role at department Q84, the context in which the role operates must also be understood. Thus, before the findings regarding the role are presented, a description of the production system at the department is presented.

4.2.1 The production system at department Q84
To understand the production system at department Q84, the system is described by first looking at input to the system, meaning how patients are admitted. The process flow of how a first time patient enters the system and gets admitted to the department is illustrated in figure 4 below.
First time patient flow

Patients at department Q84 are often children, but teenagers are also sometimes admitted if capacity allows. When a child gets ill, the first contact with the hospital is the Children’s emergency room, where contact can have been initiated from a local health centre or directly from the child’s home. If a doctor can find where the symptoms originate, the child is transferred to a symptom specific department, otherwise he/she is transferred to a general care department and in both cases tests are sent to a laboratory for further analysis. If the analysis of the test results from the laboratory strongly implicates that the child has cancer, the child is admitted to the department. If results are indicating that the child might have cancer, a doctor contacts the department’s oncology specialist at department Q84 for counsel (“S-Dr.” in figure 4), and often more specific examinations are carried out to determine the nature of the illness. When a child is admitted to the department, he/she needs a room before a treatment process can start. The coordinator role at Q84, in figure 4 described as “PASS”, hence need to coordinate capacity and possibly order medicine and schedule a surgical procedure as well.

Interviews with a nurse and with the doctor at the department show that different professionals and expertise need to be involved in the diagnosis and treatment of cancer patients, requiring timing so that necessary resources can be in the right place at the right time (Nurse B; Doctor A). The ailments treated at the department are categorized as blood cancer, brain tumors and other solid tumors, and each category corresponds to approximately one third of the patients treated at department Q84 (ibid). From a production perspective these categories differ

Figure 4: First time patient flow in to department Q84
mainly in the initial process, when the patient is being diagnosed. The differences are illustrated in figure 5 below.

**Figure 5: Diagnosis categories at department Q84**

When the patient has been diagnosed, the treatments for most patients are similar, including regular admission for chemotherapy and in some cases radiation treatment (Nurse B; Doctor A). This process of recurring treatments of a patient is depicted in figure 6, which illustrates what happens after the patient has been diagnosed.
Recurring treatments

The Start in figure 6 is directly linked to the last “Treatment” node in figure 5 and the End is when the patient in four out of five cases fully recovers (Childhood cancer survival statistics, 2014). The arrows pointing upwards indicate treatments at Q84, and the different shapes illustrate different medicines.

While the treatments for most patients at department Q84 follow the same pattern, nurses describe the treatments themselves as having an inherent variation which affects the level of flow in the production system (Nurse B; Nurse C). Chemotherapy treatments involve heavy medication and therefore it is important to make sure that the patient’s body is strong enough to handle the medication before starting each course of treatment in order to avoid unnecessary harm to the patient. This is often done using blood tests which are conducted shortly before treatment is to begin. If the patient is unable to begin treatment, it has to be rescheduled (Nurse B; Nurse C; Doctor A). The most common reason for rescheduling is low white blood cell count, and is not unusual (Planning your chemotherapy treatment, 2012). It is very common for treatments at department Q84 to be delayed (Nurse B; Nurse C).

The patients have their rooms at the department to which the doctors and nurses come and administer care, however patients can be transported around the hospital when for example a surgical procedure is necessary. Patients are only admitted to the department’s ward when necessary. When patients have to come in for shorter treatments that last less than a day, they can go to the outpatient clinic, thereby freeing up resources for handling admitted patients at the ward (Nurse B). Patients admitted to the ward are the main foci for the coordinators at department Q84, but the planning of their visits for treatment are done by their respective doctors (ibid).

4.2.2 The role for coordination at department Q84

The role for coordination at department Q84 is shouldered by a nurse at the department, who still has the responsibility to act as a nurse when there is time available from the role. Through interviews with the nurses shouldering the coordination role at department Q84, and through observations of their work, the main responsibilities of the role have been identified. The nurses shouldering the coordination role at the department described the role as an “information hub” who receives and distributes information at the department (Nurse B; Nurse C). The main task of the role is to ensure steady flow of production and to avoid
overcrowding and exceeding the department’s capacity. In order to achieve this, the role needs to maintain a planning sheet detailing when patients are to be admitted to the clinic and for what reason. The role also has to gather and coordinate information regarding the patients. The main tasks associated with accomplishing the responsibilities of the role have been identified as (ibid):

- Maintaining a patient planning sheet
- Answering incoming phone calls to the department
- Acting as an information hub for questions from employees

Further, there is a formal description of the activities and responsibilities of the role, which include the following:

- Keeping the list of occupied beds up to date
- Updating the schedule for surgical procedures
- Coordinating bone marrow biopsies (a common procedure at the department)
- Maintaining overall responsibility for the department
- Ensuring that treatments for the following day have been prepared and coordinating with the lab
- Coordinating the preparation of medicine for chemotherapy
- Assessing the need for personnel in relation to complexity of patients treatments
- Ensuring that a list of scheduled treatments for the following week is available so that doctors can prescribe medicine
- Dividing individual patient responsibilities for the upcoming shift

Also, the nurses shouldering the role stated that they have the responsibility to coordinate the following activities as well (Nurse B; Nurse C):

- Coordinating a meeting every day at 6.45
- Coordinating a meeting every day at 9.00
- Giving a status report to afternoon staff at 13.30
- Coordinating a meeting every day at 14.45

In addition to these responsibilities, there are activities that the role has to coordinate which occur on specific weekdays or sporadically. According to interviews with two of the nurses, these activities further burdens the role and consumes time, and include coordinating with nutritionist, counselor, physical therapist as well as the clowns that come to the department to entertain the children (Nurse B; Nurse C).

The role for coordination is an around the clock responsibility at department Q84, and interviews with nurses revealed that there is a formal requirement that someone should shoulder the role at all times (Nurse B; Nurse C). The main responsibilities of the role are to be carried out by a nurse during daytime on weekdays. On evenings, nights and weekends, the role is more of a formal requirement and implies that the main responsibilities during that time is to make sure that staffing needs are met and to order in additional staff when necessary, rather than to act as an information hub (ibid). This implies that the nurse shouldering the role during the day has to finish all the responsibilities before the evening shift comes on.
Interviews with the nurses shouldering the role for coordination at the department reveal that all responsibilities listed above belong to the role for coordination alone and that there are no support services or personnel available to assist (Nurse B; Nurse C). Further, the nurses stated that the responsibilities have to be carried out during one shift of the day, and thus the role becomes overburdened and stressful (ibid). Complementary interviews at departments B78 and Q80 at KS revealed a different situation, where coordinators were supported either by secretaries or by other functions shouldering some of the responsibilities. Department Q80 had several secretaries handling phone calls (Head Nurse B), while department B78 had several coordinators who cooperated (Head Nurse A). The interviews with nurses shouldering the role for coordination revealed that due to the large amount of responsibilities for the role at department Q84, and the lack of supporting services such as secretaries or receptionists, the one shouldering the role is completely utilized all of the time (Nurse B; Nurse C). Another reason that was expressed for the complete utilization of the role is the sub-optimal IT-support tools, which require a lot of unnecessary work to be performed (Nurse A; Nurse B; Nurse C), which is also supported by the report Clinical Innovation Fellowships - Observations at the Pediatric Oncology department by Scheutz et al. (2014).

4.3 IT-support tools at department Q84
The first step in achieving improvements in the IT-support tools was to describe the different tools and their functions in relation to the role for coordination. An example of how the coordination role uses different IT-support systems and tools is shown in figure 7, where the process of coordinating a bone marrow puncture procedure for a patient is shown from the coordination perspective, in combination with the systems used. The figure illustrates the use of different systems at different stages in the process of a bone marrow puncture procedure.

