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Framework for Layout Design Supporting Patient Flow in Outpatient Departments

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Preface

This master's thesis is the final part of the Master of science degree in Global Manufacturing Management at the Department of Mechanical and Industrial Engineering at NTNU. This thesis investigates patient flow in outpatient departments, and how layout can support patient flow, with the objective of developing a framework for layout design supporting patient flow in outpatient departments.

I would like to thank my supervisor, Marco Semini, for his guidance, constructive feedback, and being available when needed. I also would like to thank my co-supervisor, Aili Biriita Bertnum, for her encouragement, constructive feedback, valuable ideas to my thesis, and being available when needed. In addition, thanks to Giuseppe Fragapane for his interest in helping me, and valuable ideas to my thesis.

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Abstract

In the last decades, there has been an increase in demand for outpatient services, as inpatient treatments are more often done on an outpatient basis. Increase in demand, and long waiting times in the access of outpatient services, is a concern in several countries, whereas waiting time is an important indicator on availability and quality in health care services. In addition, literature concerning layout and patient flow in outpatient departments are scarce. A proper layout is important in realizing efficiency in the production of services, as layout directly affects the performance of a process. The main objective of layout is to ensure efficient flow, whereas improving patient flow can allow for serving more patients. In addition, long walking distances for patients exposes the patients for risk of adverse effects.

The objective of this master's thesis is to study patient flow in outpatient departments, and how layout can support patient flow, to develop a framework for layout design supporting patient flow in outpatient departments. Supporting patient flow is to facilitate high patient throughput volume, short patient throughput time, low patient waiting time, high personnel utilization, low personnel overtime, and short travel distances for patients and personnel. To answer the objective, the following research questions are answered to provide the groundwork needed to develop the framework:

RQ1: What are the characteristics of patient flow in outpatient departments?

RQ2: How can layout support patient flow?

The research design of the master's thesis consists of a literature study to find relevant research, combined with a case study including three orthopedic outpatient departments. The aim of the literature study is to answer the research questions, and to answer the research objective by developing a preliminary framework. The aim of the case study is to provide additional insight to the topics studied. The development of a revised framework is based on the information gathered in the literature and case study combined.

Patient flow in outpatient departments can take place either within one outpatient department, or multiple departments of a hospital. Patients move to registration and waiting areas, and to the departments and rooms where they are to receive consultations. Patients may undergo one or multiple consultations during a visit to the hospital. The components of a system that affects patient flow are available capacity and variability. Regarding available capacity, health personnel, especially doctors are bottleneck resources, that determines the throughput volume of an outpatient department.

The relative location of registration areas, waiting areas, rooms, and departments affects how the patient flows throughout a hospital facility. Concerning how layout can support patient flow, the components of layout that can affect the patient flow to be considered are: length of flow, clarity of flow, predictability of flow, flexibility, and coordination capabilities. The different components more or less concern length of flow, whereas reducing the length of flow for patients reduces risk of adverse effects and allow for shorter throughput times. For health personnel, reducing length of flow allows for more time spent on care, and facilitates communication, coordination, teamwork and productivity.

The result of the master's thesis is a framework for layout design supporting patient flow in outpatient departments. The framework provides a structured overview, and entails a definition of patient flow and layout, components of a system and of a layout that can affect the patient flow, and how layout should support the patient flow in outpatient departments. The framework can be used as a support in layout design of future hospital buildings, with emphasis on supporting outpatient department flow. The framework may also be used for other patient flows in hospitals, as the framework presented is mainly based on general layout objectives.

Sammendrag

Det har vært en økning i etterspørsel av polikliniske tjenester de siste tiårene, ettersom behandlinger som tidligere krevde innleggelse på sykehus, oftere er utført poliklinisk. Økning i etterspørsel, og lange ventetider for polikliniske tjenester er gjeldende i flere land, hvor ventetid er en viktig indikator på tilgjengelighet og kvalitet for helsetjenester. I tillegg er det knapphet på forskning som omhandler layout og poliklinisk pasientflyt. En god og tilpasset layout er viktig for å oppnå effektivitet i produksjonen av tjenester, ettersom layout virker direkte inn på utførelsen av en prosess. Hovedmålet til layout er å sørge for effektiv flyt, hvor en forbedring i pasientflyt kan muliggjøre å gjennomføre flere pasientkonsultasjoner. I tillegg, lange gåavstander utsetter pasienter for uheldige bivirkninger.

Formålet med masteroppgaven er å studere poliklinisk pasientflyt, og hvordan layout kan støtte pasientflyt, for å utvikle et rammeverk for layout design som støtter poliklinisk pasientflyt. Å støtte pasientflyt er å legge til rette for høy pasientgjennomstrømning, lav pasientgjennomløpstid, kort pasientventetid, høy personalutnyttelse, lite overtidsarbeid for personalet, samt korte gåavstander for pasienter og personell. For å svare på masteroppgavens formål, er følgende forskningsspørsmål besvart for å legge grunnlaget som trengs for å utvikle rammeverket:

RQ1: Hva er karakteristikkene ved poliklinisk pasientflyt?

RQ2: Hvordan kan layout støtte pasientflyt?

Forskningsdesignet består av et litteraturstudie for å finne relevant litteratur, kombinert med et casestudie bestående av tre ortopediske poliklinikker. Målet med litteraturstudiet er å svare på forskningsspørsmålene, og å svare på oppgavens formål ved å utvikle et foreløpig rammeverk. Målet med casestudiet er å tilføre ytterligere innsikt i de studerte emnene i oppgaven. Utviklingen av et revidert rammeverk er basert på informasjon fra litteraturstudiet og casestudiet kombinert.

Poliklinisk pasientflyt kan ta plass enten i en poliklinikk, eller i flere avdelinger i et sykehus. Pasienter går til registreringsområder, venteområder, til avdelinger og rommene som de skal motta konsultasjoner i. Pasienter kan motta en eller flere konsultasjoner i løpet av et besøk til sykehuset. Komponentene i et system som påvirker pasientflyten er tilgjengelig kapasitet og variasjon. Angående tilgjengelig kapasitet, helsepersonell, da særlig leger, er flaskehalsressurser, som avgjør pasientgjennomstrømningen i en poliklinikk.

Den relative plasseringen av registreringsområder, venteområder, avdelinger og rom, påvirker hvordan en pasient beveger seg gjennom et bygg. Når det kommer til hvordan layout kan støtte pasientflyt, er komponentene i layout som kan påvirke pasientflyten, og som må vurderes: flytlengde, flytklarhet, flytforutsigbarhet, fleksibilitet og koordineringsevner. Alle komponentene omhandler mer eller mindre lengde av flyt, hvor det å redusere flytlengde for pasienter reduserer risiko for uønskede bivirkninger. Ved å redusere flytlenge for helsepersonell, muliggjør det å bruke

mer tid på pasienter, samt at det legges til rette for kommunikasjon, koordinasjon, teamarbeid og produktivitet.

Resultatet av masteroppgaven er et rammeverk for layout design som støtter poliklinisk pasientflyt. Rammeverket gir en strukturert oversikt, og inneholder en definisjon av pasientflyt og layout, komponenter av et system og av en layout som kan påvirke pasientflyten, og hvordan layout bør støtte poliklinisk pasientflyt. Rammeverket kan bli brukt som støtte i layout design av fremtidige sykehusbygg, med vektlegging på å støtte poliklinisk pasientflyt, men kan også brukes for andre type pasientflyter i et sykehus, ettersom rammeverket presentert hovedsakelig er basert på generelle layout mål.

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Acronyms and Abbreviations

CT = Computerized tomography

FFA = Factory flow analysis

GCR = General consultation room

GT = Group technology

HF = Health enterprise (in Norwegian: helseforetak)

MRI = Magnetic resonance imaging

NCR = Nurse consultation room

n.o. = No observation data

NTNU = Norwegian University of Science and Technology

OPD = Outpatient department

OPD1 = Orthopedic Outpatient Department at St. Olavs Hospital

OPD2 = Surgical-Orthopedic Outpatient Department at Levanger Hospital

OPD3 = Surgical-Orthopedic Outpatient Department at Vesterålen Hosptial

OT = Occupational therapy

PCR = Plaster cast room

PFA = Production flow analysis

PRN = Product route number / Patient route number

PT = Physiotherapy

TOV = Trøndelag Orthopedic Workshop / Trøndelag Ortopediske Verksted

W1 to W5 = Waiting areas related to OPD1

W6 to W8 = Waiting areas related to OPD2

W9 to W10 = Waiting areas related to OPD3

WC = Water closet

Health Care Terminology

In this thesis, different health care terms are used, and in this chapter, they are explained shortly. The terminology is divided into two lists: common terms, and terms for the thesis. The 'terms for the thesis' were created for this thesis, as they may not be a common term, or their definition may be defined based on the thesis' context. In addition, the 'common terms' may not be complete. Anyway, the terms in both lists are meant to give an overview of different health care terms used in the thesis, as well as quick access to words that may be unknown to the reader.

List of Common Terms

Cast = "A protective shell of fiberglass, plastic, or plaster, and bandage that is molded to protect broken or fractured limb(s) as it heals" (Medicinenet, 2016).

Computerized tomography (CT) = "A form of tomography in which a computer controls the motion of the X-ray source and detectors, processes the data, and produces the image" (Oxford Dictionaries, 2018b). Tomography is imaging by sections.

Diabetes foot wound (or Diabetes foot ulcer) = Foot wounds caused by late complications of diabetes: neuropathy and arteriosclerosis (Gürgen et al., 2005). Causes hindering of daily functions, and in some cases amputation is necessary. Despite proper treatment, the wounds are often chronic (Norsk Helseinformatikk, 2017).

Elective patient = Patient with a planned treatment (Kåss, 2009).

Gastroenterology = Branch of medicine which concerns the digestive system.

General surgery (or Surgery) = Branch of medicine where doctors conduct surgeries to achieve or expedite healing (Schlichting, 2018).

Gynecology = Branch of medicine which concerns the female reproductive organs.

Inpatient = A patient that requires to remain at hospital for the entire duration of treatment (Côté, 2000).

Medical imaging (or Radiography) = "The use of electromagnetic or ultrasonic radiation to produce images of organs and tissues within the body for diagnostic or screening purposes" (Oxford Dictionaries, 2018d). E.g. X-ray, CT, MRI, ultrasound.

Magnetic resonance imaging (MRI) = "A technique for producing images of bodily organs by measuring the response of the atomic nuclei of body tissues to high-frequency radio waves when placed in a strong magnetic field" (Oxford Dictionaries, 2018c).

Neurology = Branch of medicine which concerns the nervous system.

Occupational therapy (OT) = "Occupational therapy is a method of helping people who have been ill or injured to develop skills or get skills back by giving them certain activities to do" (COBUILD Advanced English Dictionary, 2018).

Oncology = Branch of medicine which concerns cancer.

