DEGREE PROJECT IN MEDICAL ENGINEERING,
SECOND CYCLE, 30 CREDITS
STOCKHOLM, SWEDEN 2021

Improving management of patient flow at Radiology Department using Simulation Models

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Improving management of patient flow at Radiology Department using Simulation Models

Förbättra hanteringen av patientflödet på radiologiska avdelningen med hjälp av simuleringsmodeller

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Degree Project in Technology and Health
Advanced level (second cycle), 30 credits
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Abstract

The Swedish healthcare system is considered to have good healthcare productivity and efficiency with moderate cost but seems to have some future challenges. Sweden is moving towards the aging population as it requires development in medical care techniques and technologies to provide care to elderly patients. This increases the pressure on the healthcare system. Hence, the number of patients in the hospital increase, as a result, the flow of patients within the wards are increased. Furthermore, the pandemic has increased the number of people admitted to hospitals. As a consequence, even for high-priority cases, the wait times are rising.

The Skaraborg Hospital Group, SHG, and other general hospitals, in particular, are focusing on how to handle patient flow at various levels within departments and clinics by improving patient flow quality. Production and capacity preparation (PCP) is a commonly used industry tool for resolving bottlenecks. Hence, this method needs to be adopted within the hospital and by the healthcare sector to a larger extent.

Since many patients from different specialty departments use the Radiology department's facilities, it is often a "bottleneck" in inpatient traffic at hospitals. Furthermore, the influx of patients with covid-19 has increased the department's workload.

This master's thesis aims to assist the Radiology department in improving their production and capacity planning to increase unit flow performance. The project involves supporting key staff in the department in estimating demand to align different patient movements with equipment and personnel services. Improving radiology department flow efficiency can lead to more even and healthy patient flows around the hospital, reducing "buffers" of patients and longer stays at different specialist clinics.

Keywords: Production planning, Capacity planning, Bottleneck, Patient flow, Demand forecast.

Sammanfattning

Det svenska sjukvården anses ha god hälsovårdsproduktivitet och effektivitet till måttliga kostnader men verkar ha några framtida utmaningar. Sverige går mot den åldrande befolkningen eftersom det kräver utveckling av tekniker och tekniker för medicinsk vård för att ge äldre patienter vård. Detta ökar trycket på sjukvården. Därför ökar antalet patienter på sjukhuset, vilket leder till att patientflödet inom avdelningarna ökar. Dessutom har pandemin ökat antalet personer som läggs in på sjukhus. Som en konsekvens ökar väntetiderna även för fall med hög prioritet.

Skaraborg sjukhusgrupp, SHG och andra allmänna sjukhus fokuserar särskilt på hur man hanterar patientflöde på olika nivåer inom avdelningar och kliniker genom att förbättra patientflödeskvaliteten. Produktion och kapacitetsberedning (PCP) är ett vanligt branschverktyg för att lösa flaskhalsar. Därför måste denna metod i större utsträckning antas inom sjukhuset och inom sjukvården.

Eftersom många patienter från olika specialavdelningar använder Radiologiavdelningens anläggningar är det ofta en "flaskhals" i slutenvården på sjukhus. Dessutom har inflödet av patienter med covid-19 ökat avdelningens arbetsbelastning.

Detta examensarbete syftar till att hjälpa Radiologiavdelningen att förbättra sin produktions- och kapacitetsplanering för att öka enhetsflödesprestanda. Projektet innebär att stödja nyckelpersoner på avdelningen för att uppskatta efterfrågan för att anpassa olika patientrörelser till utrustning och personal. Förbättrad radiologisk avdelnings flödeseffektivitet kan leda till jämnare och hälsosammare patientflöden runt sjukhuset, vilket minskar "buffertar" hos patienter och längre vistelser på olika specialistkliniker.

Nyckelord: Produktionsplanering, Kapacitetsplanering, Flaskhals, Patientflöde, Efterfrågan.

Acknowledgements

I would like to convey my heartfelt appreciation to everyone who has assisted me in completing this thesis project. First, I Would like to thank Dr Svante Lifvergren and Dr Anders Plantin for providing this wonderful project taken place at Skaraborg Hospital, Skövde and Chalmers University of Technology, Gothenburg. I would further like to express my appreciation to Dr Svante Lifvergren and Dr Anders Plantin for providing me an external support and supervises in every possible way.

I would also like to thank my KTH supervisor, Mohamed Nezar Abourraja, who is kind enough and willing to offer his valuable time to assist me in the advancement of my thesis. I am grateful to Dr Sebastiaan Meijer and Dr Maksims Kornevs, for guiding me in the correct direction and providing me with important comments based on their broad expertise in the subject.

I would also like to thank the Radiology Department at Skaraborg Hospital for supporting me in tackling the problem. My hope is that my work will serve as a basis for future efforts to enhance hospital processes.

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1 Introduction

- How the production and capacity planning needs to be integrated with the Hospital models in order to get better handle towards the improvisation in reduction of Patient waiting Time?

1.1 Context

Sweden has one of the best and well-established Healthcare systems in the world but in certain fields, they are lacking behind (Batun 2013). The current and future challenges faced by the healthcare system are reflected in the reports (Batun 2013; Stolt 2009). Approximately 20% of the 10 million population are aged above 65 and this number is estimated to rise above 23% by 2025 (Stiernstedt et al., 2016). Hence, Sweden is entering a phase where one in every fourth person will be considered as elderly (Stolt 2009). The expenditure generated by the elderly is considered to be high when compared to the others in the population as the service for elderly is frequent. As the result, the pressure and demand towards the healthcare system increase significantly and get complicated (Stolt 2009). The performance regarding the quality of medical care is considered to be high according to the publications released from the OECD Department of Economics (OECD, 2016) and statistics stated by Sweden's Finance Ministry (Ministry of Finance, 2010). Apart from these conditions, the economy of the country, technology, and the management of healthcare are considered to be the future challenges that are created in the health systems (Jacobsson 2010). This requires a change in the traditional approach when there is a change in the population to make use of resource when the demand is increased (Batun 2013). When the demand and capacity is maintained, it leads to the sustainable healthcare systems. In case, if the demand and capacity is not met, it leads to the long waiting time of the patients, which give a negative impact on the society and dissatisfied patients (Tai and Williams 2008) Extra care and treatment is required when there is a delay in the care and may also increase the cost of the treatment than the initial scenario.

International perspective of Sweden's Healthcare system is considered to be good but when compared to the productivity performance of the Nordic countries, Sweden hospital performance is lower (Mazzocato 2020). Renstig et al. (2003) states, the medical practitioners are treating less patients than before. In addition, Swedish practitioners seems to hold less percentage in meeting patients and spend more on other works (Fölster et al. 2014).

According to an international survey, Sweden spend about 9.5 % of Gross Domestic Product to the development of healthcare (Socialstyrelsen 2015). The problem of efficiency in the healthcare system is not by the resource that are current available (Batun 2013). But, there are several other aspects that affects the productivity, such as, structure of the organization, the control and maintenance, and how the work is actually done. The patient flow system need to be improved only when the flow of entire system throughout the hospital is changed (Batun 2013). The effect of limited availability, creates less low of patients , which results in the long waiting time of patients in the Radiology Department (RD).

1.2 Problem Analysis

In order to avoid increased burden on Sweden's healthcare systems, healthcare services are becoming more flexible, with an emphasis on providing the most cost-effective treatment possible (Batun 2013). To improve flow, connected wards should be levelled up to achieve coordinated flow, with the overall patient flow across the wards being considered rather than concentrating on single wards to prevent erratic flow (Halsted 2008).

The downstream system seems to be problematic when there is an issue in the flow process. When there is no slots at the downstream system (Radiology department), the patient should wait at the previous ward and the queue increases. This condition will increase the waiting time of the patient at Emergency Department (ED) (Socialstyrelsen 2015).

As a result, the radiology department's slot availability has an immediate impact on patient care. Due to budget constraints, increasing resources within the wards are limited; thus, the hospital should prioritize the enhancement and growth process (Gunal 2012). For past three decades, the Swedish Healthcare Systems were working on different philosophies in Lean Management with good results (Poppendieck 2011). Previously, the utilization of the resources seems to be focused among the Healthcare systems but the Lean management focuses on the flow within the wards (Rognes and Åhlström 2008).

Queueing is considered a problem not only in the healthcare sector but also in other sectors like industries, airports, and markets. The reason behind the queueing is due to the change in supply and demand, and limited available resources (Vissers 2005). To increase the operational efficiency in a sector, the main focus should be on the implementation of a tool for planning and control, and utilization of methods related to operational management.

According to Chung (2004), simulation is a tool to analyse newer or methods to be changed in a production line in reality. Compared to traditional research and mathematics, simulations have fewer analytical requirements and require less time for computation. Simulation helps to create real-time system design and allows using tools to plan cost-effectively. Besides, simulation provides animation as a tool for communication and visualization during the time of demonstration.

This thesis study is carried out at Skaraborg Hospital Groups (SkaG), which includes hospitals in four different regions: Mariestad, Skövde Lidköping, and Falköping. In the Radiology department even for high-priority cases, the hospital is facing a condition of lengthy patient wait times. Initially, the hospital management had tried many flow methodologies to improve patient flow efficiency. As the flow between the wards is interlinked, e.g. when there an issue in the Radiology Department, it directly affects the patient in the front of the chain, and the patient queue is created. Thus, the patients seem to remain in the ED ward, waiting for the diagnosis (Socialstyrelsen 2015). This in sense, the risk of patients waiting time and patient safety is created. For a better view, a good system is required to view the whole wards that are connected to understand the status of the ward. Good forwards planning needs to be installed, for patients to have a better experience in the hospitals and to feel comfortable.

The downstream ward for investigation was the Radiology Department, where the patient of care is limited i.e. patients only from the emergency department of the respective hospitals are considered. The patient flow towards the radiology department is higher and has been worse in the COVID 19 situations. Based on the identified problem, the RD is considered to be the primary focus area as the flow is to be altered without providing any negative impact on the Department.

1.3 Purpose and Research Questions:

The main goal of this master's thesis is to create a realistic model for improving patient flow quality in the hospital's Radiology Department. The aim is to investigate patient flow in a single ward and to examine patient flow at all stages. In addition, a simulation model is created to analyse the system and suggest possible changes.

Research Questions:

Two research questions have been formulated in order to achieve the above aim. These questions may serve as a reference for conducting research in order to identify areas for improvement.

- RQ 1: *How to balance patient flows at micro-, meso- and macro level with available resources (modalities, personnel) on a short- and long-term basis to improve overall patient flow efficiency at the Radiology department?*

- RQ 2:*What production and capacity planning methods can be developed and adapted to improve patient flow efficiency at the Radiology department?*

1.4 Delimitations

The main delimitation of this thesis study is to focus on the information and decision made by the Radiology Department to the patient flow from the Emergency Department. The study is delimited only to provide improvement recommendation for the efficient patient flow. in the study, the improvements are not implemented within the organization.

1.5 Report Outline

Chapter 1 - This chapter aims to provide background information for the review, as well as problem analysis, intent, research questions, and delimitations.

Chapter 2 - This chapter discusses the analytical principles used in this review to help readers grasp the concepts that are critical to addressing the analysis questions.

Chapter 3 - This chapter contains the research methods, conducted during the study and as well as the reason for using them. Data collection and data interpretation methods are discussed along with ethics and reliability.

Chapter 4 - It describes the operation of the Skaraborg hospital, which helps to make a clear vision about the patient flow between the departments of Radiology and Emergency wards.

Chapter 5 - In this chapter, a simulation model is developed to analysis the bottleneck moment in the patient flow of the radiology department using the empirical data.

Chapter 6 - In this chapter, the factors which affect the patient flow within the Radiology Department are discussed initially and the following chapter is discussed about the research questions.

Chapter 7 - The conclusion for the defined research questions is provided in this chapter with the help of analysis and discussion.

2 Background

The theoretical concepts used in this study are discussed in this chapter to help to understand the concepts that are essential to answering the research questions.

2.1 Flow and Process

According to Bergman and Klefsjö (2012), Flow is an activity that is connected as a network and is repeated in time. Its ultimate aim is to satisfy the customer by using only as few resources as possible. When there is an activity, the flow has two-point, a start and an endpoint. According to (Trebble 2010), flow is considered as a boat channel, where the flow itself is considered as a channel and the boat is an entity that is transported within the channel. The transported entity may be the information or material from the organization (Bergman and Klefsjö 2012). The flow during the transportation is done step by step according to the need of the customer.

Theory of Flow

Historically, the resource efficiency is considered to be the highest level when the organization uses the resource to its maximum point. It also seems to be natural for people who thinks about the efficiency. This says that, to make the resource work continuously, the unit must wait in order to make sure that the resource is working constant (Modig and Åhlström 2015). The maximum utilization of resource is not guaranteed as it tends to increase the work load (Modig and Åhlström 2015). Besides, efficiency can be characterised as a level of performance in term of resource usage (Jacobsen et al. 2008).

Flow efficiency is new to many companies as they think of it is a maximum resource utilization due to its contradictory way of thinking. But actually, it is deemed to be a neutral way of defining efficiency. Flow efficiency is not considered to be new among organizations, because it has been since 1500, but usually, organizations think of resource utilization when it comes to the operation. As mentioned above, flow efficiency concentrates on the unit, which can be a piece of information or material from the organization. It helps to understand and satisfy the customer needs, if we are considered as a patient, the primary satisfaction is to get better in health (Sánchez 2018). The flow efficiency can also be defined as the time added for a resource is equal to the time taken for the throughput process i.e. resource to unit transformation. Throughput time is the amount of time take by the unit to move across the system boundaries.

Sánchez (2018) states that the process helps to create the efficiency in flow. The process within the organization is defined differently. The most prevalent misconception of the process is that it is perceived as a single work procedure, which it is not. As previously said, the process is seen as a set of events. In a hospital setting, information or a patient is an unit that is transported between systems for different operations in the process.

Activities that optimize the unit, as well as activities that relate to meeting consumer demands, are referred to as value-adding activities. According to Bergman and Klefsjö (2012), main process, management processes and support processes are the three main different processes in the industry. Main process holds the activities that are related to the value adding process. Whereas support process holds the activities that are not value-adding process but helps to develop the business and but not included in the main process. According to Hartmann (1996), a non- value-adding process helps in releasing resources.

The universal rule of Process

Three universal rules apply to all systems (Sánchez 2018). The bottleneck law, Little's law, and the law of differences/variation all have an impact on operations.

- *Bottleneck law:* It means, Bottleneck can be present in all processes. It takes a huge amount of time, which limits the activity. The bottleneck can be identified by the presence of a queue in front of activity and free space immediately following it.