![Figure 7: Coordination process and systems used in a bone marrow puncture procedure](image)

4.3.1 Existing IT-support tools
The main IT-support tool used at department Q84 is the patient journaling system called TakeCare, which primary purpose is to store patients’ medical records. TakeCare is a large system with many different functions and is by its developers said to “cover the entire healthcare sector” (About TakeCare, 2014). It is also said to “eliminate unnecessary workflow duplications” (ibid), and is designed to be a single-sign-on system that connects staff to all other systems. Nurses shouldering the role for coordination stated that apart from storing medical records for each patient, TakeCare is used to store information about patient’s visits and treatments, as well as for maintaining a list of all the beds at the department (Nurse B; Nurse
C). Many other treatment related activities also use functions from TakeCare, such as printing information to send to patients prior to visits.

However, not all functions needed by the department exist in TakeCare (Nurse A). Ordering medicine for chemotherapy treatments is a time consuming and complex task and it cannot be done using TakeCare. Instead, for medicine ordering, department Q84 uses another system called Cytodos. While there are some existing integration between Cytodos and TakeCare, they are still two separate systems. Cytodos is most commonly used by doctors at the department, however the nurses shouldering the coordination role said that they infrequently use it to double-check orders for medicine (Nurse B; Nurse C). Further, they stated that scheduling surgical procedures cannot be done in TakeCare, forcing the department to use another system, called Orbit, which is dedicated to the scheduling of surgical procedures and can be used to share information between departments regarding upcoming procedures (ibid).

The tool which is used most frequently in combination with TakeCare, is an excel spreadsheet that enables an overview of patients at the department in order to control the production process and to keep track of patients (Nurse B; Nurse C). The spreadsheet, or the Patient overview, displays a week’s overview of the department, where information is presented about what room each patient is in and what treatment they are receiving. Also, information regarding when the patients are planned for treatment as well when they expect to be discharged are displayed. The Patient overview also displays the amount of occupied beds at the department and patients getting treatment temporarily at other hospitals. The Patient overview system is illustrated in figure 8 below.

*Figure 8: Patient overview*
Nurses shouldering the role for coordination at department Q84 said that the Patient overview is essential for coordinating production at the department as it illustrates the capacity in a weekly overview (Nurse B; Nurse C). The fields that are displayed in the Patient overview contain information about production procedures, e.g. treatments and capacity. A field can contain the name of a patient and a color describing the treatment or planned procedure of the patient. From the top at the column of a field is the time of treatment, and to left in the row of a field is the room where the patient is staying. Further down in the overview, patients that were planned for treatment at the department but had to be transferred to another hospital are listed, as well as patients that have been transferred to the department for treatment but have another hospital as original place of treatment. The bottom row in the table shows total capacity. The Patient overview spreadsheet is stored on a single computer which is accessed only by the coordinators. However, the information in the Patient overview is vital for the department to function properly, and sometimes other nurses at the department need to access this information. This results in the coordination role to function as a relay for information that others could retrieve by themselves if it was located in TakeCare and not only in the excel sheet.

4.3.2 Overlapping systems
What can be seen from the example in figure 7: Coordination process and systems used in a bone marrow puncture procedure, is that system usage overlaps. The Patient overview can be seen as an extension of TakeCare as the information that is displayed in the Patient overview mainly comes from TakeCare, and a comparison of the information displayed in the Patient overview compared with information existing in TakeCare is illustrated in table 3 below.

Table 3: Information comparison between TakeCare and the Patient overview

<table>
<thead>
<tr>
<th>Information</th>
<th>TakeCare</th>
<th>Patient overview</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient name</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Room number</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Treatment</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Number of beds</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Admittance date</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Discharge date</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Surgical procedure</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

The comparison indicates that data on what room a particular patient is being treated in, the number of available beds as well as discharge date is non-existent in TakeCare. This information is vital for the scheduling of patients, as the number of beds indicates the department’s capacity and the discharge date indicates when a new patient can be admitted, and what rooms are available decides where the patient will be staying. However, the additional information that exists in the Patient overview is created from data in TakeCare: the information about when a
patient is scheduled for admittance to the department in combination with the information about what treatment the patient will receive, determines the discharge date. The information about the discharge date is then inserted manually into the Patient overview. What room a patient is going to get is decided by information existing in the Patient overview by looking and re-calculating capacity for the department, in combination with the age of the patient and treatment history.

From the observations and interviews it is evident that when the coordination role performed one of the responsibilities which involved TakeCare, the Patient overview were used as well (Nurse B; Nurse C). TakeCare and the Patient overview were identified as the most vital systems used by the coordinators, and due to the inherent variation in the treatment process of patients at the department, a majority of the time spent on IT-support tools were spent on these (ibid). As the treatment processes for patients at the department are of a stochastic nature, and patients need to be tested and checked upon daily (if not hourly), changes in the schedule occur continuously. These changes are often related to the treatment process, and the condition of the patient.

As a patient must have acceptable blood levels and be free from fever and infection before initiation of a treatment process, the start of a treatment process must be postponed if they are not (Doctor A). If a patient suddenly becomes more ill, the treatment process can be cancelled or paused, which also affects the schedule and needs to be adjusted for in both TakeCare and the Patient overview. It is also not uncommon that a patient becomes ill after a full treatment process, and thus must stay at the department for a longer time, which in turn also needs to be adjusted in the systems. Also, interviews with the coordinators at Q84 revealed that during daily rounds it is quite common for patients to be discharged ahead of schedule or to have their stay extended, which is something that needs to be coordinated in the systems (Nurse B).

Handling this foreseen uncertainty is a part of the challenge of coordinating production at the clinic and for the coordinators to maintain the Patient overview. However, using two systems for managing these changes is time-consuming and inefficient (Nurse B; Nurse C): having the same information in two systems and keeping both systems updated and synchronized manually can be considered unnecessary work (Business Developer A). Interviews with the nurses shouldering the role for coordination show that the Patient overview came to be out of necessity for a weekly overview of capacity and patients, and is not an integrated part of TakeCare (Nurse B; Nurse C). The nurses also said that they have gotten used to the system, and that they see all the required extra work as necessary workarounds rather than something they can affect and improve (ibid).

Observations show that the tasks of performing the three main responsibilities of the role for coordination: to maintain a patient planning sheet, to answer incoming phone calls to the department and to act as an information hub for questions from employees, often are irregular and affected by interruptions. The interviews with coordinators at the department also indicated that conflicts between these three activities are common and problematic (Nurse B; Nurse C). One particular example given by a coordinator during one of the interviews (Nurse B) is when the coordinator is in the midst of updating the Patient overview as well as TakeCare with data regarding a rescheduling of a treatment. If the data has been updated in the excel sheet but not in TakeCare (or the other way around) and the telephone rings, there is a risk that the finalization of the update (inputting the data in the
second system) is forgotten, and thus the two systems will be out of sync. Similar conflicts when updating the schedule and colleagues enter the room to ask for information have also been observed, as well as confirmed in the interviews. These situations can pose a risk for patient security, as someone could act based on inconsistent and incorrect information (ibid).

### 4.4. Optimizing IT-support tools at Q84

In this subchapter the information gathered through interviews and observations in phase one are applied to develop a prototype for a patient overview system for department Q84. By accounting for the findings regarding the developed prototype, the practical aspects of realizing improvements can be highlighted, which is important in order for the outcomes of this project to be applicable for the organization.