Ophthalmology = Branch of medicine which concerns the eye.

Orthopedic technician = Health personnel who works with design, manufacture and repair of orthopedic aids (Reikerås, 2009).

Orthopedics = Branch of medicine which concerns treating deformities, diseases, injuries, and congenital malfunctions in the musculoskeletal system. Treatment may include surgery, physiotherapy, use of protheses, bandages, or other technical aids. (Reikerås, 2017)

Orthopedist = A doctor who is a specialist within orthopedic surgery (Reikerås, 2017).

Otorhinolaryngology = Branch of medicine which concerns the ear, nose and throat.

Outpatient = A patient that is treated and released the same day (Côté, 2000).

Physiology (or Clinical Physiology) = A medical diagnostic specialty where patients undergo specialized tests of function of different organ systems, mainly heart, blood vessels, lungs and kidneys.

Physiotherapy (PT) = "The treatment of disease, injury, or deformity by physical methods such as massage, heat treatment, and exercise rather than by drugs or surgery" (Oxford Dictionaries, 2018e).

Plastic surgery = Branch of medicine which concerns reconstructive surgery. It borders on several other surgical disciplines, and complements these in several areas. (Harbo and Solheim, 2018)

Proctoscopy = Examination of the rectum.

Radiology = Branch of medicine which concerns the use of medical imaging for diagnosis and treatment of diseases (Brekke, 2018b).

Radiographer = Health personnel who conduct medical imaging which do not require injection of contrast agents or other interventions (Brekke, 2018a).

Rheumatology = Branch of medicine which concerns rheumatic diseases, which is an umbrella term for diseases with pain in the musculoskeletal system (muscles, joints, tendons, connective tissue) as main symptom (Kåss, 2018b, Kåss, 2018a).

Somatic health care = Physical health care

Ultrasound = "Sound or other vibrations having an ultrasonic frequency, particularly as used in medical imaging" (Oxford Dictionaries, 2018d).

Urology = Branch of medicine which concerns diseases of the urinary tract system, and male reproductive organs.

Vascular surgery = Branch of medicine which concerns the vascular system (in Norwegian = Sirkulasjonssystemet).

X-ray = "A photographic or digital image of the internal composition of something, especially a part of the body, produced by X-rays being passed through it and being absorbed to different degrees by different materials" (Oxford Dictionaries, 2018f).

List of Terms for the Thesis

Acute patients = Unscheduled patients that require treatment within a short period of time.

Doctor on duty (in Norwegian: vakthavende lege) = A doctor who can be contacted and asked for advice by other doctors or health personnel (Duvaland, 2014).

General consultation room (GCR) = Standardized rooms, which contains computers and other necessary equipment doctors' needs.

Nurse consultation room (NCR) = Rooms suitable for nurses, but not doctors to use, i.e. contains equipment necessary for nurses' needs.

Plaster cast room (PCR) = A room with the equipment needed to lay or remove casts.

Pre-surgery outpatient department = Outpatient department which receives patients that have received a surgery date to make all preparations before surgery.

Consultation = The time a patient spends with a medical staff member, either to be examined, diagnosed, or treated. Consultation has been used as an umbrella term to avoid the use of several different, but similar, words. However, some places other words are used where appropriate.

1. Introduction

In this chapter, the background and motivation of the thesis is presented, followed by a presentation of the research objective and questions, the research scope and the thesis structure. Throughout the thesis, acronyms and abbreviations, and health care terminology are used, whereas their explanation can be found in the chapters 'Health Care Terminology' and 'Acronyms and Abbreviations'.

1.1 Background

The Norwegian health care system today is perceived to be of high quality (OECD, 2014, Helse- og omsorgsdepartementet, 2009), and according to Helsedirektoratet's national health service objectives, the health services should have good quality, be safe, available, efficient and effective, with shortest possible waiting times (Helsedirektoratet Norge, 2015). There has been several trends when it comes to infrastructure and organization of the Norwegian health sector. Since the end of the 1980s, a policy has aimed at replacing relatively expensive inpatient treatments with less costly outpatient treatments (Ringard et al., 2013). Inpatient treatment is when the patient requires to remain at a hospital for the duration of their treatment, while outpatient treatment is when the patient is treated and released the same day (Côté, 2000, SINTEF, 2005).

The policy aiming at replacing inpatient- with outpatient treatments has led to an increase in the use of outpatient treatments, often possible due to new treatment methods (Ringard et al., 2013). Treatments that previously were inpatient treatments are more often done on an outpatient basis (Wiig and Hedum, 2001). In Norway, the ratio between outpatient- and inpatient treatments increased from 4:1 in 1990 to 6:1 in 2011 (Rønningen and Helsedirektoratet Norge, 2016). Following, in the periods 2011 to 2015, and 2014 to 2015, the number outpatient treatments respectively increased with 4,3% and 2,2 % (Rønningen and Helsedirektoratet Norge, 2016). Further, the waiting times for elective treatment, i.e. non-acute planned treatment, in Norwegian hospitals are long compared to other countries, which constitute a barrier in accessing care (Ringard et al., 2013). According to a survey by the Organization for Economic Co-operation and Development (OECD) in 2010, 50% of the Norwegian respondents had to wait more than four weeks for a specialist consultation, which was the third highest score in the survey (OECD, 2011). Out of in- and outpatients, the latter constitute the majority type of patients waiting for elective treatments (Helse- og omsorgsdepartementet, 2015), see Appendix A. Waiting time is an important indicator on availability and quality in health care services, as long waiting times can reduce the patients' opportunities to achieve maximum health outcomes of the treatment and can also indicate a capacity problem in the hospitals (Helse- og omsorgsdepartementet, 2015). In 2014 in Norway, the somatic discipline orthopedic surgery was the discipline with the highest number of elective patients, and was among the top three disciplines with highest percentage of waiting times above 3 months for elective treatments (Helse- og omsorgsdepartementet, 2015), see Appendix B. Increase in demand for, and long waiting times for outpatient services, is also a concern in other countries (Hong et al., 2013, Froehle and Magazine, 2013, Cayirli and Veral, 2003).

Sykehusbygg HF is a health enterprise owned by the four health regions in Norway, and shall amongst other things ensure a national competence environment for hospital planning and building (Sykehusbygg HF, 2018). Sykehusbygg HF is the main contact company for this thesis, and have expressed a need for a better understanding of the operational perspective of outpatient departments, to provide insight to the planning of outpatient departments, including layout. Hospital planning is strategic, and has main considerations in resource and capacity planning (Arnolds and Nickel, 2015). However, a building and its layout, will influence the operational work flows as well, and it is important to combine the architectural aspects with logistics, such as patient flow, inside future hospital buildings (Arnolds and Nickel, 2015). A proper layout is important in realizing efficiency in the production of products and services, as layout directly affects the performance of a process (Kulkarni et al., 2015). Thus, the building should be determined by the process, and not the other way around (Arnolds and Nickel, 2015).

The main objective of layout is to ensure efficient flow of work, materials, customers and information throughout the system (Stevenson, 2014) and must support the strategic objectives of an operation (Slack et al., 2010). One of the objectives in delivering health care services, as mentioned, is to have shortest possible waiting times in the access of services (Helsedirektoratet Norge, 2015). Improving patient flow frees up resources' capacity (Allway and Corbett, 2002), which in turn can make it possible to serve more patients (Litvak et al., 2006), and thus increase the throughput volume of a system (Swisher et al., 2001), and allow for increased revenue (Litvak et al., 2006). Serving more patients is positive in terms of reducing waiting times, although waiting times are also dependent on other factors, such as demand.

Regarding layout, efficient location of the organizational units can reduce the distances traveled, whereof reducing distances is a means of saving time, and consequently resources (Arnolds and Nickel, 2015). Also, patient transfers in hospitals are a potential source of adverse effects on patient safety, as well as being a non-value added activity (Karvonen et al., 2017). In addition, reduction in transfer times can lead to more time to spent on care, which in turn leads to increased patient and personnel satisfaction (Arnolds and Nickel, 2015). According to Tompkins et al. (2010), most existing research on layout concerns quantitative approaches (Tompkins et al. cited in Kruger 2017), which generate layouts efficiently (Kruger, 2017). However, the results of quantitative approaches often fail to entail all layout design objectives (Kruger, 2017). Thus, layouts require both quantitative and qualitative considerations (Hasan et al., 2012).

There are different aspects of layout, such as the assignment of departments within a hospital, and the layout of a single department (Arnolds and Nickel, 2015). Although the literature on facility layout planning in manufacturing is rich, studies concerning the layout of single departments in hospitals are relatively scarce (Ma et al., 2016). To the best of the author's knowledge, there are very few, if any articles concerning the layout of single outpatient departments in hospitals. Regarding assignment of departments within a hospital, Karvonen et al. (2017) performed a patient flow analysis on a group of hospital departments, including an outpatient department, and stated that patient flow analysis, based on group technology (GT) and Burbidge's Production Flow

Analysis (PFA), is a valuable additional tool in hospital design (Karvonen et al., 2017). GT is a product organization method where related parts are grouped together, whereof the PFA is a technique for finding the groups (Burbidge, 1989). As pointed out by Karvonen et al. (2017), patient flow analysis may be applied in a study concerning layout of a single department in a hospital.

1.2 Research Objective and Questions

As stated in the background, there is an increase in demand, as well as long waiting times, for outpatient treatments, whereof waiting time is an important indicator on availability and quality in health care services. This, combined with Sykehusbygg HF's need for operational insight in outpatient departments, and the research gap on outpatient department layout, motivates the thesis to study the patient flow in outpatient departments and identify important considerations in layout design to support this patient flow. In addition, the thesis is motivated to be primarily of qualitative nature, as most existing research on layout concerns quantitative approaches, although qualitative considerations are required as well. As a means of studying the patient flow in outpatient departments, the thesis is also motivated to use patient flow analysis. For this thesis, patient flow in outpatient departments is not only limited to the movement inside an outpatient department, but the movements of the outpatients as they may require related services during a visit to the hospital, which may lay outside an outpatient department as well.

Based on the motivation, the objective of the thesis is to develop a framework that combines patient flow in outpatient departments and how layout can support this flow. Supporting patient flow is to facilitate high patient throughput volume, short patient throughput time, low patient waiting time, high personnel utilization, low personnel overtime (Koo et al., 2010), and short travel distances for patients and personnel (Karvonen et al., 2017). To answer the objective, the following research questions were developed:

RQ1: What are the characteristics of patient flow in outpatient departments?

RQ2: How can layout support patient flow?

The first research question focuses on gaining insight on patient flow in outpatient departments in hospitals and patient flow constraints, while the second research question focuses on gaining insight on how layout can support patient flow. Henceforth, the acronym OPD is used interchangeably with outpatient department, for simplifying purposes.