- *Little's law:* It states that the throughput time is proportional to the loop/cycle time compounded by the number of units in the operation. When a unit completed its process it is considered as a cycle time and the unit under the process is refers to the unit within the process.
- *Law of differences/variation:* Variations can exist in systems, and although it is difficult to avoid them, they may be planned and regulated, which is beneficial for companies. With an increase in resource efficiency, the throughput increases as the variance increases.

According to Hartmann (1996), when an organization focuses on the value-adding process that serves the consumer, it is referred to as productive and successful. Furthermore, non-value-added processes and throughput time can be limited and minimized.

2.2 Flow in Healthcare process

In healthcare, the process will start and stop when the patient is admitted and discharged from the hospital. In addition to the flow of patients, the information flow is also included in the healthcare process. The time between the start and endpoint of the process is called the Length of Stay (LoS). LoS varies depending on the patient's condition and care, and sometimes within the same disease. As previously said, rather than relying on a particular framework, the knowledge and patient flow system must be seen as a whole. For example, if the emphasis of patient flow is solely on the emergency room, without regard for bed availability, a queue forms among the patients (Halsted 2008). When queueing is present, patients tend to receive low quality care if they are put in less suitable wards, according to Halsted (2008). According to Batun (2013), historically hospitals have relied on resource efficiency, but today's hospitals must pay greater attention to the unit's flow efficiency. Unit improvisation in the organization were not encouraged by the Nyman (2007), rather imposes the view towards the whole flow structure. Working between the units, the improvisation can be reduce but it is harder to break down the barriers in the hospital (Croxton 2001; Meijboom et al. 2011). A coherent knowledge flow across the whole organization is crucial in an organization that lacks priorities and where units frequently function individually (Davis 1993).

The three stages of the healthcare system are the admission phase, the in-patient period, and the discharge process. Not all stages of a patient flow are completed in a single ward, and an effective infrastructure is needed to keep these processes running smoothly (Bahall 2018). To avoid the delays in the patient process, the bed management among the wards are most important.

When flow of patients within the hospital is tracked over time, one can able to change the flow internally as well as externally (Walley et al. 2006). External change may refer to an object that would be delivered to the patient, while internal change refers to the patient's time in the hospital (Halsted 2008). Compared to the patient flow many changes are interlinked with the effective flow e.g. schedule of a surgeon (Allder et al. 2010). To improve the flow of the patients, the two groups of changes i.e. the external and internal changes can be connected (Halsted 2008). The improvements can be possibly implemented within and outside of the hospitals. The process including preparation and planning are implemented when the patient discharge is called discharge process. E.g. in an operation/ surgical ward, the discharge forecast can be done by 85% of accuracy. Early forecast helps to improve the flow of patients within the ward (Bahall 2018; Halsted 2008). For certain medical procedures, the early forecast for discharge time can be predicted, which helps in prior planning (Liker 2004).

2.3 Occupancy rate

Occupancy refers to the level at which the utilization of the resource is planned. The occupancy rate is regularly measured in the hospital. In consideration of the patient flow and the cost, the planning is made by the ward manager (Halsted 2008). The target set for the occupancy rate is 80 to 85 %, which is measured at midnight of the day. When the targets reaches to 85 percent, problem is raised which leads to the decrease in the quality of care. According to Brandt and Palmgren (2015), to build a levelled flow, overcapacity is required.

2.4 Separating Flow

Separating flows is a normal occurrence in an industrial setting, and it can be seen as a requirement for achieving a quick and levelled flow (Liker 2004). The productivity can be increase, by eliminating the non- value added processes (Dolan 2003). As mention above, the flow is maintained based on the different activities in the industry and the value that are created among the customers (Liker 2004). One major contrast between a business versus a healthcare such as a hospital is that in a hospital, the patient consumes the service at the same time that it is delivered (Adan 2002). According to Dolan (2003), the focused factory defines why the industries are not yielding the same productivity. When the flow is monitored separately of the same output, it gets less complex and most successful in productivity. Similarly, the patients in the hospitals can be monitored based on the specific requirement and flow can be organized based of the treatment they required. Furthermore, the workers flow may be segregated in order to execute their tasks with the same target in mind. This approach aims to coordinate the movement of patients inside the wards and reduces errors (Jacobsson 2010). According to Hyer et al. (2009), when a healthcare switched to a more focus-based approach, the LoS strengthened. Separate flows often allow for diverse techniques to be used to prevent overcapacity (Olsson and Aronsson 2012).

2.5 Production and Capacity Planning

Production and capacity planning (PCP) aids in the systematic determination and management of patient traffic (Batun 2013). When a resource is first put to use, it must be carefully prepared and tracked (Mattsson and Jonsson 2013). According to Batun (2013), PCP assists in the organization of resources that are currently required, allowing for the provision of high-quality services to patients. In the Swedish healthcare system PCP is not usual to be seen and importance is provided to predicting potential demand for treatment to address potential challenges. To reduce wastes and unit improvisation in a patient flow, healthcare must be more constructive. Examining current demand will help to properly align staffing schedules (Brandt and Palmgren 2015).

2.6 Standardization

Standardization is another way to enhance the process's efficiency. Standardization in an activity must be always monitored, questioned, and regularised because it is not always perfect. Once the standardization is created, the variation will get reduces as the staffs follow the routines as per the standards (Jacobsson 2010). Standardization helps the manager to create a clam and organized routine environment and not as a control method (Seddon 2010).

Standardization also helps to eliminate the number of erroneous procedures and increases the improvisation in the routine (Spear 2005). By installing standardization, the routine among the staffs will improve as it is easy to follow the repeated tasks. Once the entire work is organised, it act as a platform to reach the newer position. According to Liker and Meier (2006), Procedures and improvements are more likely to be overlooked by design, and operations will return to the processes that are considered to be not standardized.

2.7 Visualization

Visualization method helps to visualise the process of certain activity in the form of picture. The visualization is commonly used in the industries in order to understand the process path (Monden 1983). There are distinctions between manufacturing and services, such as the hospital procedure, where the service is utilized immediately when required, making it more difficult to assess the service's outcome. Though the final result are harder to visualize, the process can help to improve the system (Jacobsson 2010). In a hospital scenario, the process can be visualized in the form of a map and can be discussed about the number of patients in wards and availability of beds. By this managers can understand where the problem occurs and can solve the issue with the help of visualization (Jacobsson 2010).

2.8 Lean Philosophy

According to lean, all work is done with the client in mind, and work is graded as either a value add or a waste. The main focus of the lean is to eliminate the waste which is considered as a non- value added process (Liker 2004). According to Womack and Jones (2010), Lean is structured based on the five principles:

1. Defining the value
2. Value flow mapping
3. Flow creation
4. Based on the customers demand establish the pull
5. Steps taken for continuous improvement.

According to Liker (2004), certain practices in the Lean are called waste, such as high production and waiting time. In a healthcare system, the waste can be categorized as activities that are not- value added to the patients and staffs (Jackson 1996).

Healthcare has adopted the lean in the early 2000s. As previously said, one of the most significant discrepancies between lean in business and lean in healthcare is when the value is generated. Treatment procedures, unlike industrial processes, are often dynamic because the patient's situation changes with the progress of the operation (Adan 2002). The emphasis on flow rather than resources is a key difference between hospitals that use lean and those that don't (Cote 1999). Owing to the high variation in the inflow, it is impossible to provide fast throughput times while still providing a high resource usage (Jacobsson 2010).

Despite the fact that many good lean applications in healthcare have been introduced, there is still opposition to it, even though many people think it belongs to the industry (Stefl 2008). The techniques and principles used in the industry as lean methods can also be followed by the healthcare systems but not the exact solution (Adan 2002). Implementing lean in healthcare may also be a failing mechanism if the individuals concerned are not paying attention during the inspection, which becomes crucial. Lean techniques should be used in low variation processes which helps to remove the trouble with an increase in efficiency (Tennant 2000).

2.9 Situational Awareness

In a complex system, the decision must be made with a clear understanding of the situation and it is referred to situational awareness (Endsley 1995). The one’s situational awareness must be based on the information that is understood, and decisions are made based on the objective and goal of the system, which is based on the current scenario and future aspects. Situation sensitivity refers to a high level of understanding of a system's inputs and outputs. According to (Endsley 1995), many choices must be made in a short period in complex settings, and tasks are based on a continuous check within the system. The framework of situational awareness through communication for cooperation is addressed by (Mackay 2013). As a result of not realizing that other teams don't have or need such information, it's normal to fail to share it.

2.10 Simulation

Simulation is a method of computing that is used to create real-world models in order to better understand their function and plan for future developments (Banks 1998). Simulation has been regarded as a key technology in the twenty-first century because it aids in the improvement of systems in a variety of fields. Simulation is primarily used in the manufacturing and improvement of industrial products (Kriegel 2015).

Because of its computational power, the cost of operation, and the advanced method for special fields, simulation is widely used in a variety of fields. It's also widely regarded as a useful tool for system analysis and operational research (Banks et al. 2005). Simulation methods like Discrete Event Simulation are considered as a decision support method, which helps in making decisions about daily problems within production systems along with the optimization methods. Other methods exist namely, value stream mapping, lean approaches, linear programming but simulation methods appear to be the most appropriate approach to study complex systems with high variations (Brailsford 2008).

Almost all processes can be divided into discrete and continuous categories. Few of them are discrete or continuous, but this grouping is generally based on the more prevalent form of the two previously described, discrete or continuous (Law & Kelton 2000). There is a lot of uncertainty and complexities in the healthcare sector, so it's a good idea to use Discrete Event Simulation (DES) as an empirical tool (Hay et al. 2006; Brailsford 2008). DES is absolutely important for managing the widespread complexity and flow of patients that typically passes through healthcare clinics (Kaplan 2006). The developing of simulation technologies over the year helps the healthcare system to increase the productivity (Centeno et al. 2010).

The opportunity to apply "what-if" questions or scenarios to current healthcare delivery processes is one of the most fitting highlighted features of DES research applied in healthcare systems. This trait is particularly useful for assessing improvements or differences in the staff's systems, equipment, or practices to improve productivity more smoothly and efficiently.

In the literature, DES is the most commonly recorded technique in healthcare, followed by Monte Carlo Simulation and Machine Dynamics (Young et al. 2009). DES has been a common method for healthcare decision-makers to use to significantly increase the quality of healthcare processes and reduce distribution costs. In a healthcare system, DES can also act as a forecasting tool for analysing the flow of patients and for resource allocations if needed (Kaplan 2006).

The computer is used to run simulation software. Once the model is error-free, the future situation of the related real-world system can be analysed. The main advantages of the simulation are the short computational time based on the model, the ease with which models can be demonstrated, and less of a need for analytics (Jingshan et al. 2017). Because simulations are computer models, they do not affect the real system. New settings, such as animation, aid in visualizing and demonstrating the model (Chung 2004).

According to the simulation, if the input data is accurate, we can expect the model to behave based on the input, which appears to be accurate when compared to the real model. However, if the input data is random, the simulation will produce a different result, which will be inappropriate. This demonstrates that the simulation model does not solve the problem; rather, it simulates the real system and assists us in taking decisions along with the improvisation methods.

3 Methods

This chapter contains the research methods, conducted during the study and as well as the reason for using them. Data collection and data interpretation methods are discussed. Finally, ethics and reliability will also be discussed.

3.1 Research Method

The master thesis was structured in a hybrid/ mixed methodology as a single case study, by that the thesis holds the mixture of quantitative and qualitative methods. According to Bryman and Bell (2015), for good expression of facts, a mixed methodology is preferred as it allows for the use of a variety of methodologies. A single case study method was chosen since the research performs process solutions in the hospital environment that developed in industrial principles. It allows researchers to investigate a phenomenon inside a complex system with a blurry line between phenomena and context (Yin 2003). Partial data is collected by qualitative method to increase the understanding about the social phenomenon (Bryman and Bell 2015) and to understand the patient and system flow behaviours, the quantitative methods were also used.

The study was divided into three parts, each of which was referred to as a phase. The first phase is comprehending and describing the issue, the second phase is the problem's investigation, and finally, the improvement proposal phase, see Figure 1. The goal of the first step was to comprehend and characterize the problem in the context of healthcare. The second step involved a study of the problem, followed by the improvement proposals.

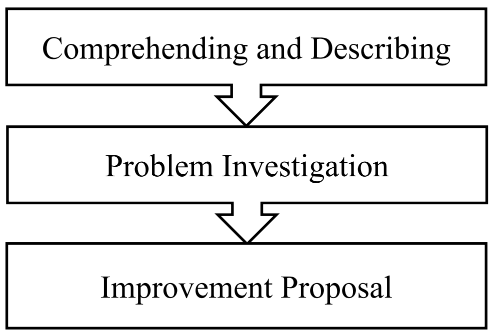

Figure 1 The three phases of thesis research

When thesis research is conducted, the empirical data and the theory can be related in different ways. An abductive technique was adopted for the interaction between empirical evidence and theory, which is a hybrid of inductive and deductive reasoning. Inductive reasoning is based on actual facts, whereas deductive reasoning is based on a hypothesis that has been created through theory and finally evaluated against empirical facts (Bryman and Bell 2015). Since of the flexibility between inductive and deductive methodologies, the abductive technique was the best fit for this study because it builds findings on factual data while not rejecting current hypotheses (Alvesson and Sköldberg 2008). The abductive technique model is in Figure 2 (Kovács and Spens 2005).

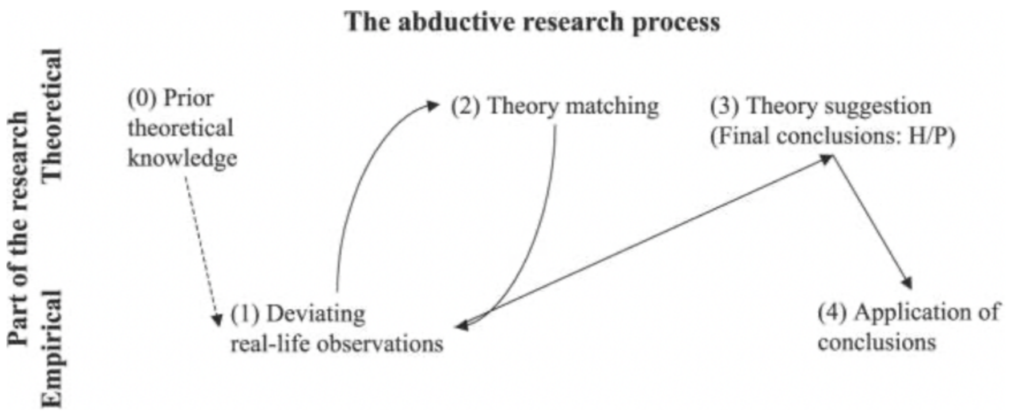

Figure 2 The Abductive Technique Model

Once the problem investigation is identified in the given empirical data, the conclusion of this study is created. A comment is also developed both independently and in partnership with the organizational employees. In addition, to test the efficacy of recommended modifications, a comparison of the current theory is performed for analysis, and this approach is meant to be an abductive technique.