#### 4.4.1 Requirements for prototype

Before development of the prototype began, the requirements for the prototype were formulated. This was accomplished through further interviews with the nurses shouldering the role for coordination at department Q84 (Nurse B; Nurse C). The requirements are summarized below (ibid):

- **It should be completely automated** - Meaning that the system should automatically retrieve and display information and not require any interaction from the user.
- **It should display fresh (recent) data** - Meaning that when a change is done in TakeCare, it should be quickly reflected in the overview.
- **It should be easy to interpret and use** - Meaning that the responsible coordinators should require little to no training before using the application.
- **It should be future proof and manageable by the organization** - Meaning that the application has to adhere to existing standards and frameworks, and be open for further development.
- **It should fulfill all the purposes of the previously used system** - Meaning that all the functions of the Patient overview presented in chapter 4.3 should exist.

Further, there were some questions that had to be addressed in order to enable the development of the prototype. These questions had to be answered by functions inside KS, and thus further interviews with departments responsible for Information Security, Strategic Business Development and Enterprise Information Systems were conducted. The questions were:

- Patient information is a sensitive subject, what is possible to do when it comes to automatic retrieval of such data?
- How should the prototype be developed, what frameworks and standards exist at KS?

#### 4.4.2 Information security

In order to understand the situation regarding the automatic retrieval and display of patient information, an interview was conducted with the Information Security Coordinator at Karolinska University Hospital. The interview revealed that the organization of KS at the time of this case study was in the process of establishing a
structured policy for information security, which the development of the prototype had to adhere to (Information Security Coordinator A). The policy follows the well-established model for Confidentiality, Integrity and Availability (CIA) (Bhaiji, 2008; Perrin, 2008; Confidentiality, Integrity and Availability (CIA), 2014), which is illustrated in figure 9 below.

![Figure 9: The CIA model for information security policy (Bhaiji, 2008)](image)

The different aspects of the model are simplified and described below, including the traceability aspect which is added by KS:

- **Confidentiality** - Preventing unauthorized disclosure of sensitive information.
- **Integrity** - Preventing unauthorized modification of data, systems and information.
- **Availability** - Preventing loss of access to resources and information, making sure that information is accessible for authorized users at all times.
- **Traceability** - Making sure that events related to the handling of information can be traced.

The interview with the Information Security Coordinator also showed that Availability and Traceability could be considered lacking factors for the coordination role at department Q84 (Information Security Coordinator A). Interviews with the nurses shouldering the role for coordination showed that due to the fact that data is copied back and forth manually between systems, there was a risk for data inconsistency as stated earlier in the report (Nurse B; Nurse C). Because of this, the coordinator could never be certain that all data is available in
either system without looking in the other system as well. Since availability is part of the information security policy at KS, it needs to be corrected by the prototype. In summary, the prototype had to adhere to all the above aspects of information security and also add the previously lacking availability aspect.

4.4.3 Frameworks and standards
In order to facilitate efficient development of the prototype within the timeframe of this project and to make use of existing frameworks for software development at the organization while fulfilling information security standards, interviews at the department for Strategic Business Development were conducted. Another reason for the interviews was to make sure that the prototype was developed in a sustainable fashion and that it will be managed by the organization after it has been deployed. The department for Strategic Business Development provides in-house development of IT-support tools with the mission to achieve the strategic goals of the organization. The interviews reveal that the Strategic Business Development department is a driver for continuous improvement and lean thinking, and have developed a web based internal distribution platform for IT-support tools. This platform serves to ensure that future improvement and development is aligned with the objectives of the organization (Business Developer A; Business Developer B). However, one of the interviews with a nurse shouldering the role for coordination at the department showed that the existing system for creating the Patient overview at department Q84 is not a part of this platform, which motivates its replacement by a new system using the platform (Nurse B). The platform is designed in .NET and C#, and fulfills the requirements posed by the organization’s modified CIA-model, and facilitates efficient development within a secure environment (Business Developer A), and was therefore used to develop the prototype.

Since TakeCare is designed to ensure security of patient information, it is designed in such a way that traditional methods for retrieving information are unavailable. Instead, a middle data layer is used in order to retrieve data from TakeCare and display it in an external system. Thus, in order to retrieve data from TakeCare and to fulfill the availability aspect of information security and still achieve high performance, the distribution platform uses two separate databases to aggregate data (Information System Developer A; Information System Developer B). One with data being updated once a night called KarDa, and another one which updates its data at least every five minutes and is called NarDa. Applications that require “fresh” data have to use the NarDa database, while less time-critical applications use the KarDa database. The structure of the platform is illustrated in figure 10 below.
Using this platform, internal applications can retrieve data safely from the journaling system while adhering to the principles of the modified CIA-model.

4.4.4 Development of the prototype

One of the requirements of the prototype was that data had to be fresh and up-to-date for a near real-time display of information, thus the NarDa database had to be used for retrieving data. Interviews were conducted with the department for Enterprise Information Systems which manages the NarDa and KarDa databases in order to ensure that information could be made available in NarDa. The interviews revealed that some of the data which was needed for an implementation of the prototype only existed in KarDa and not in NarDa (Business Developer A; Information System Developer A). Therefore, the prototype had to initially use data from KarDa as a proof of concept, and be programmed in such a way that it can simply switch to using data from NarDa when that data is made available.

The process for developing the prototype included continuous follow-up interviews with coordinators at department Q84 to discuss details of the development and to get high involvement from them in order to create motivation for using the tool when it is deployed. The interviews also served to ensure usability so that the coordinators will not have to create workarounds in the future (Lowry et al., 2014). As the requirements for the prototype and the revolving security requirements were well defined, these parts of the development process were made easier. Since a functional prototype was developed in this project, a brief chronological description of the development process is presented below, with the intent of highlighting details of the functionality in the prototype, and to illustrate how it should be used.

As the prototype replaces the Patient overview but should retain the same functionality, the information available in the new system should correspond to the previously used system and fulfill previously mentioned requirements. This enabled a straightforward development process with clear objectives since the old system had been thoroughly investigated and requirements clearly specified. The development process began with creating an empty table showing a weekly view, with date and time slots in the top rows, and room numbers in the leftmost column.
Next, data was to be prepared for display in the table. As the development environment and patient security regulations do not allow for the use of actual patient information or a connection to KarDa or NarDa, dummy data was generated for testing and demonstration purposes. However, the structure of the data was designed so that the dummy data can be switched for a database connection when deploying the prototype. When the data had been prepared it was structured as events containing the necessary information including:

- The patient’s name
- Bed number
- Time for admittance
- Time for discharge
- Reason (such as surgical procedure or treatment)
- Comment

The next step was to process the data and display it in the table, and to make it look and feel like the previously used tool did. Also, since the process of retrieving data, preparing data and finally displaying the data was to be automated, errors resulting from bad formatting of data in TakeCare needed to be handled automatically in the prototype as well. Thus, for example if an incorrect bed number is entered, the new patient overview clearly indicates this and warns the user, and the same goes for when two patients have been scheduled in the same time slot. This way, human errors resulting from the input of data into TakeCare can be easily detected and rectified, effectively increasing the ease of use of the system. Functionality was continuously tested during development, and when all functionality was in place, testing was conducted using many series of automatically generated data to simulate all potential situations where errors could occur. A screenshot of the prototype developed in this project can be seen below in figure 11.

![Figure 11: The prototype of an automated patient overview](image)

The code for the prototype can be found in Appendix A and demonstrates the functionality. In order to finalize the application and move from prototype to finished product, necessary database connections to NarDa needs to be in place. Further interviews with the departments for Strategic Business Development and Enterprise Information Systems revealed that the final steps of development of the prototype will have to be completed after this project has ended (Business Developer A; Information System Developer A; Information System Developer B).
The task of making data available in NarDa will have to be performed internally for safety reasons and because of the complexity of the Swedish healthcare system, with decision making on three different levels, as well as priorities in the organization, it will not be completed in the time frame of this project. This part of the application development is therefore shouldered and managed by the department for Strategic Business Development upon the completion of this project (Business Developer A).
5. Analysis and improvement suggestions
In this chapter an analysis of the findings from the case study is presented with a focus on answering the research questions previously stated in this report. The research questions are elaborated on with the intent to suggest improvements for department Q84.