1.3 Research Scope

Due to time constraints, reductions in scope have been made. The following reductions in scope are given below, alongside with justifications. This chapter also gives a deeper insight of the entirety which the scope is reduced from.

From an operational perspective, patient flow is the movement of patients through a set of locations in a healthcare- facility or system (Medina-León et al., 2014, Zhao and Lie, 2010, Côté, 2000, Hall et al., 2013). According to Côté (2000), patient flow can also be defined from a clinical perspective where it represents the progression of a patient's health status (Côté, 2000). However, this thesis is concerned with the operational perspective of patient flow. This entails being more concerned about the physical movement of patients through a facility rather than looking at different diagnostics of patients and their health status progression. However, the clinical perspective will be mentioned when appropriate.

Healthcare has traditionally been differentiated as either inpatient or outpatient, where inpatient care is provided when patients are required to stay in the hospital for the duration of their treatment or illness, while with outpatient care patients are treated and released the same day (Côté, 1999). However, the terms outpatient treatments and day treatments are sometimes used interchangeably. SINTEF (2005)distinguishes between four levels of hospital treatment:

- Inpatient treatment (hospital stay with one or multiple overnight stay)
- Inpatient day treatment (hospital stay without overnight stay, treatment over one or multiple days)
- Outpatient day treatment (outpatient consultations for day medicine or day surgery, no overnight stay)
- Other outpatient consultations (controls, examinations and simpler treatments, no overnight stay)

The two latter are performed in OPDs (SINTEF, 2005), and as this thesis is not concerned with the clinical perspective, it will not be distinguished between these. Also, when receiving care in an OPD, it may be called treatment, examination, or consultation (SINTEF, 2005). However, to simplify, consultations will be used as a unified term, again since this thesis is not concerned with the clinical perspective. However, words such as 'treatment' and 'examination' are used for explanatory reasons when appropriate.

Outpatient consultations are offered by both OPDs in hospitals and by private specialists in external outpatient clinics (Ringard et al., 2013). The word clinic can be used for both OPDs in hospitals, and external outpatient clinics (Oxford Dictionaries, 2018a). However, this thesis is concerned with OPDs located in hospitals. This has to do with access to case company and time constraints. However, literature found on external outpatient clinics was not excluded if found supplementary to the literature on OPDs in hospitals.

Layout can affect both flow of patient, health personnel, material, equipment or information, whereof the different flows may affect the patient flow. Through the literature study, doctors were discovered to be a scarce resource. Thus, due to timely constraints, only patient flow and health personnel flow is considered. In this thesis, observations of patient flow were conducted, as described in chapter 2.2. However, observations were not conducted for health personnel flow. This limitation was made to reduce the scope due to time constraints, as well as making the observation feasible, i.e. it was only feasible to study one flow at a time. However, operational aspects regarding health personnel will be included when answering the research objective.

As the main focus of this thesis is on the patient flow in outpatient departments, and the layout it takes place in, the thesis is not concerned with improving patient flow by scheduling or resource allocation, nor the layout inside a room. Literature regarding scheduling and resource allocation were included when found useful in describing patient flow and constraints.

1.4 Thesis Structure

Table 1: Thesis structure

Chapter 1 Introduction	Presentation of background and motivation of the thesis, research objective and research questions, research scope, and thesis structure.
Chapter 2 Research Methodology	Presentation of the selected research approaches and how the literature study, case study, and analyzation were conducted.
Chapter 3 Literature Study	Presentation of the topics from the literature study, with the purpose of answering the research questions and objective. Literature on patient flow in outpatient departments, patient flow constraints and layout is presented. Based on the findings in the literature study, a preliminary framework for layout design supporting patient flow in outpatient departments is presented.
Chapter 4 Case Study	Presentation of the case outpatient departments: OPD1, OPD2, and OPD3. Firstly, a short introduction of each outpatient department is given. Following, more extensive information regarding the layout, the patient flow-, and constraints of OPD1 is presented, followed by supplementary information regarding layout of OPD2 and OPD3.
Chapter 5 Analyzation	The case study is analyzed in the light of the literature study, in addition to the information concerning the patient flow of OPD1 being structured using patient flow analysis, with a basis in Burbidge’s production flow analysis. The aim of the analyzation is to present the findings from the case study, to give a deeper insight to patient flow in outpatient departments, and to find important considerations in layout design to support patient flow in outpatient departments.
Chapter 6 Discussion	Discussion of findings from the analyzation towards the literature study. The findings are seen in a broader context than just the case outpatient departments. The discussion concerns how layout can support the different aspects of patient flow. The result of the discussion is a revised framework for layout design supporting patient flow in outpatient departments.
Chapter 7 Conclusion	Presentation of how the research objective has been answered in the thesis, limitations of the research and suggestions for further research.

2 Research Methodology

Transparency is one of the fundamental characteristics of scientific research, as it is necessary with access to the logic that generates the conclusion in order to evaluate an argument (Ketokivi and Choi, 2014). Research methodology is the general approach the researcher takes in carrying out the research project (Leedy and Ormrod, 2015). Research approaches can either be quantitative, qualitative, or a combination. Within each approach, different study designs exist, and the choice of study design will shape the procedures used to conduct the research (Creswell, 2012). The methodology used for this master thesis qualitative, but uses supporting quantitative data, thus uses a qualitative approach to mixed methods research (Hesse-Biber, 2010). Mixed methods is a combination of qualitative and quantitative methods, and involve collection, analysis, and integration of quantitative and qualitative data in a single or multiphase study (Hesse-Biber, 2010). The core argument for selecting mixed research design is that the combination of using both qualitative and quantitative data will generate a better understanding than the either of the types of data by itself (Creswell, 2012). The research approach is illustrated in Figure 1.

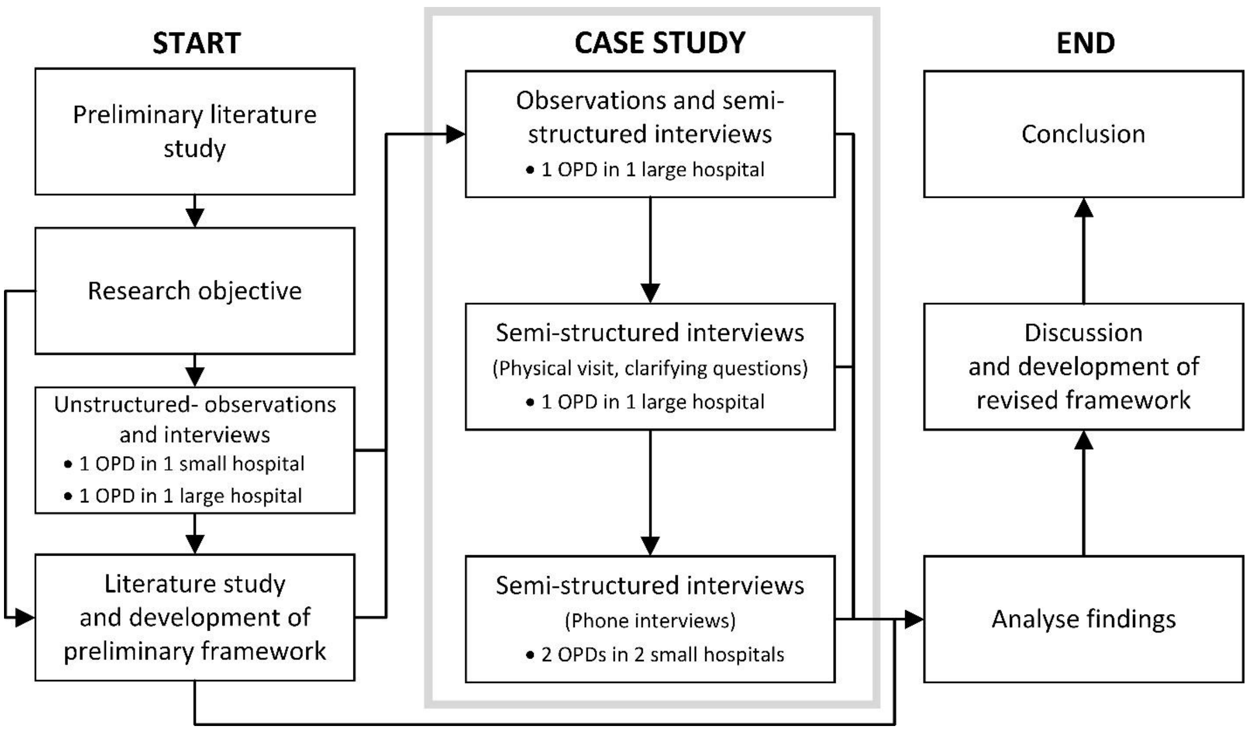

Figure 1: Research approach

The research design consists of a qualitative literature study and a mixed methods case study. A literature review or study, is an important step in the research process to gain more insight on the research topic, to build on previous knowledge, and avoid replicating prior research (Creswell, 2012). Conducting a case study is preferred in situations when there is a need to understand a contemporary problem from the real-world, and questions like how and why are asked to answer the research questions (Yin, 2014). Combining the information gathered from the literature study and the case study, forms the basis for the analysis. Methodology for the literature study, the case study and the analyzation are respectively presented in chapter 2.1, chapter 2.2, and chapter 2.3.

2.1 Literature Study

The purpose of the literature study was to gain knowledge on the topics of the thesis, and to find research related to the main topics: patient flow in outpatient departments, patient flow constraints, and layout. The aim is to answer the research questions to the extent possible, and to develop a preliminary framework for layout design supporting patient flow in outpatient departments. The contribution of the literature study is to give a deeper insight on the topics of the thesis, and a groundwork for the further parts of the thesis work. As the literature study is a means of getting familiar with the topics, it is not a systematic literature review giving a complete overview over related literature.

Multiple databases were used to retrieve relevant literature: Google Scholar, Web of Science, Oria and Scopus. The main databased used for searches was Google Scholar, as it leads the user to other databases, in addition to that it allows for searches within full texts. The most used words, keywords, when searching for literature, are divided into group A and group B, which are presented in Table 2. The keywords developed throughout the process in searching for literature. Keywords of group A were used in the search for literature to support in answering research question 1. The keywords in group A were combined with each other where appropriate. Keywords of group B were combined with keywords of group A, to give a deeper insight on layout in hospitals and OPDs, as a means of supporting the answering of research question 2. Out of the literature concerning layout, general layout literature was retrieved from two operations management text books by Stevenson (2014) and Slack et al. (2010).

Table 2: Keywords used in the search for literature

Keywords of group A	**Keywords of group B**
Outpatient	Layout
Outpatient department	Layout design
Outpatient clinic	Layout planning
Hospital	Facility design
Patient flow	Space design
Process	Spatial design

When retrieving and selecting articles, firstly the title and abstract were read, and if regarded relevant, the introduction, results, and methodology were read to decide on further relevance. If so, the paper was read more in depth. During the search for literature, the research questions were developed further and were adjusted to the available research. The pre-study report of the thesis is attached in Appendix C to represent the development of the thesis.