The answers for the research questions are developed, based on multiple methods used to collect the data, as the mixed methodology is used. By interviews and through conversations with department managers, the data for the research is collected. Observation of daily patient flow through process line is also a part of data collection. With the help of the department managers, the problem areas are identified and solution is finally generated.

3.2 Research Action

The researcher's relationship to the subject of research has an impact on the research's results (Bryman and Bell 2015). Since the research is based on the genuine existing initiative problem at the hospital, this study will take an action research method. This is a characteristic of action research, which is conducted to aid in the development of a solution (Bryman and Bell 2015). Participation of staff from the organization will happen, in this course of action through a workshop, where the interaction is developed with the researcher and offer their expertise and experiences. In the case of process issues, the action research allows collecting the data in both qualitative and quantitative manner. They are quite similar to the mixed-methodology utilized in this study and therefore the justification for using the action research method (Bryman and Bell 2015).

In order to fill the gap between the managers and researchers, an involvement of managers are required, which is considered as a benefit of action research approach. Hence, the online meeting was held periodically, during the project. By this method, a solution is developed in a joint manner which is considered to be a user centric design and for the organization itself. A partnership like this typically has a favourable impact on the output, as it is related to the managers and the researchers (Bryman and Bell 2015). Because of the shared development of solutions, integrating managers in the process enhances the likelihood of implementing changes inside the organization following the implementation. The action research aims to help both real activity inside the organization and also to academic theory (Bryman and Bell 2015).

3.3 Data Collection

According to Holme et al (1997), during research, the data collection is divided into primary and secondary data. The data that is collected from observation, interviews, by example is often considered to be a primary data collection. Whereas data from an article and other thesis documents are considered secondary data (Lundahl and Skärvad 1999). In this thesis, the empirical data are collected from both qualitative and quantitative methods, which is recognized as a primary and secondary method of data collection. The data gathered from observation, workshop, and interviews fall under the primary qualitative data collection method, where an individual's perception is used to build the data and it is difficult to validate the purity.

For this thesis, the primary data collection from the hospital was started by the end of February 2021, and continued till the mid of April 2021. In this thesis, a single person was acting as a source of contact with the hospital managers to collecting secondary datasets. The primary data collection took nearly 400 hours for getting better clarity and understanding of the organization's work nature. In Table 1, the time spent on data collection is shown. The question developed for the interview section are attached in the appendix. The secondary data collection was taken place simultaneously, from the data system of Skaraborg Hospital. With the help of the data system, the past data based on the radiological reference from the emergency department is gathered from Skaraborg Hospital systems for verification and to strengthen and validate the primary data, which is collected simultaneously. Finally, additional information and clarifications are made between emails, when a question arises.

Table 1 Initial Data Collection

Position	Interviews	Conversation
Development Director	1	4
Strategic Planner	3	15
Radiology Department Manager	2	2

3.3.1 Literature Study

To understand the essential ideas and also about the topics related to this thesis, an initial literature study is made. Which also helped during the problem presentation session, conducted during the staring phase of the research in the hospital. The concepts that is to be studied for conducting research is gathered from the reflection and evaluation of the different authors of this field. The research with deeper study of current state within this field is understood by conducting an in-depth literature study. With the help of these gathered concepts and ideas within the field, the questions that are developed for conducting an interview became simple. This shows that the literature study is valuable in understanding the concepts (Bryman and Bell 2015). Upon the literature study the used are keywords are, patient flow, production planning, capacity planning, flow management in healthcare. The google scholar and KTH library were used for this research purposes.

3.3.2 Observations

Observations are considered to be a primary method to understand the nature of patient flow within the hospital. To understand the flow and to identify the lead time of each activity within the flow map, several observations are made for achieving a better result. According to Bryman and Bell (2015), the observations are differentiated into structured, unstructured, and participant observation. Unstructured observation seems to be more appropriate for this thesis study as per Bryman and Bell (2015), which is considered a good method to collect more information on the desirable observations. In this thesis, the observer as participant approach is followed by the researcher, which describes that the researcher as a complete observer or an interviewer, and mostly as non-participation (Bryman and Bell 2015). To understand the nature of patient flow in the radiology department within the hospital environment and to observe the planning of the flow map (Figure 3), the observer as participant approach along with the unstructured observation is implemented. This focuses on gathering all possible information with the activities. The local nature of the hospital culture is understood by observing the planning meeting and other activities within the radiology department.

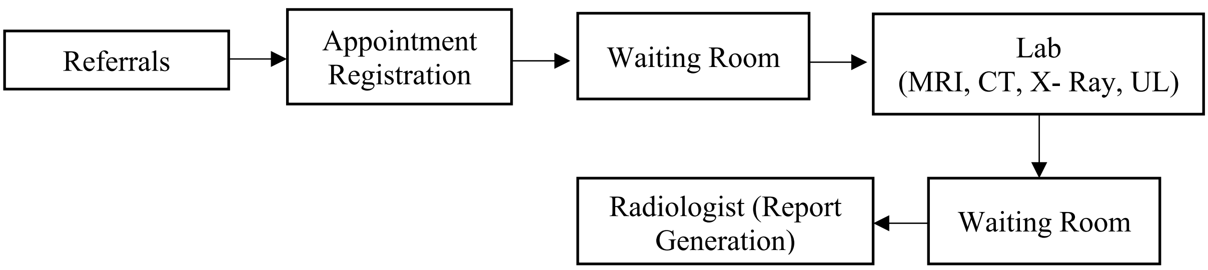

Figure 3 Flow Map: Radiology Department

On the day of observation, the information discussed based on the patient flow and area of interest is continuously noted and gathered. This small information during the observation will help during the time of data analysis (Bryman and Bell 2015). To get a better reflection, an observation is made for every activity within the flow map to understand its behaviour and time consumed. After each observation, a reflection upon the activity is written and discussed between the department head and the researcher. Later, a computer document is made for analysis purposes.

3.3.3 Interviews

According to Bryman and Bell (2015), interviews are of a different type. Among which two different types of interviews are performed in this research study. In the first phase of research, the unstructured method is used and in the second phase, semi-structured interviews are performed. In the unstructured phase of interviews, a less number of questions were prepared and discussed during the interview. This interview also allows the interviewer to ask questions upon the flow of the interview and not in a specific order. The ultimate aim of this unstructured interview is to develop an atmosphere, within which the respondent will feel free to talk about the things that go in the mind and their reflections. Thus, by this method, the aim and problem are defined and understood, which helps to understand the nature of patient flow with the radiology department.

The semi-structured interview is performed in the second phase of the research. During this phase and due to the research current stage, the interviews should be concentrated on the higher level, and hence the method of interview is changed. In the semi-structured interviews, the questions during the interviews are predefined and new questions are developed based on the response provided by the respondent (Bryman and Bell 2015). According to Kvale and Brinkmann (2009), semi-structured interviews help the respondent to move deep into the area of interest by allowing them to alter the actual framed questions. Moreover, this kind of interview is chosen as it allows frame a question starting with “what” or “how”, as these are referred to as open questions. Open-ended questions allow the respondent to express their feelings about the topic at hand. Through semi-structured interviews provide much freedom, it allows has a chance to affect the respondent by the freedom provided to the questioner. To avoid such a situation, the respondent’s judgments and understanding in the field are used to formulate the follow-up questions (Bryman and Bell 2015).

Distractions in the interviews can be minimized, by following a suitable technique for the interview as it may affect both the respondent and the interviewer (Justesen and Mik-Meyer 2011). The researchers stayed relaxed and made the respondent feel calm to minimize the distraction during the time of the interview. Before the interview starts, the response and purpose behind the interview are shared. To get the different perspectives of the same field of interest, the same questions have been asked for all the interviews. Based on the purpose of the investigation, the follow-up questions are however changes based on the respondent’s answer. Finally, notes are taken for computer documentation analysis.

3.3.4 Short Conversations

Conversations were made shortly along with the staff during the observation phase. Mostly these kinds of conversations are made relax, as the exchange of thoughts about the area of interest was made. These conversations have taken place in the short free time of the staff or during the break section for about 5 minutes to 10 minutes. Based on the previous conversation, research might find for a person to discuss the subject. Staff from the same field is chosen, when the particular person was not available. During the short conversation, mostly the notes are not taken. But for a regular or long conversation, notes are taken as it might help during planning.

3.3.5 Quantitative Data Collection

Data based on the inflow of patients towards the radiology for different referrals within the hospital are collected during the quantitative data collection. The data was collected into two different phases, the inflow of patients from the emergency department towards the radiology department and the overall patient towards the radiology department. The entire set of data belongs to the year 2020 and it is taken out from the data systems at Skaraborg Hospital. These data help in understanding the flow of patients within the departments of the hospital and helps while creating a simulation phase.

3.4 Data Analysis

From the provided data, the data was split into two half to understand the flow of patients easily. According to Barley (1990), handling too much data is a challenge. So, the first half of the data is used during the data analysis and also for developing the simulation model. To identify the problem area and developed issue, a simultaneous vision towards the collected data along with the qualitative data is so important (Miles and Huberman 1994).

To simplify the analysis study, a modified Shiba model was chosen (Shiba 1987). This model helps in qualitative data analysis by including data production and reduction, and also the conclusion verification. The ultimate aim of the data analysis is to understand and identify the problem that aims to solve the issue. According to the problem structure, the data was divided accordingly and their three hierarchical levels in the hospital as micro, meso, and macro levels were identified (Figure 4). The macro-level involves all the managerial level in the hospital who is responsible for the planning of wards. In the meso level, the mid- managerial level who manages the patient flow with their department are involved. And finally, the micro-level involves all staff working within the ward in daily operations.

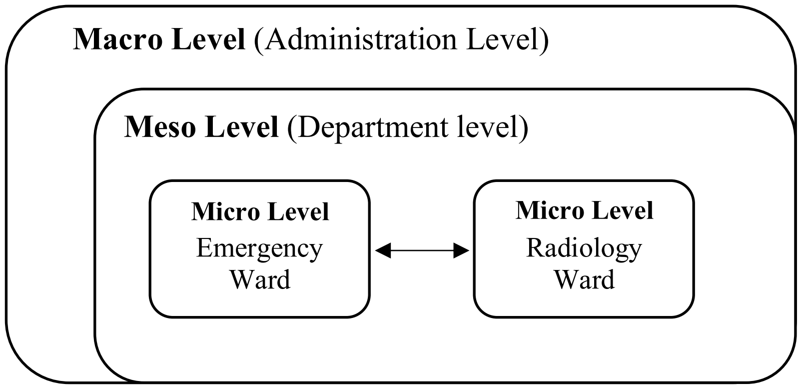

Figure 4 Levels Within The Hospital To Manage The Patient Flow

Once the observation or a conversation about the activity is made, a small note is taken to write a better reflection about the process that has been undergone during the day. A problem area can be identified based on the successful observation and reflection, during the data analysis. In addition, to understand the perception of the identified problem, a short conversation/workshop is conducted. Later, the problem related to the specific hierarchical level is notified and analysis is made based on the problem between them.

Different conditions like patient inflow and waiting time can be understood using qualitative data (Eriksson and Paul 2008). To identify the difference and similarities in the data, the collected data is grouped, which helps in understanding and planning the total number of machines available in the radiology department. The result that is to be acquired can also be based on what type of data is processed (George 2005).

3.5 Ethical Aspects

The four areas of ethical consideration based on Bryman and Bell (2015),

- ⇒ Medical indication
- ⇒ Participant preference
- ⇒ Quality of life
- ⇒ Contextual features

During this master thesis, the main consideration of the ethical aspects were participant preference and contextual features. It is important to be informative to make sure about the confirmation of participation in the conversation and research. Their involvement in the conversation and interviews was voluntary and that they might quit at any time. Every participant in the conversation and interviews was anonymized and all the data are aggregated to avoid the respondent identification being revealed. The respondent is made aware of the data that they provide and how the data is going to be used. During the discussion, the reveal of the previous discussion is not made, as this thesis research is based on the action research plan. Additionally, the data that is retrieved from the data systems at the Skaraborg Hospital is used securely. The gathered data included only the total number of treatments that were made and does not include any patient's name. So, the ethical review was not necessary.

3.6 Reliability

According to Hartman (2004), when the reliability is high, repeatability occurs during research when the outcome appears to be the same regardless of who did the study. As reliability is considered to be a social factor, it is adverse in qualitative research mainly in healthcare divisions. Sometimes, a border generalization is harder to reach during the analysis of a single instance is a disadvantage of a case study (Bryman and Bell 2015). According to Denscombe (2010), for a fair creditable result of the survey, a case study helps in provides a pool of resources of data collection as prerequisites are increased. Another way to increase the reliability in research is by avoiding the partial interviews, as it affects the interpretation of the respondent over the area of interest (Starrin and Svensson 1994). With the help of an elaborate explanation about the data analysis technique and method approach, the reliability of this research can be improved.

3.7 Validity

To identify the quality of the research, a validity assessment is required. Validity assessment helps a researcher to identify whether the models and ideas used during the research are exact of which the researcher wants them to measure. So, if there is high validity then there is a high relevance to the collected data. According to Bryman and Bell (2015), for high validity, the relation between the theory and collected data must be high. When the observations and interviews are made, a researcher or a supervisor was present to obtain the research in high validity. Thus, from the collected data an interpretation is made and a comparison with the theory is matched. According to Bryman and Bell (2015), the validity check for the qualitative data is risky as the interpretation would be done by someone in the same way. To maintain a better validity, the researcher should be unbiased, as it affects the answer to the respondent during the interview. Additionally, to strengthen the validity of the research data collection of a different type is performed. As a result, an issue is viewed from multiple angles for better results (Yin 2003). The research work is reviewed along with the organizational staff, where the uncertainty and misinterpretation can be cleared or eliminated.

3.8 Generalization

Results of the case study with similar occurrences are referred to as generalization. When compared to multiple research work methods, a case study seems to be difficult in generalization. According to Bryman and Bell (2015), to check whether the results are applicable in other circumstances, there is a purpose for a comprehensive description of a case study.

3.9 Reflection Of The Research

The research is started by analyzing the historical data which helps to match the resource along with the demand. The hospital has a board data about the patient flow across all the departments in their data system, thus the focus towards the production and capacity planning is initiated with the help of a simulation tool, to find the bottleneck in the Radiology Department. After the analysis of the qualitative observation, a simulation model is created in replication with the flow map from the emergency department to the Radiology department. The simulation models help in understanding more about the utilization and queue created within the wards. Developing a simulation model took time, as the module in the simulation represent different action and the correct module is required to be used as the outcome should match the reality. For the correct numbers of patient inflow and outflow, quantitative data was gathered. Using the historical quantitative data, similarities and difference are found i.e.: mean, length of stay and variations, which is used as an input to the simulation development.