5.1 Production system and role for production control
This subchapter centers on the first research question, “How are roles for production control in hospital departments specified?” by describing the role for production control at department Q84 and the context in which it operates.

In order to understand how a role for production control is specified, the production system in which the role operates must be understood as well. The production system at department Q84 is characterized by having many professionals and a lot of different expertise cooperating in the production process, e.g. to treat patients for cancer. This kind of production system is categorized as convergent (Segerstedt, 2001), and implies that the production inherently requires timing of resources. This, in combination with the high level of variation in the treatments administered at the department as well as a lot of rescheduling of treatments, according to nurses shouldering the role for coordination, creates a situation where scheduling becomes critical to the success of the department (Nurse B; Nurse C). Further, characterizing the product layout of department Q84 is not straightforward, since resources are grouped together as well as patients. Thus, the Q84 can be said to combine the benefits of both a process layout and a product layout, as all department specific functions exist in the same place as the patients, while still focusing on the utilization of resources. This implies a potential for a rather high rate of flow at the department (Segerstedt, 2001), meaning that there should be rather few interruptions in the treatments of patients.

As departments at KS are specialized in delivering care for a specific ailment, their methods for delivering care differ to such a degree that they can be said to have their own production systems. The organization of KS thus exerts no direct control over production in the different departments. This implies that decisions regarding production are the responsibility of the individual departments and the organization can be said to follow the focused paradigm for production control (McKay & Wiers, 2004). In order to facilitate production at department Q84, the department has a role for coordination. The roles responsibilities include acting as an information hub, coordinating information between employees at the department. It also includes everything from handling the department’s entire scheduling and follow-up to coordinating daily meetings at the department, effectively making the role stressful and overburdened. When opportunity is given, the nurse shouldering the coordination role should work as a nurse while still fulfilling the responsibilities of the role, further adding to the stressful nature of the role. The framework for healthcare planning and control by Hans et al., (2011) is used to relate the responsibilities of the role to the managerial areas and hierarchical levels of production control, and is illustrated in figure 12 below.
Figure 12: The responsibilities of the role in the framework for healthcare planning and control

As can be seen in the figure above, the role has responsibilities spanning three of the four managerial areas for production control, namely medical planning, resource capacity planning and materials planning, but not financial planning. Hierarchically the role is identified to focus more on the lower, offline and online operational levels, since most activities are reactive in nature. However one activity is identified to be on the tactical level, which is to assessing the need for personnel in relation to complexity of patients’ treatments. The description of the role fits quite well in the theoretical definition of a role for production control, meaning that it acts as an information hub, gathering information on activities to facilitate decision making, as well as comprising dynamic problem solving. However, there are a lot of responsibilities added to the role at department Q84 that are time consuming (such as answering the phone and coordinating meetings). The complementary interviews with head nurses show that department B78 and Q80 respectively divide the responsibilities of their roles for coordination over several roles (Head Nurse A; Head Nurse B). Department Q80 had secretaries handling phone calls, while department B78 had cooperating coordinators. The complementary interviews also show that both head nurses at these departments perceive their roles as much less stressful than the nurses shouldering the coordination role at department Q84 (ibid).

Despite the difficult scheduling process which is affected by a lot of variation, interviews and observations reveal that the department puts little effort into its long-term planning, which otherwise could be used to mitigate the effects of variation. Most of the tasks performed by the role for production control is reactive and day-to-day oriented, and no predictions or forecasting are used. The role exists to handle the effects of variation in daily operations, but there are no support
services in place to actively learn from previous problems resulting from variation. Roles for production control are said to benefit the performance of the organization if they are pro-active and involved in planning and strategy (Butler et al., 1996). This would imply the need for roles for production control to be involved in activities on the higher hierarchical levels of the framework by Hans et al., (2011). This is an area where department Q84 is lacking, as can be seen in figure 12 above. Also, there are no prediction or forecasting tools available to help mitigate the effects of variation. Further, performance measurement tools are non-existent and thus there is no real method or structure for continuous improvement of the role.

The responsibilities for the role for production control at department Q84 ensures that the role is utilized 100% of the time, as there always are tasks to complete. This contradicts the official standpoint of KS which is that they strive to become lean and flow efficient (Business Developer B). It has been shown that 100% resource utilization is detrimental to flow efficiency and can lead to other problems as well, including secondary needs arising due to for example waiting times (Modig & Åhlström, 2012). This is confirmed by the fact that to handle variation, resources must be kept available (Variation, 2014). Thus, the high level of utilization of the role due to the vast amount of responsibilities it has counteracts one of the most important overall responsibilities of the role, which is to handle variation.

In summary, the production system at department Q84 is overall deemed healthy and production control is feasible. However, problems occur due to inefficient and suboptimal IT-support tools (Nurse A; Nurse B; Nurse C). This puts the department in a Bad situation according to the model by McKay & Wiers (2004). In order to move from Bad to Good, where the system is healthy and the methods and IT-support tools are used appropriately as well, the IT-support tools needed to be optimized.

### 5.2 Existing IT-support tools

This subchapter is centered on the research question “What IT-support tools exist today and what needs to they fulfill?”, and from interviews and observations (Nurse B; Nurse C), four IT-support tools are identified. Table 4 presents a list of the IT-support tools and their usage.

**Table 4: IT-support tools and their usage at department Q84**

<table>
<thead>
<tr>
<th>IT-support tool</th>
<th>Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>TakeCare</td>
<td>Patient journal system</td>
</tr>
<tr>
<td>Patient overview</td>
<td>Scheduling, production control</td>
</tr>
<tr>
<td>Orbit</td>
<td>Scheduling surgical procedures</td>
</tr>
<tr>
<td>Cytodos</td>
<td>Medicine ordering</td>
</tr>
</tbody>
</table>

The IT-support tools for ordering medicine and scheduling surgical procedures are used infrequently compared to time spent on TakeCare and the Patient overview (Nurse B; Nurse C). This means that potential improvements will have the most effect if they are centered on TakeCare and the Patient overview.
TakeCare is designed to be a single-sign-on system that connects staff to all other systems, as well as a system that “eliminates unnecessary workflow duplications” (About TakeCare, 2014). However, since the usage of TakeCare involves duplication of information into the Patient overview, its usage can be seen as detrimental to the operations of the organization as it is not used appropriately according to its purpose or used in the right way (Butler et al., 1996; McKay & Wiers, 2004).

5.3 Improvement of existing IT-support tools
This subchapter answers the research question “How can the existing IT-support tools be optimized?”, and by analyzing the existing IT-support tools in relation to the role and the context they are used in at department Q84, areas of improvement are identified where current IT-support tools can be optimized.

Looking at the existing IT-support tools at the department, two systems with potential improvements are TakeCare and the Patient overview, as they are used interchangeably and most time spent on IT-support tools are spent on these (Nurse B; Nurse C). The Patient overview is stored on a computer used solely by the coordinators (ibid). A direct effect of this which affects the performance of the role negatively, is that whenever anyone beside the coordinator needs to check something in the Patient overview, they have to involve the coordinator. The coordinator is supposed to act as an information hub (McKay & Wiers, 2004; Nurse B; Nurse C), but simply relaying information that could be easily retrieved by others can be considered wasteful work. The person who needs to retrieve information from the Patient overview must first go to the coordinator's office to make his/her inquiry, and secondly there is a risk that the coordinator is busy, resulting either in a waiting time to receive the information or in an interruption of the work conducted by the coordinator (ibid). This affects both the availability and the traceability aspect of information security in the CIA model used at KS (Information Security Coordinator A). As parts of information for the production at Q84 is stored in the Patient overview, e.g. room number, capacity and discharge date, and the only person with access is the coordinator (e.g. the role for production control) at the department, the availability aspect is not fulfilled. The availability aspect also suffers due to the fact that data can become inconsistent between the Patient overview and TakeCare, requiring the coordinator to check both systems in order to guarantee the correct information. The traceability aspect is also lacking, as the Patient overview is based on a single excel-file stored on a personal computer. No backups are made; having the implication that if the excel-file were to be deleted or lost, work would be lost with it and the coordinator would need to manually recreate the file.