2.2 Case Study

As defined by Creswell et al. (2007), “case study research is a qualitative approach in which the investigator explores a bounded system (a case) or multiple bounded systems (cases) over time through detailed, in-depth data collection involving multiple sources of information (e.g., observations, interviews, audiovisual material, and documents and reports) and reports a case description and case-based themes” (Creswell et al., 2007). Although, as stated, in this thesis a mixed methods case study is used. A case study is not to answer a research question completely, but to give insight and allow for further elaboration within a topic (Shuttleworth, 2008). In this thesis, a multiple-case study is used, which is a case study organized around two or more cases (Yin, 2014), in this scenario three cases. However, it is not a cross-case study where the cases are compared to each other, but are used to provide better insight to the real-world phenomenon being investigated. The purpose of this case study is to gain an in-depth understanding of the patient flow in outpatient departments and the layout it takes place in, as well as additional information concerning patient flow constraints. In the case study, data collection methods consisted of observation and interviews.

The three case companies, or case OPDs, are orthopedic OPDs at one relatively large, and two OPDs at relatively smaller hospitals. The first case OPD at the larger hospital is the main case company, whereas the two smaller case OPDs were used to gather additional information as a means of supporting the findings from the main OPD, and give a deeper insight to the topics studied. The three case companies are: the Orthopedic Outpatient Department at St. Olavs Hospital (OPD1), the Surgical-Orthopedic Outpatient Department at Levanger Hospital (OPD2), and the Surgical-Orthopedic Outpatient Department at Vesterålen Hospital (OPD3). Sykehusbygg HF functioned as a facilitator to select and get in contact with OPDs for the thesis.

Observations and interviews were conducted. Observation involves systematic observation, recording, description, analysis and interpretation of people’s behavior (Saunders et al., 2012). When collecting data, ethical issues can arise (Saunders et al., 2012). Confidentiality and anonymity can be important in gaining access to organizations and individuals, and if confidentiality contract is made, it is important that the confidentiality is maintained (Saunders et al., 2012). In healthcare settings, it is critical that patient sensitive information is not going astray, thus a confidentiality agreement was made, and no information that can lead to recognition of any patients will be given. In addition, to be able to publish the thesis, approval from REK (Regional committees for medical and health research ethics, in Norwegian: Regionale komiteer for medisinsk og helsefaglig forskningsetikk) was required, see Appendix D.

Structured observation was the main observation method, however where interesting unstructured observations were made, it was noted down alongside. The structured observation consisted of recording quantitative patient movement data, whereas unstructured observations could be of both qualitative and quantitative nature.

Regarding interviews, the use of semi-structured interviews was the main interview method. Semi-structured interviews are when a researcher has a list of themes and key questions, however their use may vary from interview to interview (Saunders et al., 2012). Throughout the process, the question themes and key questions in the semi-structured interviews developed. The interview participants were multiple nurses and medical secretaries in OPD1, and one single nurse in each of OPD2 and OPD3.

Firstly, the case study at OPD1 was conducted. Before starting the case study, unstructured-observations and interviews were conducted to get a better understanding of the operation of the OPD, and to prepare for the observation. The preparation for the observation is further explained in chapter 2.2.1. Then the observation was conducted for four days. Interviewing the OPD1 staff took place within the observations when suitable, and at the end of each day, to ask for clarifying questions. In-between each observation day, the information from the semi-structured interviews and unstructured observations were written down, which allowed for the development of new questions to the following semi-structured interviews.

After ended observation period, the quantitative data was sorted and typed into a computer, which is further explained in chapter 2.2.2. After both quantitative and qualitative data had been processed, new semi-structured interviews were prepared and conducted, which took place for 3 days, to ask clarifying questions and to verify of the findings. Thereafter, the case study data was adjusted to the information gathered through these semi-structured interviews.

After having conducted the observation at OPD1, OPD2 was visited for unstructured interviews and observations, to get a better understanding of the operation of a smaller OPD. After all the data from OPD1 was collected and processed, a semi-structured interview guide was developed to gather information at OPD2 and OPD3, and to verify the findings from OPD1 towards these OPDs. For both OPD2 and OPD3, questions regarding patient flow in outpatient departments, the layout, as well as patient flow constraints, were asked. However, in this thesis, the main focus in presenting information from these OPDs, concerns the layout of these departments.

Further, information regarding preparation for observation, can be found in chapter 2.2.1, and information regarding processing of the quantitative patient movement data, can be found in chapter 2.2.2.

2.2.1 Preparation for the Observation

When preparing for the observation in OPD1, it became evident that it was not possible to pay attention to all areas. Besides the OPD1 consultation(s) taking place during a patient visit to OPD1, a patient may require services related to OPD1, such as X-ray, blood sampling, occupational therapy, etc. (further explained in chapter 4.1 and 4.1.1). However, for the observation it was only possible to observe patients' movement in OPD1, and closely located departments. The areas of view chosen for the observation are marked red in Figure 2. Figure 2 also shows the two viewpoints decided for the observation, viewpoint A and B, as circles of darker red with corresponding letters.

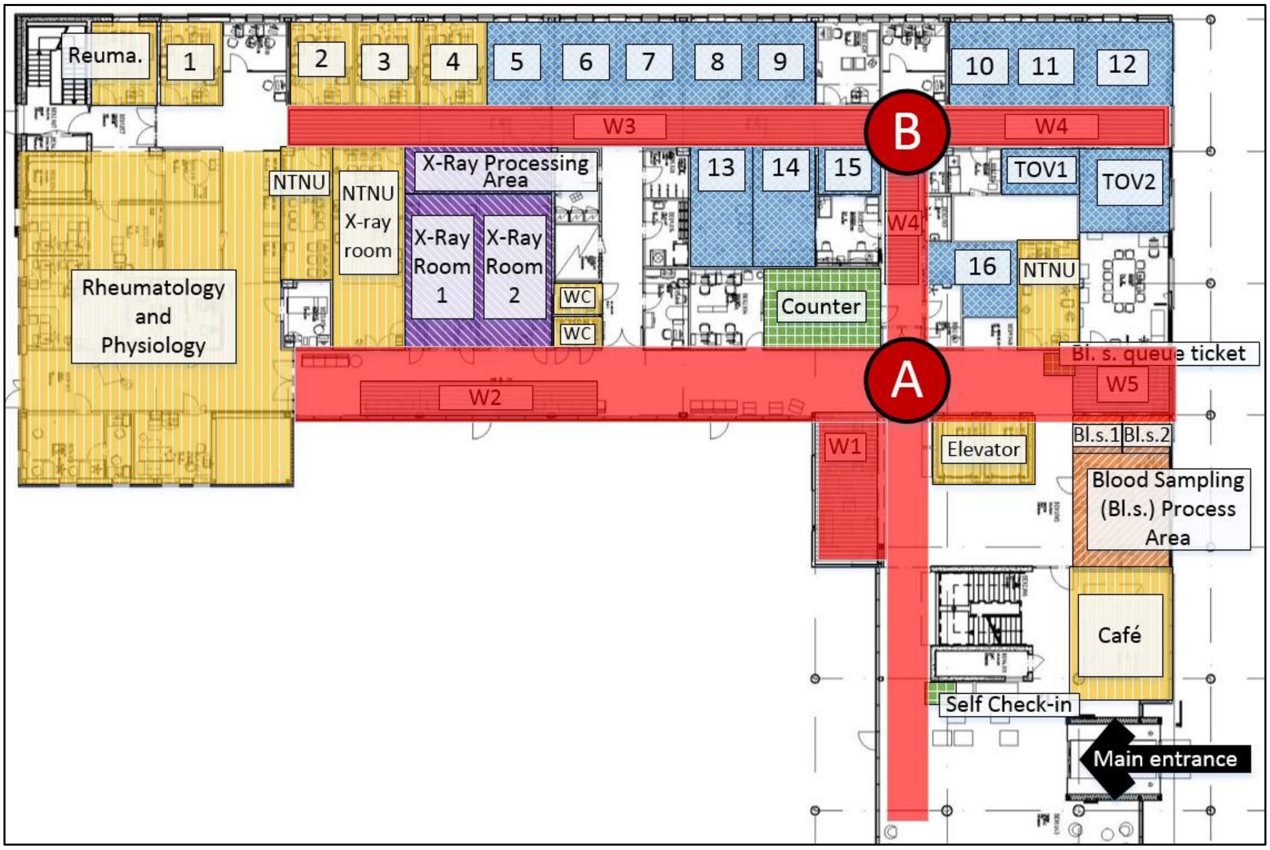

Figure 2: Observation in Outpatient Department 1: Areas of view (red areas) and viewpoints (red circles) chosen for the observation.
Source: St. Olavs Hospital. Adapted from original floor plan.

The areas of view cover OPD1, the X-ray and blood sampling department, which is related and closely located to OPD1, and registration and waiting areas. Thus, the part of the analysis concerning patient flow in OPD1 (chapter 5.1), based on the observations, only considers the patient flow taking place within these areas. However, information concerning other departments, such as occupational therapy, will be included in other parts of the thesis when appropriate.

Although, as may be clear from Figure 2, it was not possible to view the whole "areas of view" at the same time, which was a weakness of the observation. However, it was decided to put efforts in walking back and forth frequently between the two viewpoints to keep track of the patient movements. Another measure to keep track of patient movements was not to have a higher number than 10 patients being observed at any point of time.

Viewpoint A was decided as the main view point, as from this viewpoint entering the OPD, all registration areas, the X-ray rooms' entrance, the blood sampling rooms' entrance, and some of the waiting areas and walking to other surrounding areas could be viewed. Viewpoint B was included as it gives a view over the waiting areas to the different OPD1 consultation rooms. The floor plan and its elements are further described in detail in chapter 4.2.1.

To understand what rooms the patients were to walk into, it was decided that if the room was announced by the staff calling them in, it would be assumed to be correct. In the case of not hearing the announced room or the room not being announced, it was decided to observe what rooms the patients were going into, or asking the patients or staff when possible. Asking patients or staff for information also included the risk of losing track of other patients' movements.

It was also decided that if patients were to walk outside the observation area, it was noted, and if the patient was not to return, the patient was assumed to have exited OPD1. In addition, patients that were chosen for observation, and turned out not to go to OPD1, or not only go to X-ray, it was predetermined to stop following these patients any further at the moment this was discovered.

As can be seen in Figure 2, there are areas marked W1, W2, W3, W4, and W5. These are the waiting areas in OPD1, and are divided into these four areas for the observation to differentiate between the different waiting areas while noting. W3 and W4 are similar waiting areas, as both represent waiting areas outside OPD1 consultation rooms, however, for observation purposes they are divided into W3 and W4. The waiting areas are further explained in chapter 4.2.1.