After gathering and analysis of the data, the resource and the patient demand were too unstable and there is a requirement for production and capacity planning. After analyzing the planning of resources within the hospital, the research was focused on the improvement towards the production and capacity planning is made to create a smooth patient flow in the Radiology department. Different models were used during the development of simulation, which acts as an improving support tool during the improvement planning.

Finally, during the research suggestion regarding the simulation part were analyzed along with the researcher to get a different perspective, which helps during the planning phase. Interviews and short conversations help in collecting more quantitative data were collected which helps in defining the problem. As we followed a mixed method of approach, a good amount of data was collected during the study. However, some data was not used as it not relevant to the study, but still, with the other sets of data, the nature of patient flow within the radiology and emergency department was clearly understood.

4 Empirical Data And Findings

This chapter describes the operation of the Skaraborg hospital, which helps to make a clear vision about the patient flow between the departments of Radiology and Emergency wards. Additionally, the data collected from the observations, conversations, and interviews are also presented.

4.1 Operations of Skaraborg Hospital

There are four branches for the Skaraborg hospital located in Lidköping, Mariestad, Falköping and Skövde. The hospital is surrounded by 280,000 citizens, who were mostly drawn to the hospital (VGR 2020). In the year 2020, 108 559 inpatient referrals towards the radiology department were made. Out of which, 38 189 referrals are from the emergency department. In the radiology department, there are four modalities: Computed Tomography (CT), Magnetic Resonance Image (MRI), X-Ray, Ultrasound (UL). Based on the referral's need, the patient is tested in any one of the modalities.

This thesis research is carried out at the Skaraborg Hospital Skövde, where the patient waiting time for treatment varies from immediate to four weeks. By this, the radiology department performs the test for both acute and elective patients.

4.2 Radiology Department

The radiology department performs X-Ray examinations of the skeleton and lungs. Additionally, they are performing CT examinations, MRI, and UL scans. Each modality holds a certain number of working machines, see Table 2. Every machine has its test period, see Table 3, which also determines the flow of patients. In the radiology department regular shift starts from 7:10 and ends at 16: 15 with 75 minutes of rest time. There are dedicated machines for emergency cases under each modality (see Table 2) which works for 24 hours every week. The communication of the incoming patients is made via the electronic system and based on the treatment period, and appointment is booked in consideration with the patient under acute or elective. Over some time, the incoming patients level is increased, which eventually affects the normal flow of the patient within the radiology department.

Table 2 Total number of machines in each modalities

Modality	Normal cases	Emergency cases
CT	2	1
MRI	4	0
X- Ray	3	1
Ultrasound	2	0

Table 3 Test Period of each modality

	Test Period		
Modality	**Minimum**	**Maximum**	**Average**
CT	14	20	17
MRI	35	40	37.5
X- Ray	10	15	12.5
Ultrasound	15	20	17.5

4.2.1 Human Resource In The Radiology Department

The human resource in the radiology department is Unit manager, coordinator, secretary, register, supporting staffs, nurse and modality operator. Throughout each shift, the staff is assigned differently, on the weekdays and weekends. The daily operations are taken care of by the unit manager. Extra staff is allocated when there is a heavy workload.

4.2.2 Measurement and Continuous Improvement

For effective decision-making and continuous improvements, a meeting is held within the department. The aim is to work under the PDSA strategy: Plan, Do, Study and Act. The unit manager, follow-ups the previous change, and new decisions are made for future improvement. Here, the occupancy rate, ward designs, flow mapping are discussed for improvements.

4.3 Patient Flow Data

A detailed view of patient flow towards the Radiology department and acute patients from the emergency department are described in this sub-chapter, which helps in making a decision during analysis.

4.3.1 Patient flow at Radiology Department

The 65 percent of patient flow at the radiology department is from the emergency department which is considered as an acute patient. The remaining 35 percent of patients are considered to be elective, as they are from other wards or scheduled patients. Figure 5 shows that the graphical representation of the total number of inflow patients towards the radiology department in 2019 where the X axis represents the total number of incoming patients and Y axis represents the number of weeks.

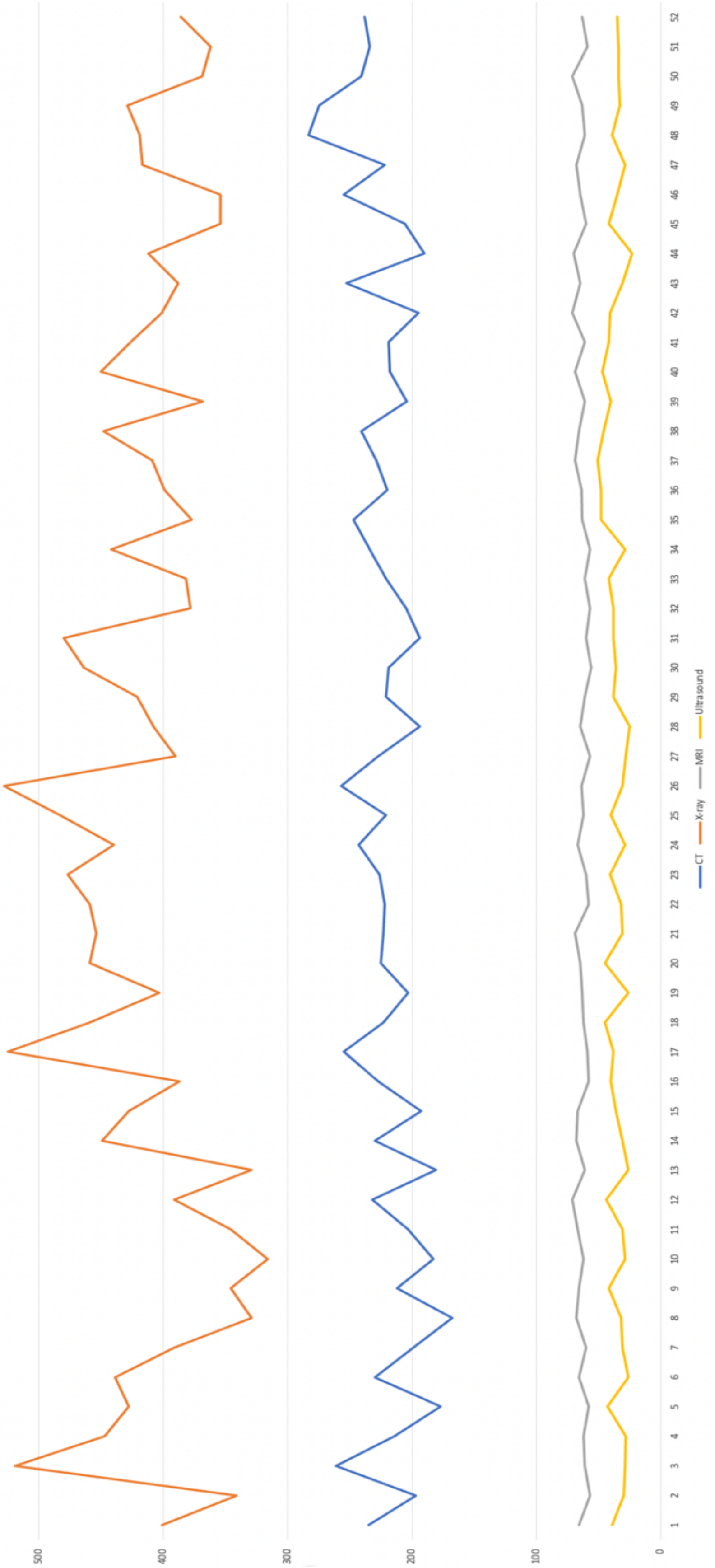

Figure 5 Weekly Inflow of Patients towards Radiology Department 2019
**X axis = Total number of incoming patients   *Y axis = number weeks in 2019*

Figure 6 shows that the patient flow starts to increase in the early morning of the day in every modality and seems to be continuously increasing by the rest of the day. The inflow of patients for X-Ray in a day is higher, which is followed by CT, Ultrasound, and MRI. Additionally, some patients are coming to the radiology department in off-shift between 16:45 and 7:10 are mostly from the Emergency Department.

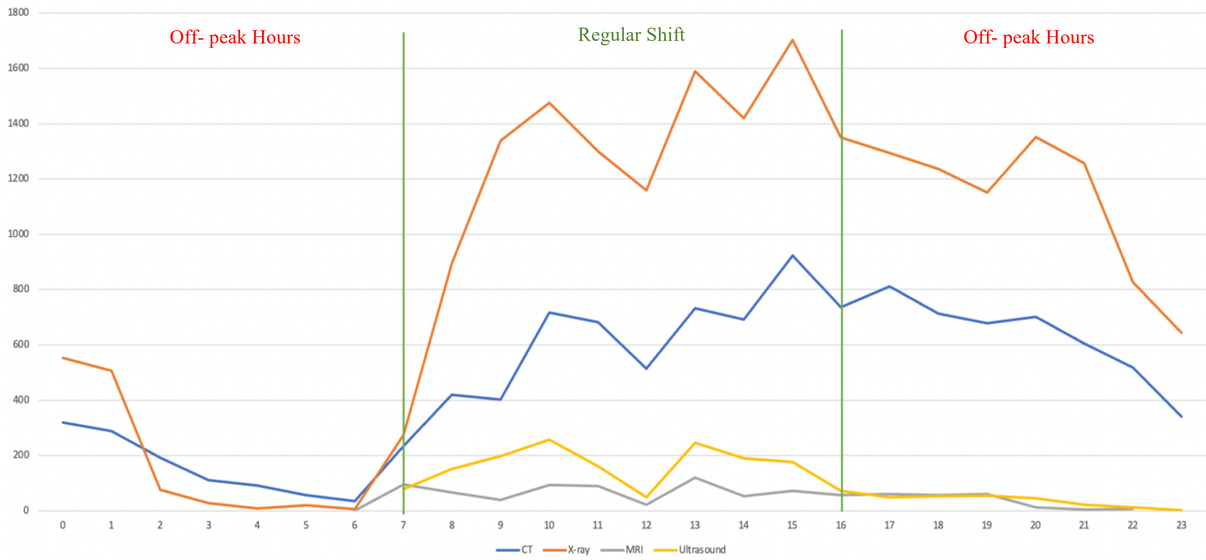

Figure 6 Average inpatient flow towards Radiology Department in a day 2019
**X axis = Time registered for incoming patients in 24 Hours' time *Y axis = Total number of incoming patients*

Figure 6 shows the continuous incoming of patients towards the Radiology department as the planned patient mostly arrives early in the day. As a result, patient inflow is higher in the morning. Like elective patients, the acute patients are not scheduled, but they are spread throughout the day from morning goes until night.

4.3.1.1 Planned Patients

Elective incoming patients are mostly from patients that are on the waiting list/ scheduling patients, a patient from the standardized procedures, and the intervention center. Figure 7 shows the flow map of the elective patients in the Radiology Department. Once the treatment is made, the patient usually visits the physicians for consultation. After consultation, the highest number of patients return to their home with 90%, second to the municipality accommodation with 6 % of outflow, and finally, 4% of patients are sent to the treatment wards.

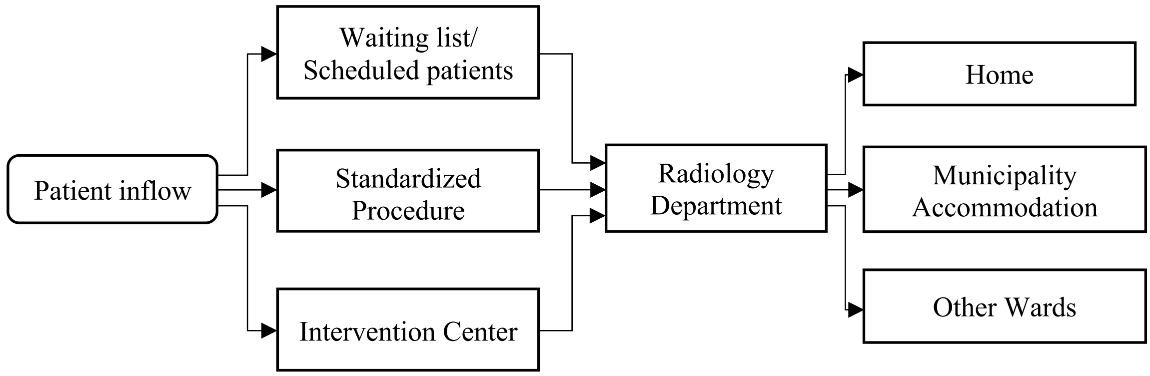

Figure 7 Flow map: Elective Patients

4.3.1.2 Acute Patients

Incoming acute patients are mostly from the emergency department and other wards, see Figure 8. 90 percent of acute patients are from the emergency department and the remaining 10 percent of patients are directed from other departments. After the test and consultation with the doctor, the patient is highly moved to the ward for further treatment with 65 % and 20% of patients are moved to the other wards. The remaining patient are moved to the municipality accommodation.

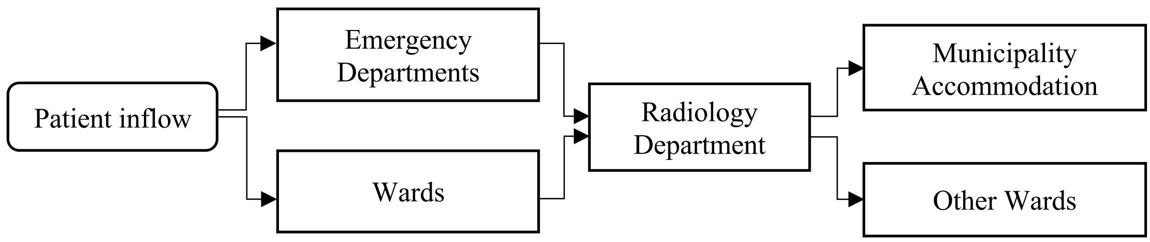

Figure 8 Flow map: Acute Patients

5 Analysis

In this chapter, the bottleneck moment in the patient flow of the radiology department is analysed from the empirical data with the help of developing a simulation model, which helps to answer the second research question.

5.1 Analysis Of Current Practice And Identified Problem

With the help of observational study and empirical data, the first and foremost thing is to identify the bottleneck moment, by knowing the process of patient flow throughout the radiology department. This can be identified with the help of a simulation model, which mimics the true environment of the interest. Initially, the thought regarding the problem for production bottleneck was due to the inefficient utilization of the machines. But actually, the bottleneck was created due to the lack of resources in the labs, which made the patients reschedule to the next day, which is identified with the help of empirical findings and simulation.