As the Patient overview is used for maintaining a weekly view of information about production and capacity at department Q84, and is also used to store information which TakeCare is designed to keep, it contradicts the fact that TakeCare is the system designed for storing information about patients at the clinic. Thus, the Patient overview becomes a necessary tool for production control at the department (Nurse B; Nurse C), and information about patients must exist in the tool. The manual transfer of this information, in combination with the fact that the availability and traceability aspects of information security are not fulfilled, has a negative impact on performance of operations, and are strong indicators for improvement suggestions.
The patient flow at the department is adversely affected by the current system for maintaining the Patient overview (Nurse B; Nurse C; Business Developer A). This is due to the irregular and risk-laden flow of information regarding the scheduling of patient treatments when creating and maintaining the Patient overview. Much of the time spent on updating the Patient overview can be considered waste, since it is manual duplication of data.

By automating the process of creating and maintaining the Patient overview, no time will be spent on manually creating and updating it, effectively eliminating this waste. Further, in addition to the removal of wasteful work, risks for inconsistency in patient information are removed, effectively making the role less stressful and freeing up resources for handling of variation.

5.4 Improving production control at Q84

This subchapter further analyzes the findings from the case study at department Q84 and presents a suggestion of how production control at department Q84 can be improved through optimization of IT-support tools.

The defining of a role for production control, production system, as well as the usage of associated IT-support tools related to production, enabled improvement suggestions regarding optimization of the IT-support tools to be formulated. The improvement suggestions regarding IT-support tools at Q84 involved the development of a prototype replacing the manually maintained Patient overview with an automated weekly overview for production and capacity. The prototype is integrated with the existing patient journaling system, TakeCare, which eliminates the risk for data inconsistency. The information displayed in the prototype is based on data existing in NarDa, which in turn is data aggregated from TakeCare, thus effectively fulfilling the availability and traceability aspect of information security as NarDa has backup systems and necessary security functions. The prototype was distributed on an internal distribution platform developed by Strategic Business Development, which enables a new level of visibility since it is constructed as a web application. The new Patient overview can be displayed on a TV-screen and can even be accessed from mobile devices.

As the prototype developed in this project will have practical implications for department Q84 and lead to changes in operations, it is aligned with the goals of the organization. Since KS is striving to become lean (Business Developer B), this project adheres to the principles of lean, including continuous improvement, waste removal and increasing flow efficiency regarding the improvement suggestion. In order to improve flow efficiency, resource efficiency must be lowered to free up resources for continuous improvement (Modig & Åhlström, 2012). Another reason to free up resources is to be able to handle variation which is detrimental to flow efficiency. Lowering resource efficiency means that resources will cause opportunity costs, which is simply the cost of owning a resource when it is not used. However, resource efficiency is a measurement of utilization rather than performance, thus by optimizing IT-support tools so that they require less work to achieve the same results (removing waste), the opportunity costs can be neglected since the performance of the resource is sustained, while still freeing up resources for continuous improvement and handling variation. Thus, by optimizing IT-support tools, waste can be removed and improvements in flow efficiency are enabled without detrimental side effects.
6. Discussion
In this chapter a general discussion on the project is held. The discussion centers around the methods used in this project and managerial implications from its outcomes. The purpose is to explain the implications of the findings and to suggest future research. Through investigation of production control at a department at KS, specifically the production system, existing roles for production control in the production system as well as the associated IT-support tools, we have identified potential improvements. The potential improvements have been analyzed in order to develop a prototype for a new automated IT-support tool to be used at the department, replacing the previously used, inefficient manual IT-support tool, effectively reducing waste.

6.1 Discussion of methods
We believe that the use of investigator triangulation in this research has strengthened the validity of our findings. The fact that observations were carried out over the entire time span of the project greatly complemented the two initial full-day observations and facilitated a deeper understanding of the investigated department. The coordinators at the department work in a hectic environment and thus observations had to be carried out without participation. We believe that it would have been possible to enhance the functionality of the developed prototype if we could have participated in the work of the coordinators if they would have had more time to spend on interviews and testing of the prototype.

By using two complementary interviews at other departments, a greater understanding of how other departments deal with production control and what IT-support tools were used could be gained. These insights could be further strengthened in terms of validity, by using more complementary interviews or by conducting benchmarking at other hospitals. Also, since organizations in healthcare have successfully adopted methods and principles from other industries, benchmarking in other industries could be expected to be similarly successful and could thus grant insights into possible best practice methods. By doing these kinds of benchmarks, the risk of adopting suboptimal methods from other departments inside the same organization can also be minimized.

The development of the prototype was conducted with a focus on usability. Theory suggest that usability can be achieved through extensive testing, however this was not possible in this project due to the stressful nature of the coordination role at the department. Since the development of the new IT-support tool resulted in an optimization of a previously used tool, usability was not affected however, as design and functionality from the previously used tool could be adopted into the new tool. This way, the need for education is eliminated and usability is guaranteed to be high since users are already comfortable with the way the system works.

6.2 Managerial implications and generalizability
We believe that insights from this project can be applicable to departments at KS similar to Q84, as well as organizations with similar conditions in terms of size, roles for production control and similar production systems. Coordinators and their managers can improve performance of their operations if they work with ensuring that the tools used for production control are aligned with the objectives of the user of the systems. Since the role for production control at department Q84 is overburdened and the vast amount of tasks leads to full utilization, an improvement
would be to follow the examples set by other departments in the organization, namely to increase capacity for production control, either by employing receptionists to handle incoming phone calls, thus freeing up the role for production control to focus on production, or to strengthen the role by letting two coordinators shoulder the role together and cooperate.

By improving the role for production control through lowering resource utilization and removing waste, flow efficiency can be increased. This can be achieved by optimizing IT-support tools in order to remove inefficient workarounds and time-consuming tasks. Lowering resource utilization results in excess capacity in the form of available time. The excess capacity for the role for production control can be used to handle variation reactively since the person shouldering the role will be less busy, but also pro-actively if methods and IT-support tools for predictions and forecasting were introduced. Theory implies that introducing forecasting would improve performance and empirical findings from this project further grants credibility to this implication. However, due to the lack of benchmarking in this project, and the fact that the effects of implementing the prototype cannot be evaluated in the scope of this project, generalizability is limited to organizations similar to KS. If tested and proven, implications should apply to all and any organizations implementing IT-support tools to facilitate production.

6.3 General reflections
The prototype developed in this project enables a new form of visibility, since it easily can be accessed from anywhere inside the organization. This could be used to display the weekly overview to everyone at the department, through for example a TV-monitor. This would involve everyone at the department in the scheduling process and the increased visibility promotes self-evaluation and continuous improvement.

The organization of KS is large, and achieving change has been perceived to be difficult. A lot of effort during the project has been put into e-mailing and otherwise communicating with different departments and functions inside the organization in order to find the right person to communicate with. We believe that the organization of KS is slow when it comes to handling change connected to IT due to its large size and the importance of preserving the integrity of patient information. Many functions that are necessary in order to achieve change in an IT-system are spread out over different departments which sometimes delegate responsibilities to each other rather than to act. Another reason is the low level of IT-maturity among employees. If hospital staff were to be educated and became more competent in the IT-systems they use, they would be more prone to detect potential improvements and changes to the systems. If the employees that use the systems believe that the problems they see are necessary workarounds, which was the case at department Q84, they will not actively try to change the situation. Small imperfections in the systems will then lead to large amounts of waste over the years.