Besides this, it was predicted that not all patient observations would be complete. In the case of losing track of a patient immediately after starting observation, it was decided to stop the observation for that patient. If a patient observation was almost complete, it was decided to consult with the OPD1 staff to assume the remaining route. Finally, it was decided that all patients chosen for observation, were to be chosen randomly, so that the observation data, to the extent possible, would lead to a realistic picture of the actual patient movement.

2.2.2 Processing of Observation Data

After the observation, the data observed was written into Excel and was divided into 4 categories, category A, B, C and D. The categories are explained in Table 3. Further, only category A and B were used for the analysis, in addition to their data sets being merged.

Table 3: Explanation of data categories

Category	Explanation
Category A	Patient went to OPD1 and full route was observed
Category B	Patient went to OPD1 and almost full route was observed, remaining route assumed
Category C	Patient was not going to OPD1
Category D	Lost track of patient / route incomplete

After dividing the observation data into category A and B, to get a better overview of the data, the observation data was further divided into sub-categories, AB1, AB2, AB3, as explained in Table 4. The sub-categories do not distinguish between whether or not the patient requires blood sampling. The sub-categories made it easier to point out different patient route numbers (explained in chapter 2.3) identified through the observation data.

Table 4: Explanation of data sub-categories, and amount of observations for each sub-category

Sub-Category	**Explanation**	**Amount**
Sub-category AB1	Only OPD1 consultation(s), from category A and B.	67
Sub-category AB2	Only X-ray consultation, from category A and B.	26
Sub-category AB3	Both X-ray and OPD1 consultation(s), from category A and B.	24
	SUM	117

The individual patient movement datasets, i.e. data recorded for each patient observed, can be found in Appendix E. The data in this appendix is divided into the sub-categories, and the different main routes which the patient took. For one individual patient movement dataset, the first movement was recorded as 1, the second as 2, and so on. In addition, for each individual patient movement dataset, the category it belongs to, either A or B, is given as well.

The data was further used to develop FROM/TO tables (see chapter 2.3). A FROM/TO table with the sum of all observations from category A and B combined are presented in the analyzation in Table 20. However, the individual FROM/TO tables belonging to the respective sub-categories (AB1, AB2 and AB3), can be found in Appendix F.

2.3 Analyzation

The input to the analyzation (chapter 5), is the information gathered and systemized in the case study. The purpose of the analyzation is to present findings from the case study, that lays the basis for the discussion. In the analyzation, the case study is seen in the light of the literature study, in addition to using PFA to structure and better understand the patient flow in OPD1. Further, a presentation of the PFA, and how it will be used for the analyzation is presented below.

PFA can be defined as "a technique for planning the simplification of material flow systems in factories" (Burbidge, 1989). The PFA is primarily based on analysis of the data contained in component route cards or process planning sheets which show the operations used to make each component and where each operation is done (Burbidge, 1989). In this case, different patient routes, and the location of different services, activities and waiting areas required by a patient throughout a patient visit.

The PFA is a stepwise technique consisting of a succession of sub-techniques, ranging from the first stage: simplifying the flow between factories (company flow analysis), and to the last stage:

finding tooling families (tooling analysis) (Burbidge, 1989). Factory flow analysis (FFA) is the second stage of PFA (Burbidge, 1989), and is the technique used in this scenario. Rather than using PFA to suggest a new layout, the PFA is used to look at the patient flow in OPD1, and how it takes place in the current layout. The FFA contains four steps, whereof this thesis is only concerned with phase A of the FFA. Phase A in the FFA is about studying the existing flow system. The steps are to identify product route numbers (PRNs), create a PRN frequency chart, create a FROM/TO table, and draw a material flow system network (Burbidge, 1989). PRN is "a code number which lists all the process code numbers for the processes used to make a part, in the sequence in which they are used" (Burbidge, 1989).

In this thesis, studying the existing patient flow in OPD1 consists of identifying patient route numbers (PRNs), creating PRN frequency chart and a FROM/TO table, as well as drawing a patient flow network. Use of samples are not ideal in PFA as they do not ensure to find all PRNs and all inter-process transfers (Burbidge, 1989). Although, in a health care setting, patients' movements are not as straightforward as materials'. Due to lack of data availability, samples of patient routes, by observing patient movements (see chapter 2.2), were created to represent the current patient flow in OPD1. PRNs were defined based on a combination of extracted data from the sub-categories and follow up questions to the staff in OPD1 to find additional routes, and to ensure correct information about the different planned patient movements identified (see chapter 2.2).

Further, creating a FROM/TO table was created for both the planned patient movements, and the actual observed patient movements (see chapter 5.1). The FROM/TO tables were a means of structuring the observation data of the patient flow in OPD1. Further, drawing a patient flow network for planned patient movements was done as a means of visualizing the FROM/TO table with planned patient movements. The patient flow network was also mapped onto the OPD1 floor plan to visualize how the patient flow takes place in the layout (see chapter 5.3.1).

Analyzing the existing patient flow in the current OPD1 layout, combined with seeing the case study in the light of the literature study, creates a foundation for discussing how layout design can support patient flow in outpatient departments.

3 Literature Study

In this chapter, literature concerning the topics of the thesis is presented, with the purpose of answering the research objective. The literature study provides insight on patient flow in hospitals and constraints, patient flow in outpatient departments, and layout. In the final chapter of the literature study, chapter 3.4, a preliminary framework for layout design supporting patient flow in outpatient departments is presented as a means of answering the research objective with the information provided in the literature study.

3.1 Patient Flow in Hospitals

From an operational perspective, patient flow is the movement of patients through a set of locations in a healthcare- facility or system (Medina-León et al., 2014, Zhao and Lie, 2010, Côté, 2000, Hall et al., 2013, Koo et al., 2010). It can also be thought of as the movement of patients through a set of activities or services in a healthcare facility (Koo et al., 2010). Throughout the patient flow, the patients require a variety of healthcare resources, such as doctors, nurses, medical equipment, and consultation rooms (Koo et al., 2010).

Zhao and Lie (2010) pointed out that patient flow can be considered as a combination of physical, information and decision flow. Physical flow includes patient pathways, flow of health personnel and materials. Information flow includes information regarding patients and states in different departments, such as test results, waiting lists and health personnel availability. Decision flow includes decisions on different pathways of physical or information flow, and depends on the diagnosis of the patient and the state in the hospital. Also, sometimes decision flow can be part of the information flow (Zhao and Lie, 2010).

The metric of patient flow is patient throughput (Asplin, 2006). Patient throughput can be expressed in different ways, either as a measure of time from patient arrival to patient departure (Asplin, 2006, Andriole, 2002), or as the total number of patients passing through a facility in a given unit of time (Andriole, 2002). To differentiate these, the first mentioned will hereby be referred to as *throughput time*, while the latter as *throughput volume*.

A good patient flow lets patients move through the various sets of locations in the health care system without delay (Pearson, 2008), e.g. waiting for a service due to lack of personnel, equipment or information (Medina-León et al., 2014), and provides benefits to both the patients and the hospitals (Pearson, 2008). Efficient patient flow consists of high throughput volume, short throughput time, low patient waiting time, and low personnel overtime combined with high personnel utilization (Koo et al., 2010), and the benefits include improved clinical outcomes, eliminated waits and delays, saved time, effort and costs, which requires an effective management of resources (Pearson, 2008).

Hall (2013) presented objectives for different health care systems' perspectives, whereof the objectives of a hospital and its departments are presented in Table 5.

Table 5: Objectives of a hospital and its departments. Adapted from Hall et al. (2013).

Perspective	Objectives
Health care center (Hospital)	• Minimizing waits as patients transition from department to department • Achieving a high level synchronization among patients, employees, and resources, so that services begin promptly on patient arrival and are provided with high efficiency • Identifying and resolving system level bottlenecks that impede the flow of patients
Department	• Support the objectives of the health care center through effective coordination • Being effective in their own right, i.e. minimizing their causing of delay within the department or elsewhere.

According to Hall (1990), the solutions to delay problems, i.e. improving flow, come in three forms: altering the service process, altering the arrival process, and altering the queuing process (Hall, 1990). Altering the service process refers to changes in scheduling, coordination, process, communication, automation, etc. which increases capacity for serving customers and increases the synchronization between capacity and customer arrival patterns (Hall et al., 2013). Altering the arrival process refers to changes in appointments, pricing, information, education programs, etc., with focus on improving the balance between capacity and demand. Altering the queuing process refers to triage, moving waiting from the health care facility to home, redesign of waiting areas, changes in prioritization, etc., to ensure that adverse consequences of waiting are minimized (Hall et al., 2013).

Regarding patient flow in hospitals and hospital departments, a hospital operates as a system of interacting departments which care is delivered through, and must coordinate patient flow, personnel, information and materials, whereof a department represents a unit within a larger center, performing one function or a group of closely related functions (Hall et al., 2013). Some examples of departments are emergency departments, outpatient departments, operating theatres, medical imaging departments, inpatient wards, etc. (Hall et al., 2013). Each department is one component of the hospital, and the hospital can thus be better characterized as a system of systems (Hall et al., 2013). According to the U.S. Department of Defense (2004), which is a well used reference within systems engineering, a system of systems is "a set or arrangement of systems that results when independent and useful systems are integrated into a larger system that delivers unique capabilities" (The U.S. Department of Defense, 2004). The upper level perspective will be affected by the lower level perspective, i.e. hospital departments and their coordination will affect the overall patient flow within a hospital.

3.1.1 Patient Flow Constraints

According to Koo et al. (2010), there are three basic components that affect the patient flow of a system: the number of patients entering the system at any point of time; capacity of the system which limits flow of patients throughout the system; and the inherent random nature of patient flow. To achieve efficient patient flow, these components must be carefully managed (Koo et al., 2010). The first two concern demand and supply of services (available capacity), whereof an imbalance between these components can lead to bottlenecks, which can cause waiting (Koo et al., 2010, Swisher et al., 2001), and underutilization causing lost time and profit (Swisher et al., 2001). The third component concerns variations in arrival, and processing times required for each patient (Koo et al., 2010), which can result in waiting time, low resource utilization, in addition to staff overtime (Koo et al., 2010). Further, this chapter is divided into available capacity, and variability.

3.1.1.1 Available Capacity

Capacity shortage is when the amount of resources available for production are not in balance with the demand for that resource at the average level of production (Villa et al., 2014). Hospitals can experience capacity shortage, such as scarcity of personnel (Erhard et al., 2018, Litvak et al., 2006, Hong et al., 2013), consultation rooms (Hong et al., 2013), equipment (Vissers, 1998), etc.