Currently, the department is working in full capacity, which maximizes the utilization of the machine up to 95%, where the issue regarding the quality of care is created. In other cases, the inflow of patients seems to be less, but the resource for examination was high than the expected value. When the hospital is started working at full capacity, working conditions will affect the flow of patients in the ward and also increase the length of stay of patients in every other ward (Blanchard and Rudin 2015). According to De Vries et. al (1999), the planning regarding the resources must be considered, before the machines reach the utilization capacity of 90%, which can help to eliminate the disturbance which is to be created in the patient flow.

By this, the real production bottleneck was thus considered due to the lack of resources within the labs. Inefficiency in the flow of patients within the department tends to increase in rescheduling of patients to the next day. As a result, the patients are indirectly meant to a lengthier stay in the Emergency department and other wards. According to Trebble et. al (2010), the improper planning of resources along with the demand is considered to be a waste in healthcare, which makes the working process ineffective. Due to this condition, the workload of staff increases in the coordination of patient flow.

5.2 Simulation Design To The Encounter Bottleneck Moment

This section contains how the simulation model is developed from the empirical data collected during the data collection phase. The finding of this simulation will help in answering the second research question. Simulation in the Skaraborg Hospital seems to have a perfect situation for the implementation of future simulation models as a support tool for the department to identify the scenarios and helps in making a future decision under production and capacity planning.

The simulation model is developed in the ExtendSim Simulation software, which is mostly preferred in the industries for making production and capacity planning. Since our aim is to identify the bottleneck moment in the Radiology department, Discrete Event Modelling is preferred. The ExtendSim Software holds different blocks of interest for the development of the model.

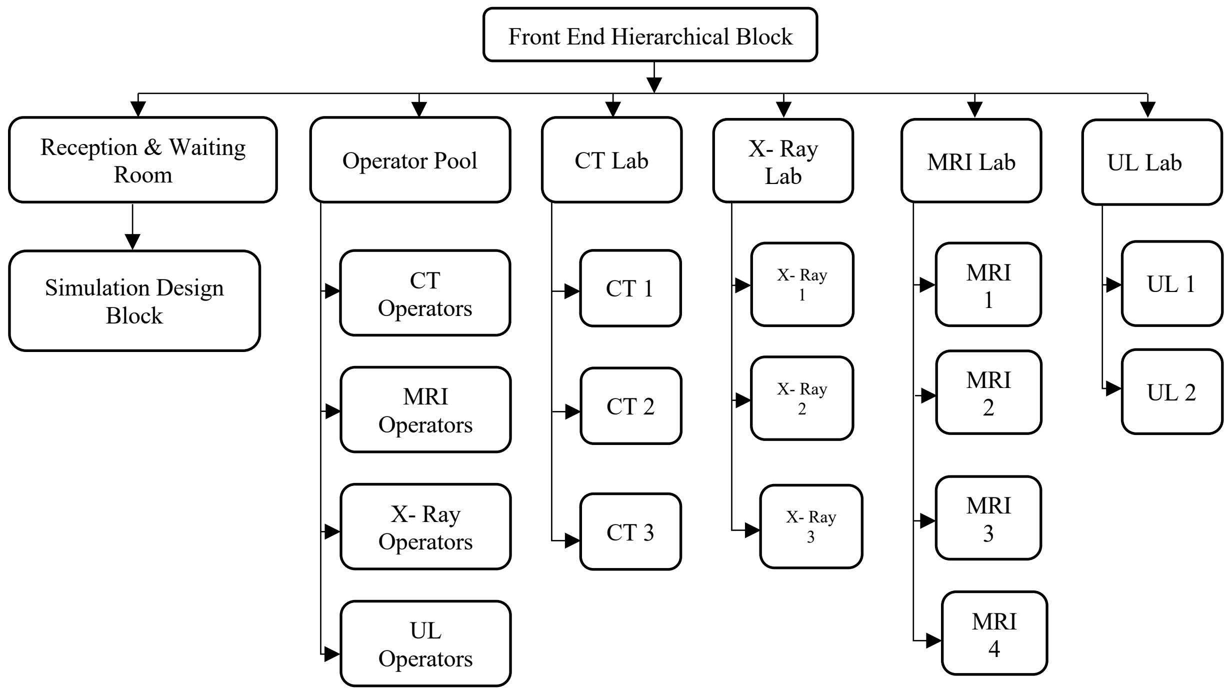

Figure 9 Block Diagram of Simulation Model

A Simulation model is developed with a 6 hierarchical block, were each one block represent different operation performed in the Radiology Department. The hierarchical blocks are created as reception and waiting room, operator pool, CT lab, MRI lab, X-Ray lab, and Ultrasound lab, see Figure 10. Modules within the hierarchical blocks are developed based on the flow map of the radiology department collected during the observational study. For the better understanding, a block diagram of simulation model is show in the Figure 9.

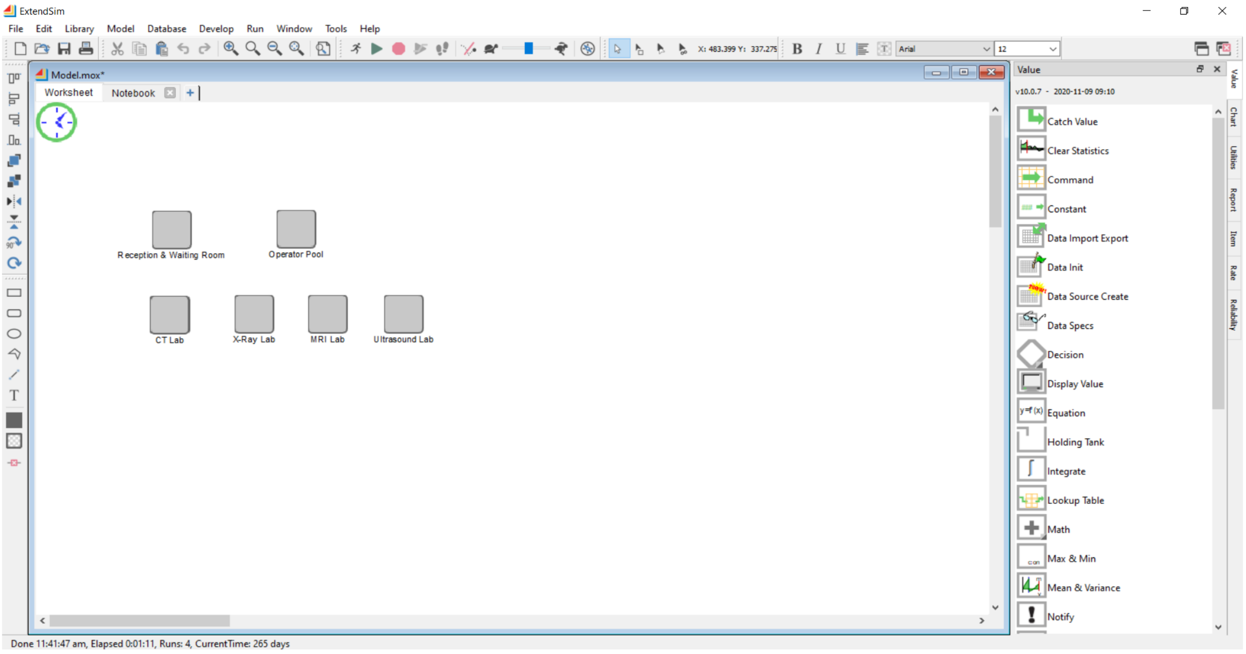

Figure 10 Front End Hierarchical blocks

5.2.1 Reception and Waiting Room

Within the reception and waiting room hierarchical block, based on the flow map of the radiology department an exact reception model is developed , see appendix Figure A1. The model mimics the nature of the patient flow, by adding modules like,

- *Create* : It creates item and values by schedule or randomly
- *Item out* : It assign a variable to the created item and send them to the selected output
- *Queue* : The sent items waits here to understand the bottleneck moment
- *Item in* : Gather the item with variable and based on the variable, item is sent to the respective lab
- *Throw item*: It helps to throw the created item to a separate function of the respective labs.

The input data feed into the model contains both the patients from the emergency ward and the other departments to the radiology department. The exact percent of emergency patients from the normal patients are, given the below table 4. By this, we could understand the flow of patients at the radiology department. Based on the radiology department flow map, the throw item module is set individually for all modalities. The item thrown from the throw module is caught at the respective lab's hierarchical block.

Table 4 Total incoming patients to the Radiology Department in 2019

Modality	Total patients	Other Wards	Other Ward Patients	Emergency Ward	Emergency Ward Patients
CT	108599	31%	23986	30%	11525
UL		10%	773	12%	1867
MRI		9%	6963	8%	3290
X- Ray		50%	38688	50%	21507
	Total	100%	70410	100%	38189

5.2.2 Operator Pool

The operator pool is designed to create items in representation to the Machine Operators. The simulation is developed in such a way that, the machine will only run when there is an operator. There are separate operators for each machine under different modalities. In each operator pool, the operators are created under a certain limit, based on the number of machines available. According to the patient's inflow, the operator pool creates an operator and sends them to the respective lab. Once the examination is done in the respective lab, the created operator is reset and again the new operator is created when there is a patient for the next examination.

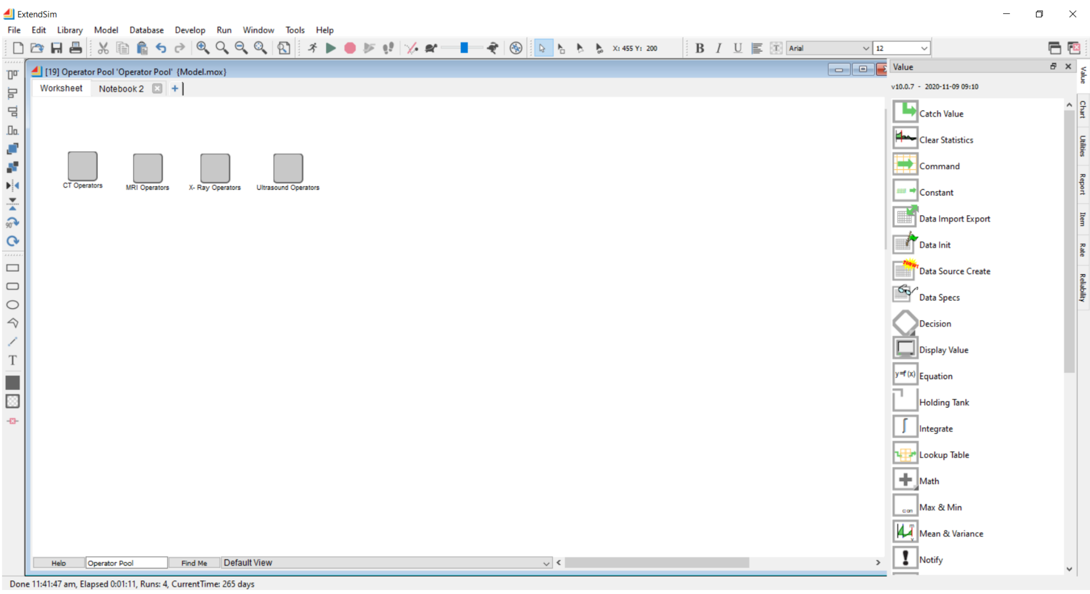

Figure 11 Sub- level hierarchical blocks: Operator Pool

When the front end operator pool is clicked, sub-level hierarchical blocks of each modality will emerge, see Figure 11. Each blocks are named as CT Operators, MRI Operators, X-Ray Operators, and Ultrasound Operators block. Under each sub-level hierarchical block, a simulation model is designed in a way to create an operation, based on the need for examination, see appendix Figure A2.

The modules present in the operator pool are,

- *Catch Item* : item received from the throw item block
- *Resource Item* : item is stored and released with an indication
- *Gate* : Restricts the flow of item
- *Throw item* : It helps to throw the created item to a separate function of the respective labs.

All sub-level hierarchical block in every modality are designed similarly with respect to the modules and the operator's function design (see appendix Figure A2, A3, A4 and A5). Each block in the sub-level hierarchical level varies based on the number of machines in each modality. Once the operator item is created, the item is ready to throw, when the catch item module is called from the lab hierarchical blocks

5.2.3 Front End Hierarchical Blocks: Lab

In the front end, each lab block contains a sub-block, concerning the number of machines they hold e.g. in the CT lab there are three machines, hence three sub-block are created (see Figure 12).

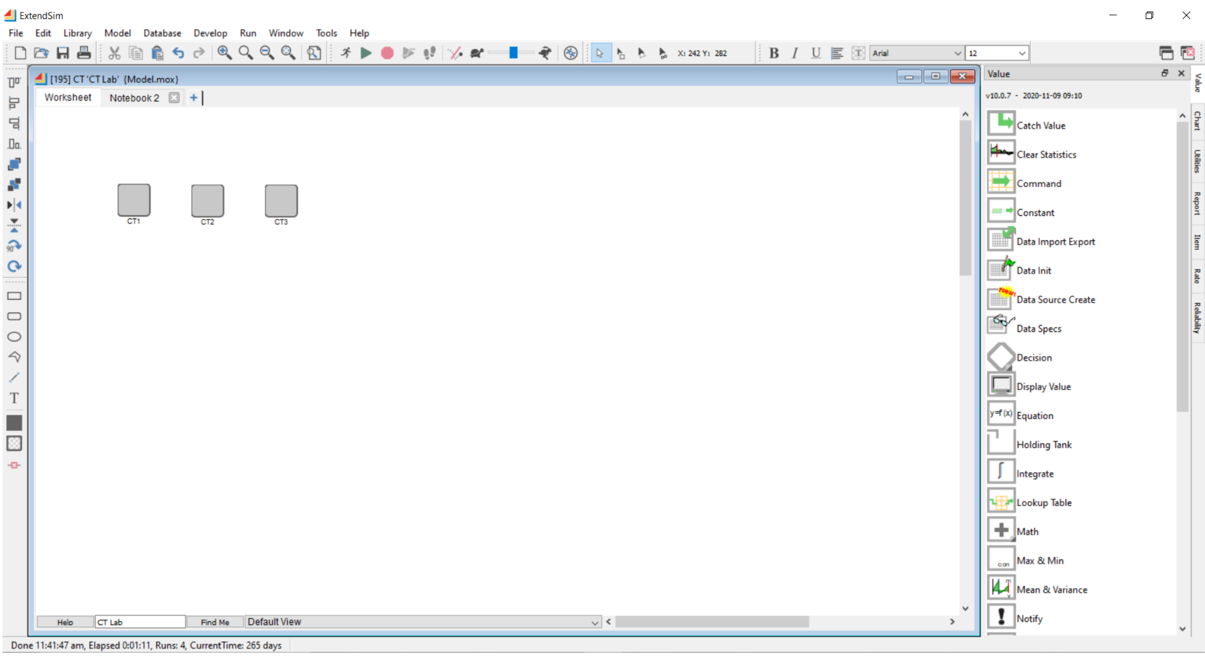

Figure 12 Sub- level hierarchical blocks: lab

Within each sub-block of every lab, simulation design is similar irrespective of all their performance. But the operation time is varied as the lab examination of each modality varies. To create a natural flow environment, the buffers are added as a module with ± 5 minutes, which creates an actual scenario, as per the observational study. As the Simulation design is similar is all modalities and the design of CT lab is attached in the appendix Figure A6.