6.4 Future research
By developing the prototype for an automated Patient overview, this project has shown that changes are possible. The implementation of the prototype would require changes in the department where it is implemented, including new usage of IT-systems. However, earlier research regarding this area is scarce, and as many healthcare organizations are in the public sector, the scope for change quickly
grows as change could affect all levels: municipalities, county councils or even nationwide. Therefore we suggest change processes surrounding IT in healthcare to be further researched.

When patients undergo chemotherapy they often respond to the treatment differently, and the treatment process can have side effects resulting for example in rescheduling of surgical procedures and treatments. If this happens, the rescheduling of the particular patient may be repeated as patients sometimes show a pattern of responding to the treatment process, which is due to the treatment process of chemotherapy often is lengthy and involves repeated treatments. If statistics of the particularities and treatment response patterns of patients were available, better production planning and control could be executed at the department. A suggestion is therefore to investigate how to implement this functionality in an IT-support tool for the production control role, further enhancing precision in control and forecasting variation.
7. Conclusions

In this chapter, conclusions drawn from the analysis of the project and its outcomes is presented, as well as conclusions regarding how production control in hospital departments can be improved through optimization of IT-support tools.

The investigation of production control at KS, department Q84 has shown that the coordination role shouldered by nurses at the department aligns with the description of a role for production control. The role handles capacity and variation control in the aspects of foreseen uncertainty, and acts as an information hub for questions from employees. This role is a vital part of department Q84 and is overburdened in comparison with roles for production control at similar departments. This is due to the fact that all responsibilities relating to production control as well as many other unrelated responsibilities falls on the role for production control alone. Theory and empirical findings suggest that the responsibilities of the role should be more focused on production control, and that support services should exist to shoulder some of the other responsibilities that were shouldered by the role for production control.

By thoroughly investigating the production system, roles and IT-support tools of an organization in relation to production control, improvements in production control are possible. Understanding the context for production control in the organization, including the production system and its characteristics, as well as understanding the role for production control and its responsibilities is necessary in order to identify existing problems and potential for improvement. Through the development of an IT-support tool for production control, this project has also shown that optimization of IT-support tools can lead to potential for increased flow efficiency. This is because of the reduction in resource utilization due to the removal of wasteful work. The removal of wasteful work frees up resources for continuous improvement and handling variation, thus implicitly increasing flow efficiency.

The prototyping of an IT-support tool for production control shows how improvements and optimizations can be made. By replacing the manually generated Patient overview with an automatically generated Patient overview, wasteful work can be eliminated and the role for production control needs to spend less time on updating information as well as controlling data-consistency in two systems. Implications for the role for production control is that there is a decrease in interruptions when performing the responsibilities of the role, e.g. the coordination of treatment of the patients, which has a positive impact on patient security by minimizing the risk of someone acting based on wrong information. By reducing unnecessary work and decreasing interruptions, the flow of information is made more efficient, and the role for production control becomes less stressful.
References
Below is a list of the references used in this report. Books and articles are listed separately from web sources.

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**Web sources**


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Appendix A - The code for the prototype

In this appendix, the code for the prototype developed in this project is presented. The code is written in C# using Visual Studio Professional 2013. The code presented below has been extracted from their respective files denoted by headlines. The code has been restructured to hide organization-specific and critical information.

Site.master

```html
<head runat="server">
    <link type="text/css" href="/Styles/q84.css" rel="stylesheet" />
    <script type="text/javascript">
        $(function () {
            $('.q84Table td').tooltip({
                tooltipClass: "q84ToolTip",
                show: false,
                hide: false,
                position: {
                    my: "center bottom-20",
                    at: "center top",
                    using: function (position, feedback) {
                        $(this).css(position);
                        $('"<div>"
                            .addClass(feedback.vertical)
                            .addClass(feedback.horizontal)
                            .appendTo(this);
                        },
                        content: function () {
                            if ($(this).attr("krock")) {
                                var div = "<div>"
                                    + "<b>Schemakrock mellan dessa patienter: </b>" +
                                    + $(this).attr("patient")
                                    + "<br/>
                                    + "</div>";
                                    return div;
                            } else {
                                var div = "<div>"
                                    + "<b>Patient: </b>" + $(this).attr("patient")
                                    + "<br/>
                                    + "<b>Planerad inskrivning: </b>" +
                                    + $(this).attr("admittance")
                                    + "<br/>
                                    + "<b>Planerad utskrivning: </b>" +
                                    + $(this).attr("discharge")
                                    + "<br/>
                                    + "<b>Kommentar: </b>" + $(this).attr("comment")
                                    + "</div>";
                                    return div;
            });
        //var date = new Date();
        //$('#q84TimeStamp').html("Data hämtades: " + date.getFullYear() +
        "-" + (date.getMonth() + "-" + date.getDate() + " " + date.getHours() +":" +
        date.getMinutes() + ":" + date.getSeconds());
        });
```
<script>
</head>

**Default.aspx**

```xml
<asp:Content ID="myBody" runat="server" ContentPlaceHolderID="BodyContent">

    <asp:PlaceHolder ID="phTable" runat="server" EnableViewState="false"></asp:PlaceHolder>
    <div class="q84TimeStamp id="q84TimeStamp">
        <asp:PlaceHolder ID="phTimeStamp" runat="server"></asp:PlaceHolder>
    </div>
    <div class="q84Footer">
        <asp:PlaceHolder ID="phLegend" runat="server"></asp:PlaceHolder>
    </div>

    <div class="q84Footer">
        <asp:Button class="q84FooterButton" id="PreviousWeekButton" Text="Förra veckan" runat="server" OnClick="PreviousWeek" />
        <asp:Button class="q84FooterButton" id="NextWeekButton" Text="Nästa vecka" runat="server" OnClick="NextWeek" />
    </div>

</asp:Content>

**q84.css**

```css
body {
}

.q84Table {
    margin: 10px 0;
    max-width: 100%;
    width: 100%;
    table-layout: fixed;
    border-spacing: 0;
    border-collapse: collapse;
    border: 1px solid #CCCCCC;
    font-family: Verdana, Arial;
    cursor: default;
    -moz-user-select: -moz-none;
    -webkit-user-select: none;
    user-select: none;
}

.q84Table div {
    height: 20px;
    overflow: hidden;
}

.q84Table td {
    border: 1px solid #CCCCCC;
    text-align: center;
    height: 10px;
}