Health personnel has the highest operating cost in hospitals (Erhard et al., 2018). In addition, most industrialized countries have experienced shortages of medical personnel. Scarcity of doctors, combined with health personnel being the highest operating cost in hospitals, forces hospital managers to find effective ways to plan and schedule the workforce (Erhard et al., 2018). As previously mentioned, patients require a variety of healthcare resources, such as doctors and nurses (Koo et al., 2010). When a flow system consists of multiple resources, there exists a bottleneck resource (Koo et al., 2010), whereas a bottleneck is the capacity constraining stage in a process (Slack et al., 2010), which governs the process' throughput volume (Slack et al., 2010, Koo et al., 2010). Koo et al. (2010) studied the patient flow in an endoscopy OPD, and discovered that for their case scenario, the medical doctors were the bottleneck. Also nurses were important resources, whereof the capacity were sufficient, however, sometimes during the week the capacity was not sufficient (Koo et al., 2010).

Due to health personnel being a scarce, and costly resource, it is important to have high health personnel utilization. Skeldon et al. (2014) drew spaghetti diagrams, which can be found in Appendix G, depicting doctor and nurse flow in an uro-oncology OPD before and after an improvement event. The diagram shows a more organized flow of both the doctors and nurses after the event, which results in the health personnel being able to spend more time in the patients' rooms (Skeldon et al., 2014). In addition, long walking routes for personnel does not support improvements in productivity (Karvonen et al., 2017).

Further, patients may wait for services due to lack of coordination. Lack of coordination between different healthcare resources may lead to delays in patient treatment (Rohleder et al., 2013). Proper coordination of healthcare resources, in the case of having the right amount of capacity, ensures that patients have access to the healthcare resources, and flow through them in an effective and efficient manner (Rohleder et al., 2013). Finally, although patient flow is constrained by available capacity, according to Walley et al. (2006), delays in health care could in many cases be caused by lack of attention on variability, rather than capacity shortage (Walley et al., 2006).

3.1.1.2 Variability

Process variabilities are important to consider, as they can affect the process (Slack et al., 2010). According to Slack et al. (2010), there are two fundamental types of variability: variation in inter-arrival times and variation in time to process a unit. There is also a relationship between the average waiting time and process utilization, where decreased variation will lead to lower queues and better utilization (Slack et al., 2010). Thus, in an ideal world, there is no variation and all processes go as planned.

However, there will always be process variabilities. Some of the reasons why variabilities can occur are late or early arrival of material, information or customer, temporary downtimes, or variation in requirements from the unit being processed (Slack et al., 2010). In the case of an OPD, variability thus may occur due to late or early arrival of patient, health personnel, variations in the patient consultation time (Chand et al., 2009), late arrival of material or information, or temporary downtimes of rooms or equipment, hindering a smooth patient flow.

Van Riet and Demeulemeester (2015) listed possible events that can cause variability to occur for surgical processes. Although listed for surgical processes, it is natural to assume that most of these events can be transferable for other health care services. The possible events that can cause variability as listed by Van Riet and Demeulemeester (2015) are as follows:

- Late arrivals of patients
- Patient not showing up (no-show)
- Late or early arrival of medical staff
- Delay in support services
- Inaccurate reservation of resources
- Setup, clean up or change over time variability
- Illness of patient or medical staff
- Acute onset of abnormal medical conditions (e.g. infections)
- Surgery duration variability
- Duration variability of all upstream and downstream activities (length of stay)
- Arrival of emergency patients

In addition, patients may be delayed waiting for services visible or invisible for the patients (Hall et al., 2013), i.e. there might be variation in these services as well. Visible services can for example be information collection as a part of the admission, diagnostics and examinations, transportation between departments, etc., while services invisible to patients can be such as transfer of medical records or laboratory specimens, analysis of test results, preparation of rooms, etc. (Hall et al., 2013).

A study by Chand et al. (2009), focusing on variation in OPDs, investigated two major problems in an OPD caused by variation: patient waiting time and doctor finishing time. Process variability was divided into four components: variabilities in arrival to registration area, variability in registration time, variability in departures from registration area to see the doctor, and variability in time with doctors (Chand et al., 2009). Chand et al. (2009) also stated that no-show patients can cause underutilization of OPD capacity and that late arrival of doctors is not uncommon, and can increase patient waiting time and improve doctor utilization time (Chand et al., 2009). Also, variability can be caused by external factors, which is out of the OPD management's control, or it could be internal factors where the management may have some control (Chand et al., 2009).

Cayirli and Veral (2003) highlights that patient waiting time is highly sensitive to the lateness and interruption levels of doctors (Cayirli and Veral, 2003). In addition to late-arrival of doctors, a doctor may be interrupted while being in the OPD. Doctor interruption includes all activities that may require the doctors attention, e.g. phone calls, writing notes, comfort breaks, interaction with support staff, which interrupt consultation times. Variabilities in time with doctors can vary due to different patient needs (Chand et al., 2009). However, standardizing tasks to be performed, where possible, could reduce the variabilities in time with doctors (Chand et al., 2009).

Furthermore, the patient arrival time has an impact on the overall patient flow, as the following activities, e.g. entering the consultation room, will be delayed as well (Okotie et al., 2008). Also, if it is a multistage system where the outpatient receives multiple services during a visit, the presence of variability will upset the schedule more than if it was a single-stage system with only one service to be delivered (Cayirli and Veral, 2003). A study by Okotie et al. (2008) showed that late patients had significantly less time with their doctor than on-time patients (Okotie et al., 2008), which may affect the clinical patient flow as well. It was also found that late patients decreased the overall clinic efficiency (Okotie et al., 2008).

Besides this, Walley et al. (2006) pointed out that resource pooling, can be regarded as an effective way of dealing with some types of variation, whereof variations related to queues (Walley et al., 2006). Providing one single common queue, where patients wait for multiple servers, and not a specific server, provide reduced variability (Chand et al., 2009) and shorter wait times (Cayirli and Veral, 2003). Nevertheless, random assignment of doctors is often seen as undesirable (Cayirli and Veral, 2003). Also, a patient can join a wrong queue, or the patient can be standing in a queue behind another patient who takes a long time while other servers are idle (Walley et al., 2006).

3.2 Patient Flow in Outpatient Departments

As mentioned, an OPD, is a department within a hospital, performing one function or a group of closely related functions (Hall et al., 2013). Some examples of typical disciplines that OPDs deliver, are services within orthopedics, urology, gastroenterology, gynecology, neurology, oncology, otorhinolaryngology, ophthalmology, etc. (Helse- og omsorgsdepartementet, 2015).

In OPDs, patients are treated and released the same day (Côté, 2000), i.e. not staying overnight. Throughout the patient flow, the patient will require a set of resources and goes through different steps in the OPD depending on the service(s) required. Different OPDs will have different activities depending on the practiced field of medicine and services they provide (Froehle and Magazine, 2013). However, based on descriptions and illustrations found in the literature, a general description of patient flow in outpatient departments is given below, and an illustration is presented in Figure 3.

Common for all patient flows are that they consist of an entrance, an exit, and a path connecting entrance to the exit, and the random nature of health care elements (Côté, 2000). First, the patient arrives (enters) the OPD. After arrival, the patient checks in (registers) (Mardiah and Basri, 2013). The patient then goes to a waiting area, waiting to be called in for consultation (Côté, 2000, Mardiah and Basri, 2013). The patient may undergo one or multiple consultations (Cayirli and Veral, 2003, Swisher et al., 2001, Côté, 2000, Mardiah and Basri, 2013), taking place in one or multiple rooms (Côté, 2000, Mardiah and Basri, 2013). After a patient's consultation(s) is finished, the patient can proceed to checkout. After check-out, the patient exits the OPD (Côté, 2000).

Waiting can occur in-between each activity. Firstly, when patients arrive, they may wait for available check-in personnel (Chand et al., 2009) or self-service machine (Almomani and AlSarheed, 2016). Secondly, after check-in, the patient may have to wait to enter a consultation room (Chand et al., 2009, Côté, 2000, Mardiah and Basri, 2013). Thirdly, if the patient is to move to other rooms, i.e. using multiple consultation rooms, waiting may occur as well before entering the preceding rooms (Cayirli and Veral, 2003). Fourthly, if the patient walks out from one room, followed by the patient reentering the same room (Côté, 2000), waiting occurs. Finally, when the patient is consulted, the patient may have to wait for available check-out machine/personnel (Chand et al., 2009).

As mentioned, patients can undergo one or multiple consultations. According to Cayirli et al. (2013), OPDs can include a single or a multi-stage system, or a combination of both, where the patients either queue for one service, e.g. single OPD consultation, or queue for multiple services, e.g. OPD consultation and X-ray. As stated by Swisher et al. (2001), an examination (consultation) is the time the patient spends with a medical staff member, either to diagnose or treat an ailment (Swisher et al., 2001). However, the patient may undergo a pre-examination or post-examination (multi-stage system), where the patient spends time with a medical staff member in a consultation room, or a room with special equipment such as an X-ray machine, collecting more extensive medical information before/after a consultation (Swisher et al., 2001). After a consultation or post-examination, the patient may have an exit interview, where the patient spends time with medical staff member for final consultation or diagnosis (Swisher et al., 2001).

Based on the above descriptions of patient flow in outpatient departments, and illustrations found in the literature, a general illustration of patient flow in outpatient departments was developed, shown in Figure 3. The illustrations found in the literature, in addition to arguments for choosing the elements in the different illustrations are respectively found in Appendix H and Appendix I. In Figure 3 the circles represent activities, triangles represent waiting, and arrows represent the movement from one activity to another (besides for arrival and departure where it represent the patient arrival or departure). In addition, the illustration allows there to be consultations delivered in three, or more rooms, which is illustrated by consultation room N, which represents that a patient may go through three consultation rooms or more.

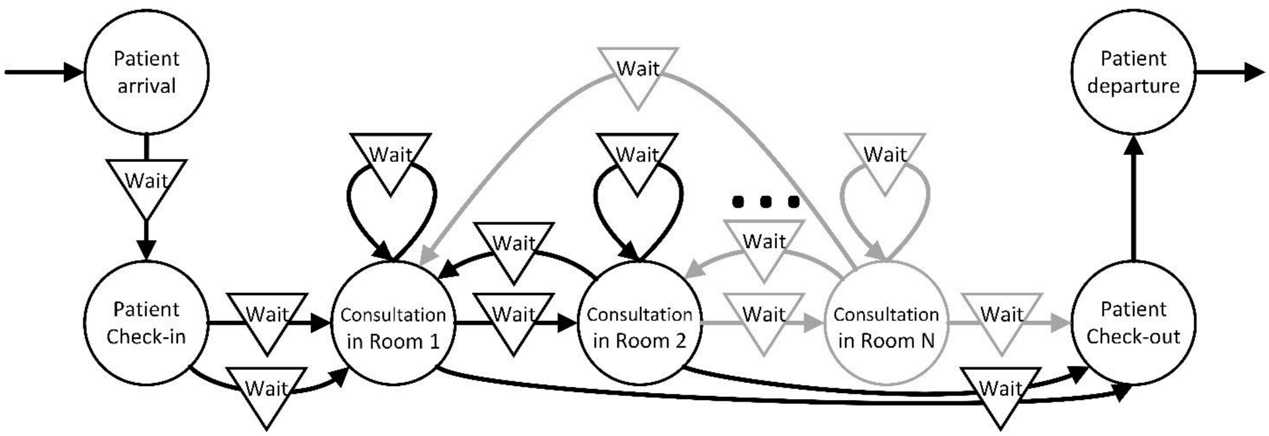

Figure 3: General illustration of patient flow in outpatient departments.
Adapted from Côté (2000), Swisher et al. (2001), Mardiah and Basri (2013), Pan et al. (2015), Chand et al. (2009), and Cayirli and Veral (2003).