All the labs will perform when there is an availability of the patients and the operator. By this, when there is no patient and the utilization of the machines can be identified and analyzed, which helps in capacity planning. The utilization of machines can also play an important role in the quality of care. According to Sheila and Brailsford (2009), a machine with a utilization percentage of 80 to 85, can yield a better result than a machine working for 95%.

6 Results And Discussion

In this chapter, the factors which affect the patient flow within the Radiology Department are discussed initially and the following chapter is discussed about the research questions. Further needs about the future work is also discussed

6.1 Introduction

The problem based on the patient flow is raised in the radiology department is due to the lack of planning. To eliminate bottlenecks in the flow, overcapacity is required (Halsted 2008). But according to Sánchez (2018), when compared to overcapacity, the bottleneck seems to be more expensive. Due to the lack of resources and increase in the incoming patient, some patients are scheduled for the next day, irrespective of their time limit for performing the test. This increases the risk of the issue and the quality of care is also affected. Therefore, the focus is needed towards the planning and continuous improvement for better flow on patients.

RQ 1: How to balance patient flows at micro-, meso- and macro level with available resources (modalities, personnel) on a short- and long-term basis to improve overall patient flow efficiency at the Radiology department?

To improve the patient flow at all levels within the organization, improvement in several areas is required. The patient flow is usually gets affected due to the standardization, which covers both procedure implementation and the transfer of information. In addition, the planning within the radiology department is made which contributes to the improvement in the patient flow. The areas that affect the patient flow within the department is discussed in the following and improvement are discussed which helps to increase the efficiency to manage the patient flow at overall levels.

6.2 Planning in Patient Flow

According to Sánchez (2018), the waiting/ delayed patients care must be reduced i.e. the length of stay should be reduced for the patients, which increases the flow of the patients. As a result, more time slots for test availability are created. Additionally, coordination with the patients at overall levels will also help to improve patient flow. By this, correct knowledgeable professionals provide the care for the patients about their conditions. This increases the safety of the patient and requiring fewer patients on the waiting list. For better decision-making and coordination, relevant information about the patient is continuously updated.

To achieve the above mention improvements, planning towards the scheduling of the patient and capacity planning of the resource is to be more valuable. Proper scheduling of patients will decrease the length of stay of the patient for a particular examination. Prior knowledge about the patient examination time will also help planning the availability of machines, results in the distribution of patients. To achieve a good quality of care and also to reduce the patient transfer from the other wards, the distribution of patients must be done earlier by the coordinator in the meso level for a better outcome. As the emergency department has the highest number of an incoming patient during early morning, a keen update about the scheduling of the patient to the radiology department is require and can be achieved with the help of current and predicted future state. This allows the coordinators to draft about what will happen in a day and required actions can be performed to avoid the bottleneck moment. According to Arimie (2011), the flow of patients towards the radiology department must be view as a whole, which provided a broad vision towards the flow of patients. As a result, an efficient flow can be achieved. As the process concerns patients as a human beings, the complexity for the implementation of the process seems to be higher, when it is compared to the product.

6.3 Separation in Patient Flow

Some process which is considered as a non-valued process should be highlighted (Hartmann 1996), which is achieved with the help of separation flow, and the non- valued process should be removed (Liker 2004). For creating the acute patient to flow smoother, the non- valued process must be eliminated inwards at meso levels. Separation flow could be helpful, for implementation and to be manageable of production and capacity planning. For better scheduling practice, the actual demand should be matched along with the actual resource. Rather than an individual schedule. The actual demand is matched along with the actual resource with the help of separation flow (Olsson and Aronsson 2012). By this, the efficiency of the flow will be improved, hence the patient in the delayed care is also reduced.

6.4 Standardization and Visualization

Situational awareness may be fostered among the staff of any particular ward to boost the flow of patients on a larger scale. In the same way, when information transmission at the ward is enhanced, information transmission at the general level may be enhanced. Currently, there is a lot of diversity in the information within the ward. As a result, vital information concerning machine use and patient queues may be lost in many ways. This raises the risk of the coordinator, who is in charge of keeping track of the patients. Thus, with variability in data, it is hard for the prediction and measure to take. According to Liker (2004), when standardization and visualization are implied in the information, can eliminate or reduce the variation in the information, which results in improved communication. By this, the overview of the patient care is created and in addition, situational awareness is also created between the ward staffs, which helps to predict the nature of the ward for the improvement of patient flow. By creating this scenario, communication between the macro and meso levels is made simpler, and easier for the other wards to decide for the improvement of the patient flow. To create a better collaboration among the working staff within the ward, sharing situational awareness is important (Mackay 2013). The poor communication to the coordinators at the meso or macro level will resist them to make a better solution with the lack of information or situational awareness.

Lack of information within the ward will create a new scenario of needs from another ward, who themselves not clear about the requested data (Bergman and Klefsjö 2012). Thus, to provide correct data within the ward, a continuous update about the issues and improvements should be done effectively. Availability of data in less time may help the coordinator to work on the issue for more time, for improvisation and better decision making within the departments. To make an accurate update upon the data, standardization, and visualization of the information is required, which also helps to eliminate the non- valued information. Hence, more time is saved. Due to the workload within the department, this could not be possible at some times. When there is a situational awareness about the present and future state of the ward, it would be helpful on the meso and macro-level regarding the decision-making for patient flow. Thus, the delay in waiting time of the patients can be eliminated by making the availability of the information on time.

According to Halsted (2008), to split the workload among the staff and to create precautionary activities, process standardization is required. To satisfy the customer needs, the process which could be able to standardization must be made standardize, which could able to eliminated the non- value-added process. On the other hand, standardization helps to improve the value-added processes. If the scheduling of the patients is standardized, an accurate status of the time slot is identified and no more patients are a shift to the next day. Thus, the patients are scheduled at the right time and need not a requirement for the new schedule patterns.

6.5 Continuous Improvement

According to Adan (2002), to make an organization effective, continuous improvement within the ward is required. When a ward is improvised it also improves the overall level of the patient flow indirectly. According to Halsted (2008), to eliminate the problem, it needs to be taken out and monitor continuously. By then, the process is evaluated and continuous improvements are made for the elimination of the issue currently and also for future scenarios. To know the problem better, engagement of staff within the ward in the means of workshop or a meeting with help to know more about the problem and better solutions can be achieved. Hence, time is needed to be spent periodically to solve an issue in a standardized manner. Previously, the radiology department had made some process improvements, but currently, due to the heavy workload, it's been quite tougher to perform along with all other staff. To implement the current improvement, it may take time to complete the previous running action. But small things could be eliminated and new things can be implemented slowly. By this, a feedback response is collected to check the actual improvements or if the modification was a mistake.

When the improvements within the ward are implemented, continuous measurement of the improved process is required. Measurement helps to identify the deviation that occurs after the process is improved. Thus, periodical measurement of the improvised process will help the managers to know the status of the process and long-term perspectives regarding the process can be discussed among the team.

According to Glouberman and Mintzberg (2001), in the healthcare organization, to improve the overall flow of the patients, process improvisation is required. The process improvisation helps to reduce the length of stay of a patient, as a result, the queued patients in the system are reduced. The overall patient flow is also affected by the improvements done at the ward, which may also lead to eliminating the unit improvisation with the wards. Though the hospital organization works in the continuous improvement process, the time spent for collaboration and discussion varies concerning different wards. Between each ward, there should an improvement in the communication, which helps the macro and meso level to understand the improvisation performs and their follow-ups. As communication develops, the understanding between the wards develops and which helps in understanding the patient flow among the wards. As a result, collaboration for the improvisation process and trust towards the coordinator's decision will be increased.

RQ 2:What production and capacity planning methods can be developed and adapted to improve patient flow efficiency at the Radiology department?

To make better production and capacity planning, a simulation is developed, which is considered a decision support tool. With the help of simulation, finding like a bottleneck, queue length, and machine utilization are identified, which helped to understand the condition of the ward, before undergoing the planning phase.

6.6 Production and Capacity Planning

The utilization findings with the help of empirical data help to understand the machine usage within every department. Simulation helps in creates desirable scenarios, where the machine utilization yields the best result. Table 5 shows the output of the simulation and how the capacity can be managed for better utilization.

Table 5 Machine Utilization Data

	Result based on Empirical Data		Result based on Capacity Re-planning	
Modalities	Machines	Utilization	Machines	Utilization
CT	3	0.757	3	0.649
MRI	4	0.215	2	0.513
X-Ray	3	0.952	4	0.819
Ultrasound	2	0.443	2	0.474

The most and key important challenge in the healthcare organization is Production and Capacity Management (PCM). If there is an issue in the PCM, the hospital will tend to face the dissatisfaction of the patients, improper patient flow, inefficiency in the operation, delays, and revenue loss. For the betterment of scheduling and forecasting, PCM is considered to the most important duty.

As discussed early, the utilization of a machine should be between 80 and 85 percent. But in the X-Ray division, the demand is not met with the patient inflow. Approximately, the machines are utilized completely to its ability by 95% and there is a presence of queue. This may create an issue in the quality of care when this situation continues. To manage this situation, a new machine can be installed in the unit, which could help in reducing the utilization level of the machines to 81%, which is considered to be a healthy approach.

Other the other hand, the scheduling can also be modified, by adding extra two to three hours in the working time of the lab which may also decrease the queue in the system. By this, the cost, space, and manpower for the new machine can be eliminated.

Based on the empirical data, in the MRI unit, the patient inflow is low and the machine utilization seems to be 20%, which is considered to be under usages of the machines. This shows that there are extra machines than the actual demand. As a result, the cost for implied manpower, space, and operation issues are involved. To avoid the extra cost and also to maintain the correct state of capacity level, two machines from the MRI unit should be removed, to avoid the extra cost. This will make a level up flow of patients within the department.

6.7 Patient Flow

Elective and acute patients are the two sorts of patients that pass through the Radiology department. Elective patients are usually scheduled for examinations before a week. This separates the flow of elective patients from the flow of hospitalized patients. The nurse who is attending the patients must not be mixed in with the acute patients, since this may disrupt the movement of acute patients inside the ward. There is a potential that the acute and elective patient flows will be mixed as a result of this. When contrasted to acute patients, elective patients may be easily foreseen, as the scheduling is done ahead of time.

Because the arrival of elective patients is predictable, it is preferable to have a greater occupancy rate for elective patients than acute patients (Halsted 2008). According to Brandt and Palmgren (2002), the flow of patients should be more clearly segregated. This reveals resource consumption inside the wards and also aids in maintaining a greater occupancy rate with elective patients (Halsted 2008).

The separation flow will also help the staff to coordinate easily as they perform a similar task and also helps in planning the work for the betterment of the flow. In some instance, there are chances for high variation in acute flow which result in the overcapacity. Thus, planning of resources will help in the maximum usage of machines to avoid sudden variations.

Based on the demand of the patient flow the scheduling should be planned accordingly. To avoid the bottleneck moment, the planning should be made with the overcapacity, which can able to overcome the situations like high variations. The actual resource needs to the ward can be easily identified with the help of simulation using the past data. Below table 6 shows the result of the queue created in the Radiology department of each examination while simulating the data.

Modalities	Total number of Incoming Patient (in a week)	Total Number of Queued Patients (in a week)	Queued Patients after planning (in a week)
CT	217	25	1
MRI	31	0	0
X-Ray	413	55	4
Ultrasound	39	0	0

Table 6 Simulated Data: Queue

By managing the utilization of the resource and flow of patients within the wards by proper scheduling and distribution of patients, the bottleneck effect can be eliminated. The utilization of resources must be monitored periodically in order to reduce or eliminate queue development. The communication within the ward regarding PCM issues must be continuously updated in the database, which could help the ward coordinator to make decisions wisely. Ward gathering workshops should take place every month, where the evaluation of current and new processes should be discussed. By this, the non- valued process can be eliminated and new processes within the ward can be implemented as a test run to increase the efficiency of the patient flow.

6.8 Future Work

Based on the implementation towards the improvisation of the simulation model and how the work could be improved are discussed and the future work is divided. Based on the result, the work for improvisation within the hospital should be started along with the discussions. Based on the needs of the Radiology Department, the model can be modified and quality results can be obtained. To obtain a better result, randomness within the data can be identified and hence can make a stochastic model.

Further, the factor that affects the patient flow could be identified and can be given as an input to the simulation model as a work of improvisation.

7 Conclusion

The conclusion for the defined research questions are provided in this chapter through analysis and discussion.

RQ 1: How to balance patient flows at micro-, meso- and macro levels with available resources (modalities, personnel) on a short- and long-term basis to improve overall patient flow efficiency at the Radiology department?

The primary areas of focus in the Radiology department to improve total patient flow are effective planning for efficient patient flow, separation within the patient flow, making the process standard to reduce non-value processes. Examine the process and information to minimize variances, and make improvements regularly to enhance the established procedure.

Planning and Separation For Efficient Patient Flow

To have an effective patient flow, planning must be done prior which may eliminate the patient's waiting in the system. As the queue develops, the length of stay of a patient is also increased simultaneously. This may affect the quality of care. Before every examination, preparation activity must be done in earlier to reduce the delay. Communication between the department should be maintained to have a smooth patient flow. Current updates about the available scheduling period must be continuously updated, which can help the referrals to understand the status of the ward. By this, the patient's safety is increased and the queue is decreased.

Scheduling of patients in the system must be continuously updated in addition to the capacity planning, to make wise decisions to improve the patient flow, by increase the working hours by knowing the actual demand of acute patients. The incoming patients must be distributed evenly between the machines, to make a better level of flow. This can be achieved by prior scheduling of patients for a better outcome in the overall levels. The coordinator must have an updated data about the resource capacity, scheduling of patients, and current routines, which helps to understand the situation to avoid bottleneck moments. To have a better result in patient flow, the person in charge must view the flow of patients at the overall level.