.q84TableHeader {
    background-color: #FFFFFF;
    color: #000000;
}
```

50
Default.aspx.cs
namespace MyWebApp
{
    public class Bed
    {
        public Day[] week = new Day[7];

        public Bed()
        {
            for (int i = 0; i < 7; i++)
            {
                this.week[i] = new Day();
            }
        }
    }

    public class Day
    {
        public TableCell[] timeSlots = new TableCell[3];
    }

    public class SpecialEvent
    {
        public DateTime time;
        public String description;

        public SpecialEvent(DateTime time, String description)
        {
            this.time = time;
            this.description = description;
        }
    }

    public class AnEvent
    {
        public DateTime admittance;
        public DateTime discharge;
        public String patient;
        public String reasonForVisit;
        public String comment;
        public int? bedNumber;
        public List<SpecialEvent> specialEvents;

        public AnEvent(DateTime admittance, DateTime discharge, String patient, String reasonForVisit, String comment, int? bedNumber)
        {
            this.admittance = admittance;
        }
    }
}
this.discharge = discharge;
this.patient = patient;
this.reasonForVisit = reasonForVisit;
this.comment = comment;
this.bedNumber = bedNumber;
this.specialEvents = new List<SpecialEvent>();
}
}

public class DummyData
{
    public AnEvent[] events;

    public DummyData(DateTime weekBeginDate)
    {
        int[] bedNumbers = { 11, 13, 15, 22, 23, 24, 26, 33, 34, 35 };
        String[] reasonsForVisit = { "Infektion", "Perm", "Cytostatika", "Övrigt", "Terminalvård" }; // "Operation" borttaget
        AnEvent[] events = new AnEvent[bedNumbers.Length + 1];

        for (int i = 0; i < bedNumbers.Length; i++)
        {
            Random r = new Random();
            DateTime randomAdmittance = weekBeginDate.AddDays(r.Next(-5, 6));
            DateTime randomDischarge = randomAdmittance.AddDays(r.Next(0, 23));
            String randomReason = reasonsForVisit[r.Next(0, 9999999) % 4]; // Ändra till % 5 (6 med "Operation" i listan) för att inkludera Terminalvård.
            AnEvent randomEvent = new AnEvent(randomAdmittance, randomDischarge, "Patient" + i.ToString(), randomReason, "Kommentar" + i.ToString(), bedNumbers[i]);

            if (i == 0 || i == 1 || i == 2)
            {
                SpecialEvent specialEvent = new SpecialEvent(randomAdmittance, "Operation");
                randomEvent.specialEvents.Add(specialEvent);
            }

            events[i] = randomEvent;
            System.Threading.Thread.Sleep(r.Next(0, 9999999) % 236);
        //Added for randomness purposes..
            System.Threading.Thread.Sleep(r.Next(0, 9999999) % 238);
        //Added for randomness purposes..
            System.Threading.Thread.Sleep(r.Next(0, 9999999) % 123);
        //Added for randomness purposes..
        }

        AnEvent krockEvent = new AnEvent(weekBeginDate, weekBeginDate.AddDays(8), "Krockpatient", "Cytostatika", "Lite längre kommentar för att testa hur det blir med längre text", 35);
        events[events.Length - 1] = krockEvent;
        this.events = events;
    }
}

public partial class Default : System.Web.UI.Page
{
    Dictionary<string, string> globalColors = new Dictionary<string, string>();
public Table globalBoard = new Table();
public String[] globalDaysInAWeek = { "Mån", "Tis", "Ons", "Tor", "Fre", "Lör", "Sön" };
public int[] globalBedNumbers = { 11, 12, 13, 14, 15, 22, 23, 24, 25, 26, 27, 33, 34, 35 };
public Dictionary<int, Bed> globalBeds = new Dictionary<int, Bed>();
public DateTime globalToday;
public DateTime weekBeginDate;
public DateTime weekEndDate;

protected void Page_Load(object sender, EventArgs e)
{
    //GlobalSession.InitSession();
}

protected void Page_Init(object sender, EventArgs e)
{
    globalColors.Add("Infektion", "#cf008d");
globalColors.Add("Operation", "#e9b602");
globalColors.Add("Perm", "#7e7d80");
globalColors.Add("Cytostatika", "#11adeb");
globalColors.Add("Övrigt", "#721f98");
globalColors.Add("Terminalvård", "#fa0f00");
globalColors.Add("Schemakrock", "rgb(182, 255, 0)");
globalToday = DateTime.Now;
Table table = new Table();
table.CssClass = "q84Legend";
TableRow row = new TableRow();
table.Rows.Add(row);
foreach (KeyValuePair<String, String> color in globalColors)
{
    TableCell cell = new TableCell();
    cell.Style.Add("background", color.Value);
    cell.Text = color.Key;
    row.Cells.Add(cell);
}
phLegend.Controls.Add(table);

HtmlGenericControl timeStamp = new HtmlGenericControl("DIV");
timeStamp.InnerHtml = "Senast uppdaterad: " + globalToday.ToShortDateString() + " " + globalToday.ToShortTimeString();
phTimeStamp.Controls.Add(timeStamp);

if (!IsPostBack)
{
    weekBeginDate = globalToday.AddDays(0 - GetWeekday(globalToday));
    weekBeginDate = new DateTime(weekBeginDate.Year,
    weekBeginDate.Month, weekBeginDate.Day, 0, 0, 0);
    Session["weekBeginDate"] = weekBeginDate;
    weekEndDate = weekBeginDate.AddDays(6);
    weekEndDate = new DateTime(weekEndDate.Year,
    weekEndDate.Month, weekEndDate.Day, 23, 59, 59);
    CreateBoard();
    DummyData dummyData = new DummyData(weekBeginDate);
    PopulateBoard(dummyData.events);
    AddBoardFooter();
}

}
public void PreviousWeek(object sender, EventArgs e)
{
    weekBeginDate = (DateTime)Session["weekBeginDate"];    
    weekBeginDate = weekBeginDate.AddDays(-7);    
    Session["weekBeginDate"] = weekBeginDate;    
    weekEndDate = weekBeginDate.AddDays(6);    
    weekEndDate = new DateTime(weekEndDate.Year, weekEndDate.Month,    
        weekEndDate.Day, 23, 59, 59);    
    CreateBoard();    
    DummyData dummyData = new DummyData(weekBeginDate);    
    PopulateBoard(dummyData.events);    
}

public void NextWeek(object sender, EventArgs e)
{
    weekBeginDate = (DateTime)Session["weekBeginDate"];    
    weekBeginDate = weekBeginDate.AddDays(7);    
    Session["weekBeginDate"] = weekBeginDate;    
    weekEndDate = weekBeginDate.AddDays(6);    
    weekEndDate = new DateTime(weekEndDate.Year, weekEndDate.Month,    
        weekEndDate.Day, 23, 59, 59);    
    CreateBoard();    
    DummyData dummyData = new DummyData(weekBeginDate);    
    PopulateBoard(dummyData.events);    
}

private void CreateBoard()
{
    globalBoard.CssClass = "q84Table";
    globalBoard.ID = "q84Table";
    GenerateBoardTableHeader(globalBoard);
    GenerateBoardRows(globalBoard);
    phTable.Controls.Clear();
    phTable.Controls.Add(globalBoard);
}

/// <summary>
/// Generate table header
/// </summary>
/// <param name="tblBoard">The table to modify</param>
private void GenerateBoardTableHeader(Table tblBoard)
{
    DateTime headerDate = weekBeginDate;
    TableRow topHeader = new TableRow();
    TableRow bottomHeader = new TableRow();
    for (int i = 0; i < 8; i++)
    {
        TableCell topHeaderCell = new TableCell();
        topHeaderCell.CssClass = "q84TableHeader";
        if (i == 0)
        {
            TableCell emptyCell = new TableCell();
            emptyCell.CssClass = "q84TableHeader";
            bottomHeader.Cells.Add(emptyCell);
        }
        else
        {
            topHeaderCell.ColumnSpan = 3;
        }
    }
    tblBoard.Controls.Add(topHeader);
    tblBoard.Controls.Add(bottomHeader);
}
TableCell bottomHeaderCell1 = new TableCell();
bottomHeaderCell1.CssClass = "q84TableHeader";
bottomHeaderCell1.Text = "0-8";
bottomHeader.Cells.Add(bottomHeaderCell1);
TableCell bottomHeaderCell2 = new TableCell();
bottomHeaderCell2.CssClass = "q84TableHeader";
bottomHeaderCell2.Text = "8-16";
bottomHeader.Cells.Add(bottomHeaderCell2);
TableCell bottomHeaderCell3 = new TableCell();
bottomHeaderCell3.CssClass = "q84TableHeader";
bottomHeaderCell3.Text = "16-24";
bottomHeader.Cells.Add(bottomHeaderCell3);

if ((globalToday.Year == headerDate.Year) &&
    (globalToday.Month == headerDate.Month) && (globalToday.Day ==
    headerDate.Day))
{
    topHeaderCell.Style.Add("background", "#EFEFEEF");
    if (globalToday.Hour < 8)
    {
        bottomHeaderCell1.Style.Add("background", "#EFEFEEF");
    }
    else if (globalToday.Hour < 16)
    {
        bottomHeaderCell2.Style.Add("background", "#EFEFEEF");
    }
    else
    {
        bottomHeaderCell3.Style.Add("background", "#EFEFEEF");
    }
}
headerDate = headerDate.AddDays(1);
}

if (globalToday.Year == headerDate.Year) &&
    (globalToday.Month == headerDate.Month) && (globalToday.Day ==
    headerDate.Day))
{
    topHeaderCell.Text = globalDaysInAWeek[i - 1] + "<br/>" +
    headerDate.Day.ToString() + "." + headerDate.ToString("MMM",
    CultureInfo.InvariantCulture);
    topHeaderCell.Text = globalDaysInAWeek[i - 1] + "<br/>" +
    headerDate.Day.ToString() + "." + headerDate.ToString("MMM",
    CultureInfo.InvariantCulture);

    TableCell bottomHeaderCell1 = new TableCell();
    bottomHeaderCell1.CssClass = "q84TableHeader";
    bottomHeaderCell1.Text = "0-8";
    bottomHeader.Cells.Add(bottomHeaderCell1);
    TableCell bottomHeaderCell2 = new TableCell();
    bottomHeaderCell2.CssClass = "q84TableHeader";
    bottomHeaderCell2.Text = "8-16";
    bottomHeader.Cells.Add(bottomHeaderCell2);
    TableCell bottomHeaderCell3 = new TableCell();
    bottomHeaderCell3.CssClass = "q84TableHeader";
    bottomHeaderCell3.Text = "16-24";
    bottomHeader.Cells.Add(bottomHeaderCell3);

    if ((globalToday.Year == headerDate.Year) &&
        (globalToday.Month == headerDate.Month) && (globalToday.Day ==
        headerDate.Day))
    {
        topHeaderCell.Style.Add("background", "#EFEFEEF");
        if (globalToday.Hour < 8)
        {
            bottomHeaderCell1.Style.Add("background", 
"#EFEFEEF");
        }
        else if (globalToday.Hour < 16)
        {
            bottomHeaderCell2.Style.Add("background", 
"#EFEFEEF");
        }
        else
        {
            bottomHeaderCell3.Style.Add("background", 
"#EFEFEEF");
        }
    }
    headerDate = headerDate.AddDays(1);
}

}
void GenerateBoardRow(Table board, Bed bed, String bedNumber)
{
    TableRow tr = new TableRow();
    TableCell tc = new TableCell();
    tc.CssClass = "q84Number";
    tc.Text = WrapTextInDiv(bedNumber);
    tr.Cells.Add(tc);
    for (int j = 0; j < globalDaysInAWeek.Length; j++)
    {
        TableCell cell1 = new TableCell();
        TableCell cell2 = new TableCell();
        TableCell cell3 = new TableCell();
        cell1.CssClass = "q84Cell";
        cell2.CssClass = "q84Cell";
        cell3.CssClass = "q84Cell";
        tr.Cells.Add(cell1);
        tr.Cells.Add(cell2);
        tr.Cells.Add(cell3);
        bed.week[j].timeSlots[0] = cell1;
        bed.week[j].timeSlots[1] = cell2;
        bed.week[j].timeSlots[2] = cell3;
    }
    board.Rows.Add(tr);
}

void PopulateBoard(AnEvent[] events)
{
    for (int i = 0; i < events.Length; i++)
    {
        Bed bed;
        int? bedNumberCheck = events[i].bedNumber;
        int bedNumber;
        if (bedNumberCheck != null)
        {
            bedNumber = (int)bedNumberCheck;
            bool bedExists = globalBeds.TryGetValue(bedNumber, out bed);
            if (!bedExists)
            {
                bed = new Bed();
                GenerateBoardRow(globalBoard, bed, "(" + bedNumber.ToString() + ")");
            }
        }
        else
        {
            bed = new Bed();
            GenerateBoardRow(globalBoard, bed, "");
        }
        drawEvent(events[i], bed);
    }
}

void drawEvent(AnEvent anEvent, Bed bed)
{
    String patient = anEvent.patient;
    String reasonForVisit = anEvent.reasonForVisit;
String comment = anEvent.comment;
List<SpecialEvent> specialEvents = anEvent.specialEvents;
DateTime admittance = anEvent.admittance;
DateTime discharge = anEvent.discharge;

DateTime startFill;
DateTime stopFill;

if (IsDateInWeek(admittance))
{
    startFill = admittance;
    if (IsDateInWeek(discharge))
    {
        stopFill = discharge;
    }
    else
    {
        stopFill = weekEndDate;
    }
}
else if (IsDateInWeek(discharge))
{
    startFill = weekBeginDate;
    stopFill = discharge;
}
else
{
    startFill = weekBeginDate;
    stopFill = weekEndDate;
}

int startWeekday = GetWeekday(startFill);
int startTimeSlot = GetTimeSlot(startFill);

int stopWeekday = GetWeekday(stopFill);
int stopTimeSlot = GetTimeSlot(stopFill);

for (int i = startWeekday; i <= stopWeekday; i++)
{
    int start;
    int stop;
    if (i == startWeekday && i == stopWeekday)
    {
        start = startTimeSlot;
        stop = stopTimeSlot;
    }
    else if (i == startWeekday)
    {
        start = startTimeSlot;
        stop = 2;
    }
    else if (i == stopWeekday)
    {
        start = 0;
        stop = stopTimeSlot;
    }
    else
    {
        start = 0;
    }
```csharp
    stop = 2;