3.3 Layout

Layout is concerned with the arrangement of departments, work centers, equipment (Stevenson, 2014), and staff, i.e. the physical location of the operation's transforming resources (Slack et al., 2010), with emphasis on the movement of work throughout the system (Stevenson, 2014). The layout governs the appearance of the operation, and determines how transformed resources, i.e. materials, information and customers, flow throughout the system, which affects cost and general effectiveness of an operation (Slack et al., 2010).

Layout is a part of a systems design, and layout decisions are important for three basic reasons (Stevenson, 2014). Firstly, significant investment in costs and efforts are required. Secondly, they involve long-term commitments. And lastly, layout has a significant impact on cost and efficiency of operations (Stevenson, 2014). System performance can be adversely affected by a poor layout design (Stevenson, 2014), leading to high costs, long and/or confused flow patterns, unpredictable flow, long queues, inflexible operations and long processing times (Slack et al., 2010). For instance, layout and its distances between activities can impact scheduling of activities (Morinaga et al., 2016), causing longer throughput times than necessary. Activities can also be closer than necessary for scheduling (Morinaga et al., 2016). Anyway, unfortunately, there is no algorithms that identify the best layout arrangement under all circumstances (Stevenson, 2014). Layout planners must often rely on heuristic rules to guide trial- and error efforts until a satisfactory solution to each problem is reached (Stevenson, 2014).

Layout planning is used for both planning new facilities, and in redesigning existing facilities (Stevenson, 2014). There are different reasons for redesigning layouts, which include insufficient operations, safety hazards, change in design of services or products, and changes in the volume or mix of outputs (Stevenson, 2014). Redesigning a layout can cause disruption to an existing operation, leading to lost operation time or reduced customer satisfaction (Slack et al., 2010).

Also, there are different aspects of layout, such as general layout of the hospital and layout of rooms in a department (Stevenson, 2014). Hospitals are usually arranged based on a functional layout, where each department have their own type of process, such as X-ray department, operating theatres, blood-processing laboratory, etc., whereas different layout types (see Table 7) are used within each department (Slack et al., 2010).

Layout design must start with an evaluation of what the layout should be trying to achieve (Slack et al., 2010). The overall layout design objective is to facilitate a smooth flow of work, materials, customers and information throughout the system (Stevenson, 2014), however the objectives of any layout will depend on the strategic objectives of the operations (Slack et al., 2010). Stevenson (2014) and Slack et al. (2010) respectively presented a set of seven and eight objectives to support layout design, relevant to all operations. Some of the objectives are only presented by one of them, some objectives are similar, while some objectives are more elaborated by one of the authors. The respective sets of layout objectives found by the respective authors can be found in Appendix J. A set of 10 layout objectives are presented in Table 6, based on a combination of the layout objectives presented by Stevenson (2014) and Slack et al. (2010).

Table 6: General layout objectives. Adapted from Stevenson (2014)[1] and Slack et al. (2010)[2].

Objective	Description
Quality	Facilitate the achievement of product or service quality[1].
Efficiency	Facilitate efficient use of workers[1] and space[1,2], and avoid bottlenecks[1].
Minimize cost	Minimizing material handling costs[1].
Appropriate length of flow	An operation should have appropriate length of flow[2]. In most cases[2], it is about eliminating unnecessary movement[1] or minimizing transportation[2] of workers, materials and/or customers[1,2]. However, sometimes this is not the case, i.e. in a supermarket[2].
Minimize time	Minimize production time or customer service time[1].
Safety and welfare	Design for safety[1] and welfare, i.e. locating staff away from unpleasant parts of the operation, e.g. noise[2].
Accessibility	Machines and facilities should be easy to access for proper maintenance and cleaning[2].
Management Coordination	Supervision and communication should be assisted by the location of workers and communication devices[2].
Clear flow	Flow of material or customers should be well signposted, clear and evident to workers and customers alike[2].
Flexibility	Design for flexibility[2], i.e. take possible future needs of the operation into consideration[2].

3.3.1 Layout Types

Most practical layouts are derived from the basic layout types (Stevenson, 2014, Slack et al., 2010). According to Stevenson (2014), there are three basic layout types: product, process, and fixed position layout (Stevenson, 2014). In addition, Slack et al. (2010) mentioned cell layout as a fourth basic layout type (Slack et al., 2010), whereas Stevenson (2014) presented cell layout as a combination of product and process layout, where each “cell” in cell layout (see Table 7) functions as a miniature version of product layout (Stevenson, 2014). In accordance with Stevenson (2014), Slack et al. (2010) and Burbidge (1991) stated that cell layout is an attempt to create order to the complex flow which characterizes functional layout (Slack et al., 2010, Burbidge, 1991). Also, Slack et al. (2010) pointed out that process layout and functional layout are two names for the same layout type (Slack et al., 2010). Henceforth, functional layout will be used, as the name process layout can cause confusions. In addition to the basic layout types, operations often have a hybrid layout. A hybrid layout either combine elements of multiple or all of the basic layout types, or use single basic layout types in different parts of the operation (Slack et al., 2010).

Table 7: Basic layout types. Adapted from Stevenson (2014)[1] and Slack et al. (2010)[2].

Layout Type	Explanation	Examples
Fixed Position Layout	Fixed position layouts are intended for processes where the product or customer being worked on must remain stationary[1,2]. Workers, material and equipment move to the product or customer being worked on as necessary[1,2]	Ship building yards, or operation theatres in hospitals[2]
Functional Layout	Functional layouts are intended for non-repetitive processes where items or services involve a variety of processing requirements[1]. Similar resources or processes are located together, and when materials, customers, or information flow through the operation, they take different routes according to their needs[1,2].	Machine shop with separate departments for milling, grinding, drilling, etc., or hospital with different departments for surgery, maternity, emergency[1], X-ray[2]
Product Layout	Product layouts are intended for repetitive processes where only one or a few products or services with very similar processing needs are involved, and it is feasible to arrange the entire layout to facilitate the processing requirements of the product or service[1]. The work is divided into a series of standardized tasks[1].The product, information or customer follows a prearranged route, where sequence of the processing requirements matches the sequence in which the processes are located[2].	Automotive assembly[1] or blood processing laboratory[2].
Cell Layout	Cell layout[2], also called cellular layout[1], is a type of layout which workstations are grouped into cells according to process requirements for a set of similar products or customers to be worked on which require similar processing[1]. I.e. a cell contains all the transforming resources required to process a certain set of products or customers[2]. A product or customer moves to the cell for processing, and after being processed, it may move to another cell for further processing[2]. Within the cell, the set of products or customers follow the same route, although minor variations are possible, e.g. skipping an operation[1].	“Lunch” area in a supermarket or a maternity unit in a hospital[2].

Regarding cell layout, it is based on group technology, which is a product organization method where related parts are grouped together (Burbidge, 1989). According to Burbidge (1991), where continuous line flow cannot be used, combined with the company not being too small, so that the company is in effect already a single group, it is generally possible to divide any factory into groups of machines and associated groups of parts, with no cross- or backflow between the groups (Burbidge, 1991). Organizing the production in such way will normally be more productive and profitable than with functional layout organization (Burbidge, 1991). Anyway, each layout type is intended for different purposes, and involve advantages and disadvantages. Layout types and their respective advantages and disadvantages found, based on the literature from Stevenson (2014) and Slack et al. (2010), are shown in Table 8.

Further, choice of layout type is influenced by the process types, however, a process type does not necessarily imply one specific layout type (Slack et al., 2010). Process types are the general approaches to designing and managing processes and activities (Slack et al., 2010). According to Slack et al. (2010) there are three basic service process types, which are professional services, service shops, and mass services (Slack et al., 2010). As seen in Figure 4, each service process type has different characteristics when it comes to process task complexity, variety, volume, and process flow continuity. In professional services, each product is different and customers spend considerable time in the service process (Slack et al., 2010). In service shops, fairly standardized services are provided, however the service is customized to each customer's individual need (Slack et al., 2010). In mass services, standardized services are delivered and there is little contact time (Slack et al., 2010).

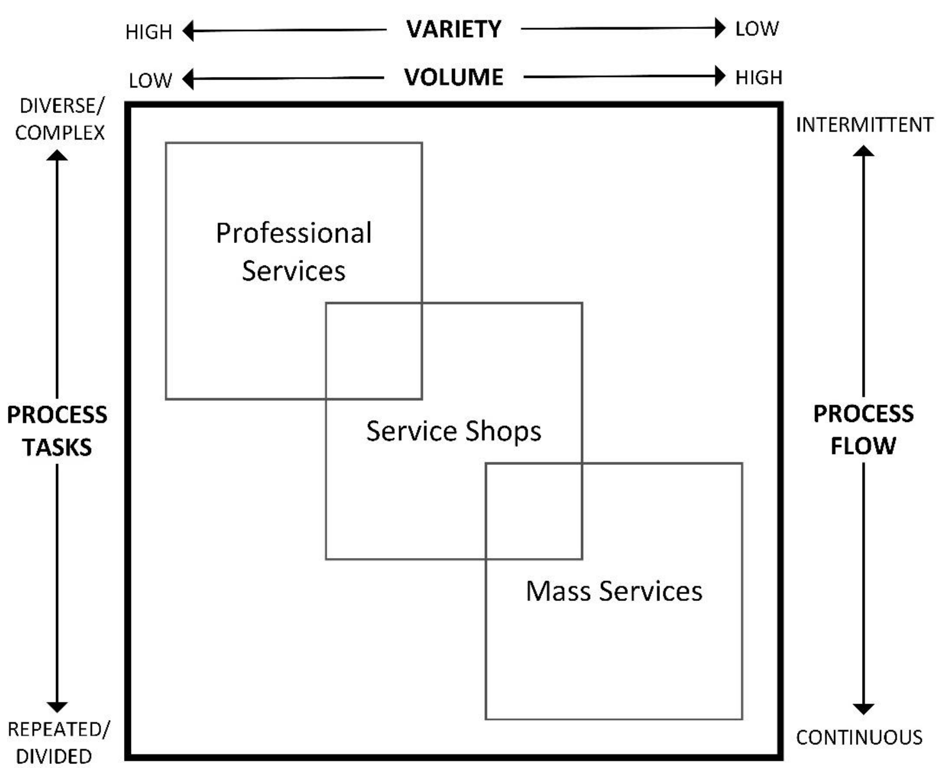

Figure 4: Service process types and their characteristics. Source: Slack et al. (2010).