The separation of flow of a patient in the radiology department should be highly concerned as it can able to manage the variations are created by the acute patients, as the time and arrival are unpredictable. By this, the planning and coordination of work are made simpler. To identify the total available schedules for examination, the data regarding the elective patient flow of this week and the previous/ historical data of the acute patients can be used. By this, the capacity can be planned as the variation in the elective patients are comparatively less than the acute patients. To avoid the bottleneck in the calculation of acute patients, data is can be considered with overcapacity as the variations are higher. But in the elective flow, the capacity is managed at the maximum extent, as we could able to predict the patient flow accurately.

This helps in the better utilization of machines based on the demand and also to understand, how much the machine is to be utilized in the future.

Thus, separation flow can improve the patient flow along with the planning and coordination within the wards. As a result, there is a reduction in the queue, which enables more available time slots for acute patients. Other than the utilization of the machine, separation flow also helps in the better utilization of manpower against the demand. Finally, by implementing the separation flow, coordination will get a continuous update about the patient flow, which helps in managing the flow of elective and acute patients.

Standardization and Visualization

By implementing standardization and visualization in the process, the valueless process can be identified and eliminated. In addition to it, missing information, the slow transmission of information within the department can be avoided. The flow state of patients within the ward must be viewed as the whole, to understand the state of flow. all the information about the patient must be completely updated in the system, which helps to avoid unnecessary communication within the department.

The continuous update will also help the coordinator to take only less time for making decisions within the hospital when there is a variation. Thus, the small effort may positively affect the flow of patients. In addition to it, current updates about the available slots, simpler processes, improved follow-ups are suggested to be done, to maintain the leveled up flow of patients.

In the case of acute flow, the schedule can be converted from the individual to a fixed schedule. Where the single nurse is maintained to the single patient which helps in avoiding unnecessary handovers. By this, a value is added to the ongoing process by implementing standardization and visualization in the process.

Continuous Improvement

To develop improvements in the process, the staff should carry out the improvements process as they know about where the problems arise and why the improvements are required continuously. Within the department, improvements must be made continuously, to identify the valued process which increases the efficiency of patient flow. To boost and engage staff in the improvement process, a measure focusing on the improvement work is important. Which helps in actively engaging staff within the activity. Measurement should in the form of statistical chart and diagrams, which continuously highlights the past and present improvement within the department. By visualizing the charts and diagrams, awareness about the situation within the department is created among the staff, which helps to engage in actively. Conducting meetings with other ward coordinators will lead to a mutual understanding of the flow within and outside the department. In addition, it also provides an insight into new ideas from the other department, which may suit the Radiology Department.

Improvement must be made throughout every ward, which aims to focus not only on the beginning of the patient flow but also after the examination. This will reduce the throughput time and helps in the improvement of the patient flow.

Improvements for Short and Long Term

The improvements within the wards can be done in two different duration. The short-term improvements are done at the ward/ micro level, where they can manage by themselves as the period is short and manageable. When it comes to the long-term improvements, meso and macro-level management are involved to run these improvements processes within the hospital departments or micro-level intensive processes are carried out on a long-term basis. As short-term improvements (Table 7), update about the patient occupancy and clear documents should be done continuously. Standardization and Visualization can be performed within the ward to understand the patient flow as a whole and to eliminate the valueless processes. Improvements that are manageable within the department must be continuously carried out, to reach an efficient patient flow. The current status of the patient flow can be visualized in the monitor board, which helps the coordinator to understand the present situation of the flow within the department. In the long term perspective, schedule management plays an important role in making available time slots, which improves the flow of patients. Simultaneously, when the flow process is separated based on the acute and elective flow, the patients flow could be easily predicted and control measures can be taken effectively.

Table 7 Micro Level Improvements

Micro level improvements	
Short Term	***Long Term***
Periodical update of patient occupancy and documents	Schedule management
Standardization and Visualization	Separating the flow
Continuous improvement	
Monitor board for current status	

Improvement in the meso and macro levels are listed below in the table 8 with respect to short and long term basis. As a short term improvement, mid- level managers should attend the meeting that happens within the ward, where idea discussion between the members helps to understand better about eh current process and view upon every stake can be discussed. As mention before in the micro level, continuous improvements in the meso and macro level is managed by the manager. Therefore, active engagement of managers within the department meeting, will help them to understand the real situation and prioritization can be made accordingly. As a long term perspective, meeting among the coordinators of respective wards should be encouraged, which helps in managing the flow across the wards and the trust among the coordinators will develop in taking important decisions.

Table 8 Meso and Macro Level Improvements

Meso and Macro level improvements	
Short Term	***Long Term***
Continuous improvement	Conducting workshops between ward coordinators
Active engagement of key members	

RQ 2:What production and capacity planning methods can be developed and adapted to improve patient flow efficiency at the Radiology department?

In this thesis, the patients flow in the Radiology department is analysis with the help of simulation tool and methods to adapt the improvement of patient flows is developed with help of production and capacity planning.

Utilization To Improve Patient Flow

By understanding the utilization of resources against the patient flow, the relation of what is required to make use of the resource effectively should be performed. Overutilization of machines is identified and solutions like buying a new resource or extending the working hours of the current machines are suggested, which in sense reduce the overall utilization of the machines. If a machine is utilized for 95%, the chance of compromise in the quality of care may occur. To avoid this situation, the coordinator must have the information regarding the patient flow across the department, and the information about the patient flow must be updated continuously. On the other hand, a machine should not also be underused, which is considered waste in the process (Stiernstedt et al., 2016). This may result in extra cost in manpower, electricity, and space involved. By visualizing the past and present data, if the variation is not a problem, then the extra machines can be removed from the unit. As a result, the utilization percentage increases, and levelled up patient flow is maintained across the department.

Planning To Improve Patient Flow

To maintain an improved patient flow among the elective and acute patients, separation of flow is more important as mentions before. When the elective and acute patients get mixed, the regular flow is messed and the queue is created. To avoid this situation separation flow must be adopted. A higher occupancy rate must be set for the elective patients as they are predictable when compared to the acute patients. Here the scheduling of patients plays an important role as elective patients are predictable, empty scheduling slots can be filled by the acute patients, who are present in the queue. This can help during the high variations in acute patient flow.

Coordination between the staff during work is also an important factor in increasing patient flow. Based on the demand, the staff is allotted by the unit manager for the betterment of flow. The simulation must be used by the coordinator in a periodical manner, which helps in understanding the actual scenario and helps in making production and capacity planning.

Thus, maintaining the utilization of resources and patient management can help in avoiding the creation of a bottleneck in the radiology department. Periodical monitoring of recourse will help in improvement planning and make a decision. By this, the valued process is implemented and the non- valued process is set for the improvisation trails to improve patient flow efficiency at the Radiology department.