    for (int j = start; j <= stop; j++)
    {
        TableCell cell = bed.week[i].timeSlots[j];
        cell.Style.Add("border", "0");
        if (cell.Text != "")
        {
            cell.Text = WrapTextInDiv("!");
            String krockColor;
            globalColors.TryGetValue("Schemakrock", out
            krockColor);
            cell.Style.Add("background", krockColor);
            cell.Attributes.Add("krock", "krock");
            cell.Attributes["patient"] += 

```
beds.AddRange(globalBeds.Values);

for (int i = 0; i < 7; i++)
{
    for (int j = 0; j < 3; j++)
    {
        int sum = 0;
        foreach (Bed bed in beds)
        {
            if (bed.week[i].timeSlots[j].Text != "")
            {
                sum++;
            }
        }
        TableCell cell = new TableCell();
        cell.CssClass = "q84Cell";
        cell.Text = sum.ToString();
        footerRow.Cells.Add(cell);
    }
}

globalBoard.Rows.Add(footerRow);

private bool IsDateInWeek(DateTime date)
{
    if (date >= weekBeginDate && date <= weekEndDate)
    {
        return true;
    }
    else
    {
        return false;
    }
}

int GetWeekday(DateTime time)
{
    int dayOfWeek = (((int)time.DayOfWeek == 0) ? 7 : (int)time.DayOfWeek) - 1;
    return dayOfWeek;
}

int GetTimeSlot(DateTime time)
{
    int timeSlot;
    if (time.Hour < 8)
    {
        timeSlot = 0;
    }
    else if (time.Hour < 16)
    {
        timeSlot = 1;
    }
    else
    {
        timeSlot = 2;
    }
return timeSlot;
}

String WrapTextInDiv(String text)
{
    return "<div>" + text + "</div>";
}

void Page_Unload(Object sender, EventArgs e)
{
    GlobalSession.CloseSession();
}
}