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Appendix

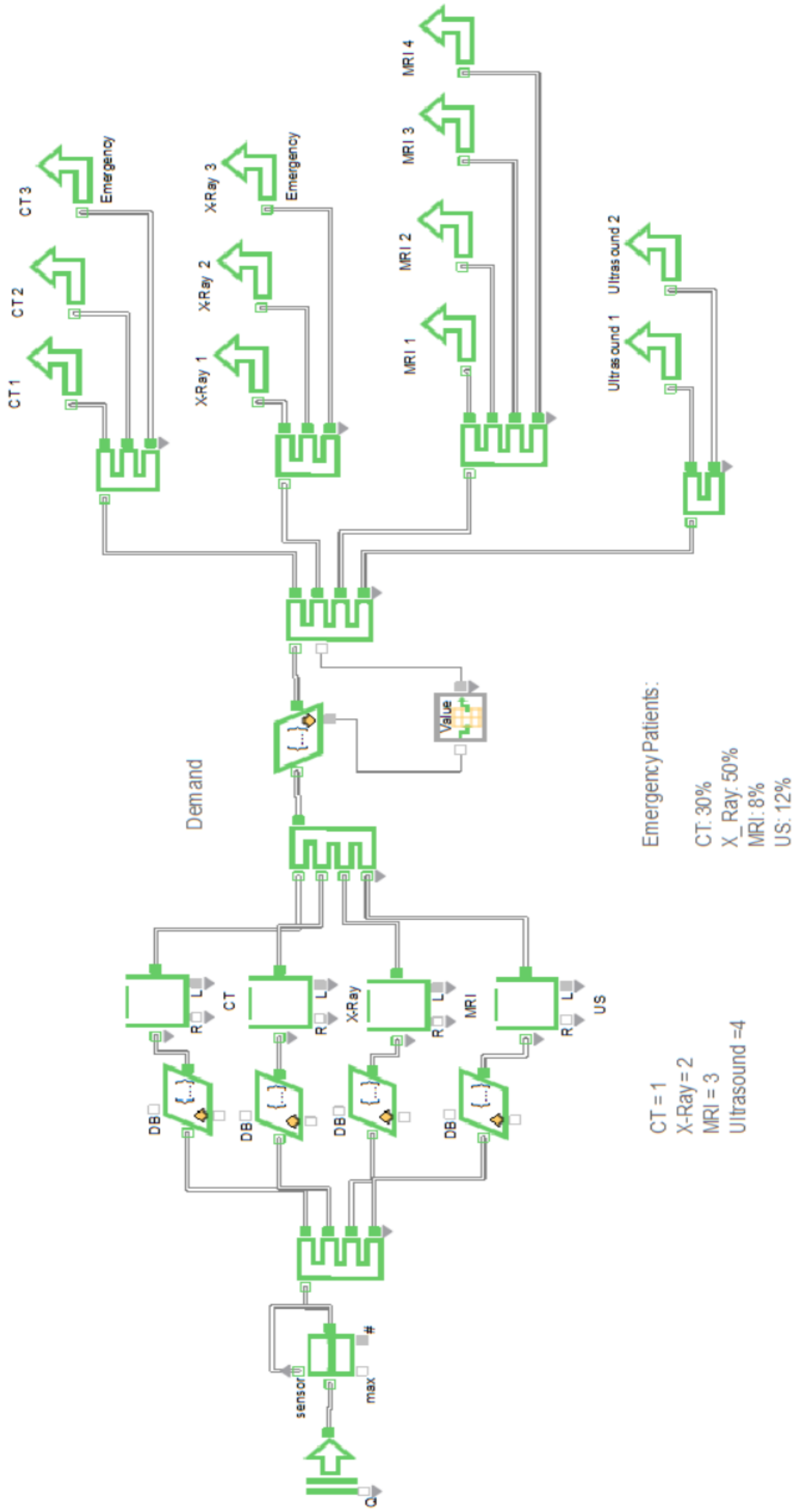

Figure A1 Simulation design of Reception and Waiting Room

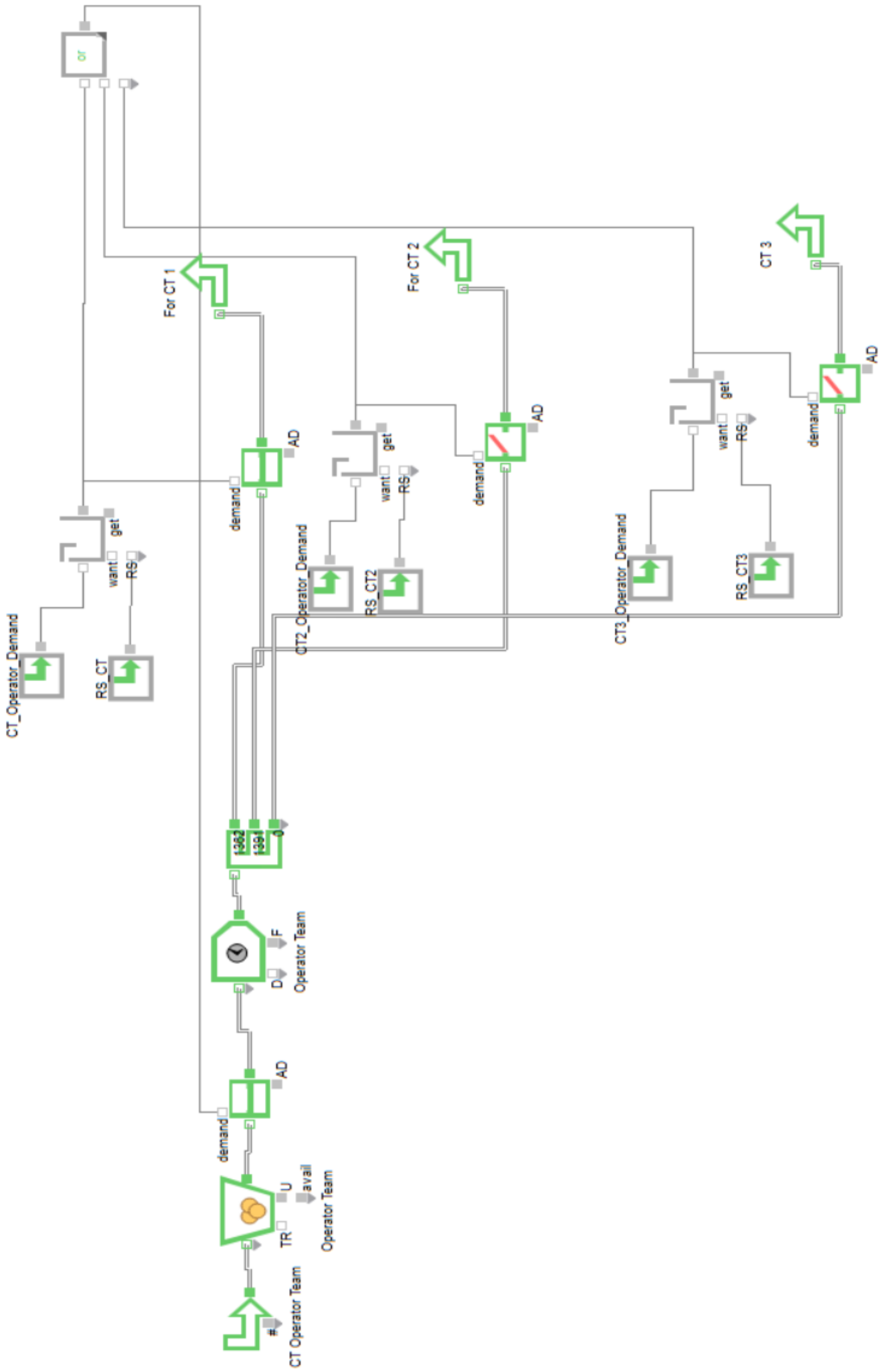

Figure A2 CT Operator simulation design

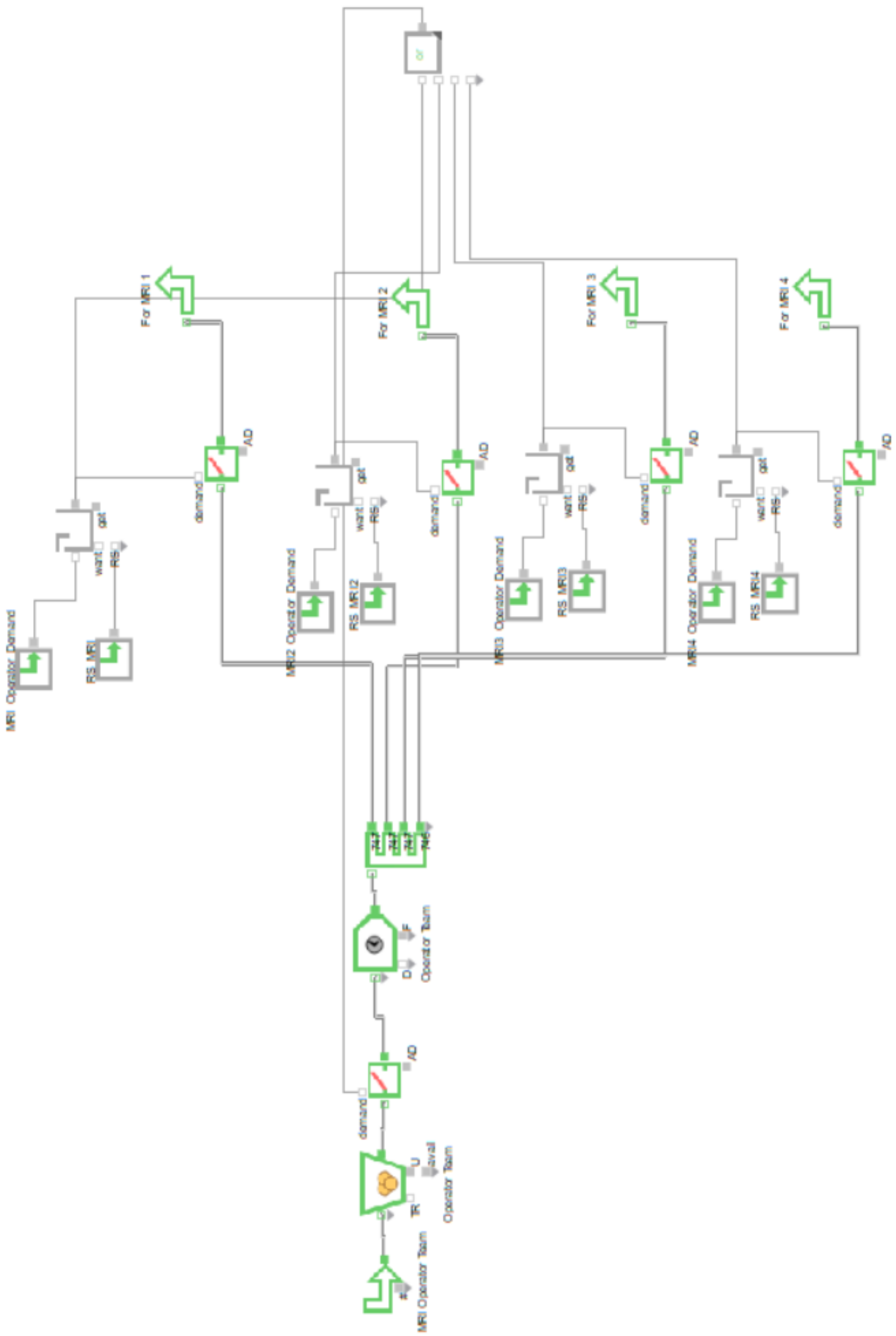

Figure A3 MRI Operator simulation design

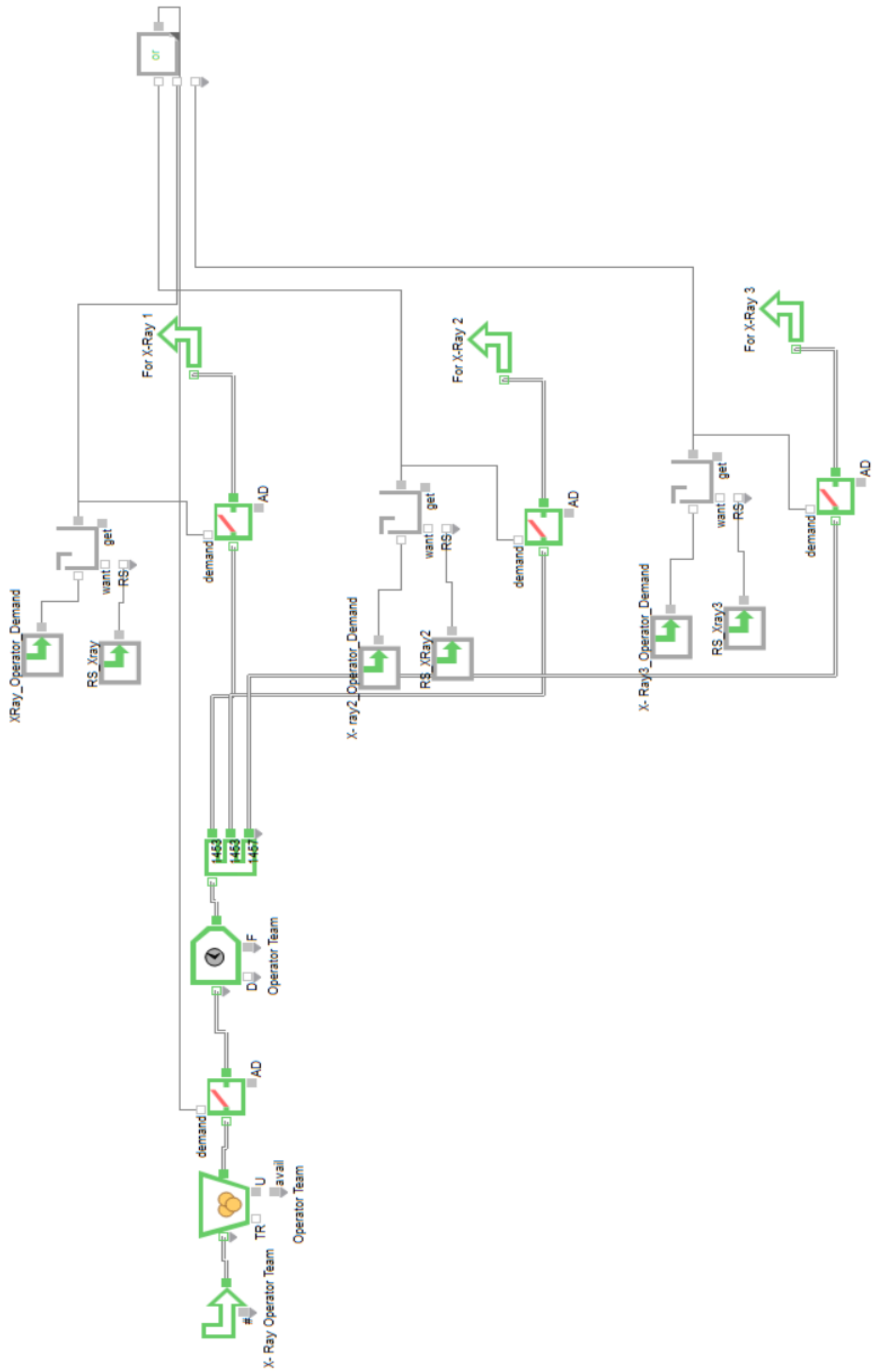

Figure A4 X- Ray Operator simulation design

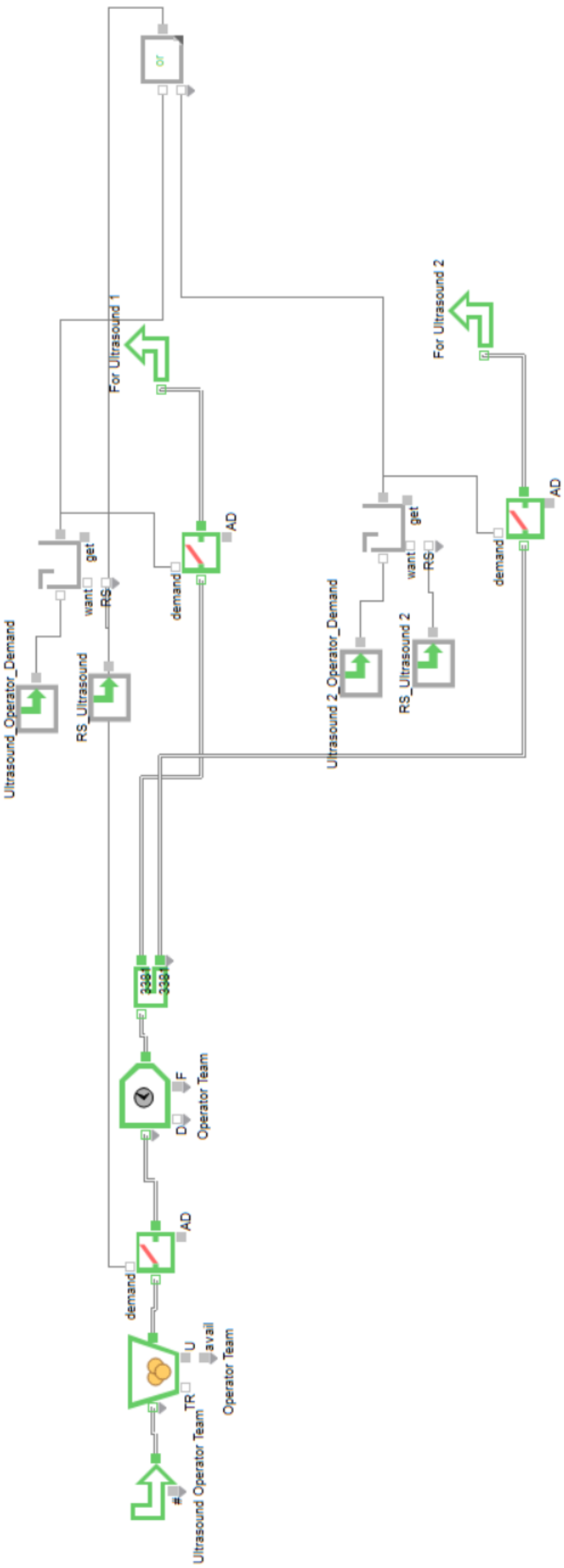

Figure A5 X- Ray Operator simulation design

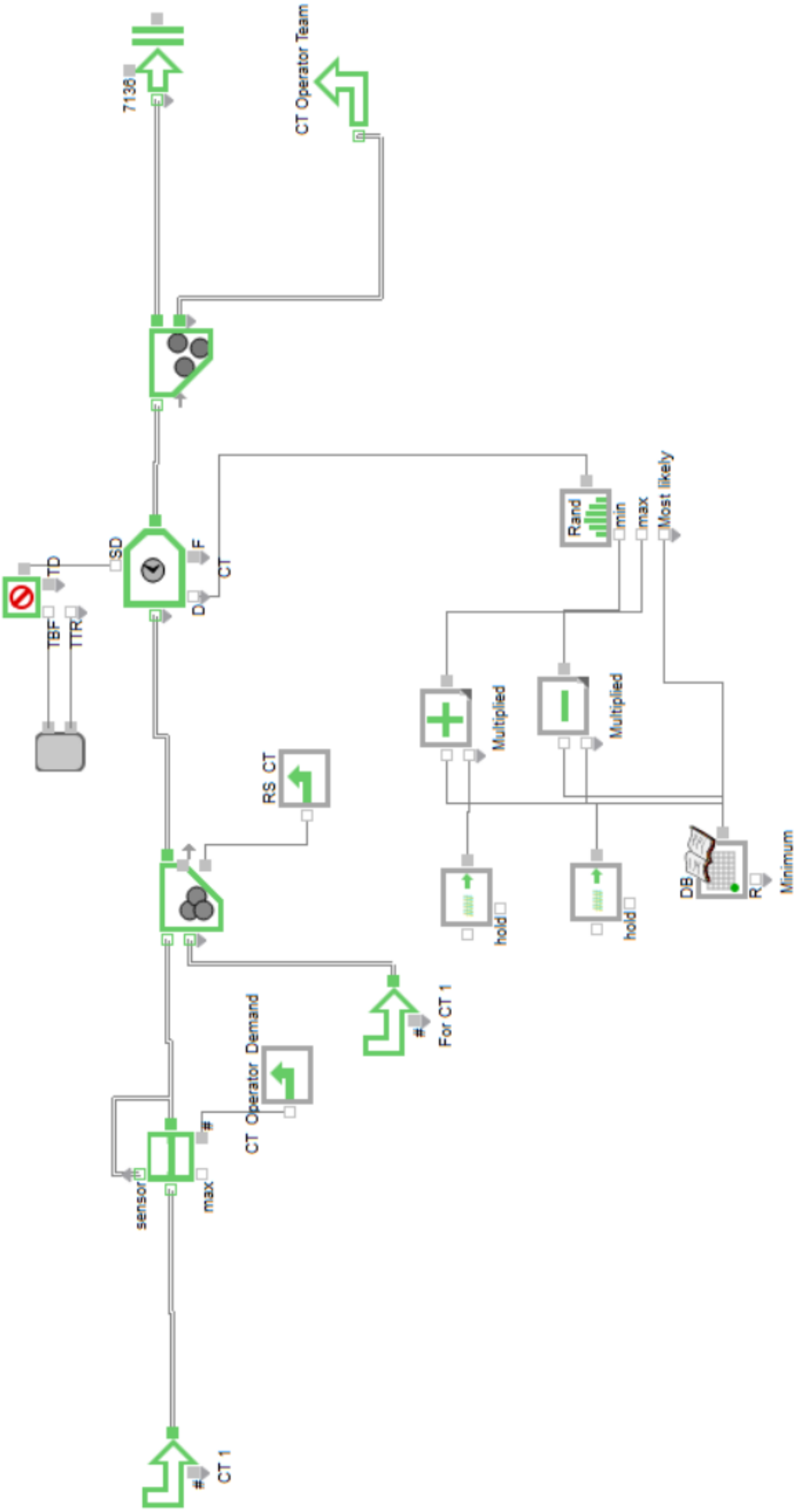

Figure A6 CT lab simulation design

Interview Question:

1. How patients enters the Radiology Department from other wards?
2. How the scheduling is performed?
3. How many resources and man power are present in the each lab wards?
4. How the bottleneck is created and what improvements are taken?
5. Is there any prerequisite that needs to be carried out by the staffs before every examination?
6. How the acute patients are treated?
   a. Do they have a separation flow?
7. Is there any current challenges present in the effective patient flow?
8. How long it takes of every examinations in each lab?
9. How staffs are communicated about the new implemented ideas?
10. Is there a common workshop among staffs to rectify the issue?
11. How data is updated into the system?
12. What control measures are taken in the department to manage the patient flow?
13. What information is discussed in the ward meeting?
14. How well the information is shared or discussed among the department in the hospital?
15. How elective patients are treated?

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