Table 8: Layout types and their respective advantages and disadvantages. Adapted from Stevenson (2014)[1] and Slack et al. (2010)[2]

Layout type	Advantages	Disadvantages
Fixed position layout	• High mix and product flexibility[2] • Product or customer not moved or disturbed [1,2] • High variety of tasks for staff[2]	• Very high unit costs[2] • Scheduling of space and activities can be difficult[2] • Special efforts to coordinate activities are needed[1] • Span of control can be narrow[1] • Can mean much movement of plant and staff[2]
Functional layout	• High mix and product flexibility[1,2] • Relatively robust in the case of disruption[1,2] • Relatively easy supervision of equipment or plant[2] • The equipment used is normally general purpose equipment, and is normally less costly than specialized equipment. Also easier and less costly to maintain[1] • Possibility to use individual incentive systems[1]	• High unit costs[1] • Low facilities[2] and equipment[1] utilization • Discontinuity of work flow due to frequent adjustments to equipment [1] • Can have very high work-in-progress inventory or customer queuing[1,2] • Complex flow, which can be difficult to supervise[1] and/or control[2] • Special attention necessary for each product or customer, e.g. scheduling, routing, machine setups[1] • Accounting, inventory control, and purchasing are much more involved than with product layouts[1]
Cell layout	• Can give good compromise between cost and flexibility for relatively high-variety operations[2] • Fast throughput[2] • Group work can result in good motivation[2]	• Can be costly to rearrange existing layout[2] • Can need more plant and equipment[2] • Can give lower plant utilization[2]
Product Layout	• Low unit cost[1,2] • High rate of output[1,2] • Gives opportunities for specialization of equipment[2] and staff[1] • Materials or customer movement is convenient[1,2] • High utilization of workers and equipment[1] • Less focus is needed on routing and scheduling[1] • Fairly routine accounting, purchasing and inventory control[1]	• Can have low mix[1,2] or volume[1] flexibility • Not very robust if there is disruption[1,2] • Work can be very repetitive and dull for workers[1,2] • Poorly skilled workers may have little interest in maintaining equipment or in the quality of output[1] • Preventive maintenance, spare parts inventory and capacity for quick repairs are necessary expenses[1] • Impractical to use individual incentive systems[1]

Layout can be seen as the physical manifestation of a process type, however there is usually some overlap between the process types and the layout types, i.e. one process type does not necessarily imply a specific layout type (Slack et al., 2010). Figure 5 illustrates the relationship between the basic layout types and service process types.

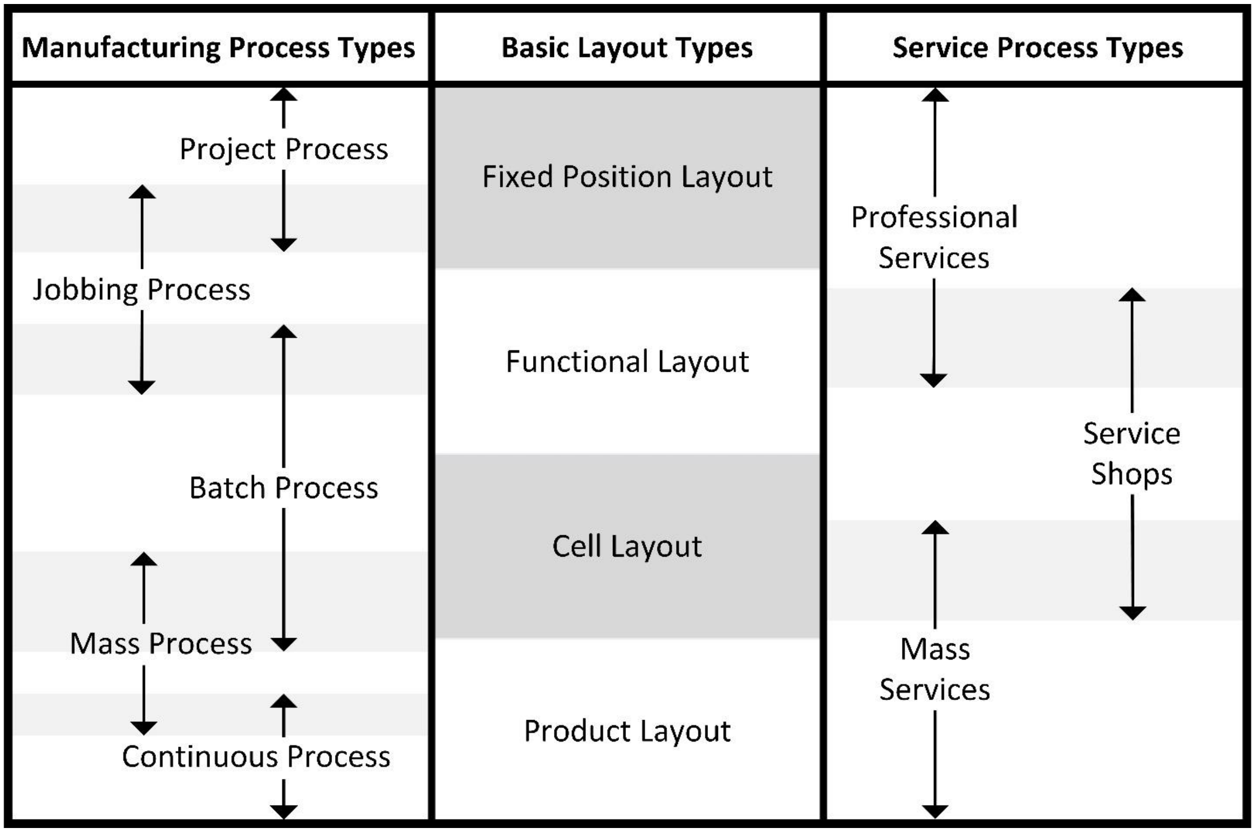

Figure 5: The relationship between basic layout types and service process types.
Source: Slack et al. (2010).

Further, the choice of layout type will be influenced by the relative advantages and disadvantages associated with the respective layout types (Slack et al., 2010). To a large extent, the choice can be narrowed down to one or two layout options if looking at the volume-and variety characteristics of the operation (Slack et al., 2010). According to Slack et al. (2010), out of different layout types' characteristics, the perhaps most generally significant are the unit cost implications that follows for each layout type (Slack et al., 2010).

Out of the layout types' advantages and disadvantages, the unit cost implications of a layout choice is perhaps the most significant characteristic (Slack et al., 2010). Different basic layout types have different variable- and fixed-cost characteristics, which can be an indication on which layout to use (Slack et al., 2010). Looking at the different layout types in the following order: fixed position, functional, cell, and product, variable costs tend to decrease from left to right, while fixed costs tend to increase (Slack et al., 2010). However, the actual variable- and fixed-cost of a layout is difficult to estimate, and will most likely depend on many factors difficult to predict (Slack et al., 2010). Thus, a layout decision can rarely depend on costs alone (Slack et al., 2010).

3.3.2 Layout in Hospitals and Outpatient Care Settings

According to Stevenson (2014), layouts in service operations can often be categorized into the basic layout types, and points out that hospitals are an example of service operations that use functional layouts (Stevenson, 2014). Functional layout is a common layout type in services, as services often consist of high degree in customer processing requirements (Stevenson, 2014). Care and safety are key elements of hospital layout design, in addition to easy access to critical resources, such as X-ray, CT (computed tomography scan), and MRI (magnetic resonance imaging) (Stevenson, 2014).

As described in chapter 3.3, there are different aspects of layout, such as general layout of the hospital and layout of rooms in a department, i.e. on a more detailed level (Stevenson, 2014). Accordingly, Arnolds and Nickel (2015) distinguished between layout planning problems on a macro and micro level, where macro level is focused on the assignment of departments within a hospital, while the micro level is focused on a single department layout (Arnolds and Nickel, 2015). Arnolds and Nickel (2015) conducted a literature review on layout planning problems in health care and divided the literature reviewed into categories.

A category called “patient service center/ambulatory care/outpatient clinics” (henceforth outpatient care setting) was categorized as macro level by Arnolds and Nickel (2015). The articles concerning outpatient care settings cited by Arnolds and Nickel (2015) are Burn (1982), Amladi (1984), Iskander and Carter (1991), Sepúlveda (1999) and Swisher et al. (2001). Unfortunately, the article by Burn (1982) was unavailable. Also, one of the articles cited concerns outpatient clinics, i.e. micro level. Anyway, the one article concerning outpatient clinics, by Swisher et al. (2001), is concerned with finding the right capacity-combination of an outpatient clinic to achieve a fit between waiting time for patients and clinic profit, rather than the layout design, and thus no information regarding layout was retrieved from this article. Further this chapter is concerned with five articles. The literature presented first, is from the articles by Arnolds and Nickel (2015) and Karvonen et al. (2017) concerning hospital layout on a macro level. Lastly, the relevant literature from the articles by Amladi (1984), Iskander and Carter (1991), and Sepúlveda (1999) is presented, which is also on a macro level, but in an outpatient care setting.

According to Arnolds and Nickel (2015), the aim of hospital layout researchers is to minimize distances, or associated costs of locating departments inside hospitals (Arnolds and Nickel, 2015). Different objectives of the papers reviewed by Arnolds and Nickel (2015) include patient centeredness, personnel centeredness, facility design, distance minimization, workflow optimization, occupant flows, resource utilization, cost minimization, closeness rating maximization, and occupancy rate (Arnolds and Nickel, 2015). Hospital design focuses mainly on long-term perspectives, such as resource and capacity planning (Arnolds and Nickel, 2015).

However, the building will also influence short-term aspects, such as operational workflows, i.e. the building should be determined by the process, and not the other way around (Arnolds and Nickel, 2015). Thus, before entering the design phase of a construction process, an analysis of the processes should be carried out, providing information on the movement of patients, personnel and material (Arnolds and Nickel, 2015). Efficient location of the departments can reduce the distances traveled, whereof reducing distances is a means of saving in time and consequently resources. More time to spend on care turns into patient and personnel satisfaction. However, the objectives of reducing distances travelled for patients and personnel can be conflicting. (Arnolds and Nickel, 2015)

In the study by Karvonen et al. (2017), a patient flow analysis was used for the planning of a musculoskeletal surgery unit in a new hospital with multiple departments, including an operating theatre unit, an emergency department, inpatient wards, outpatient departments, X-ray, and computed tomography (CT). The patient flow analysis was based on Burbidge's Production Flow Analysis (PFA) (Karvonen et al., 2017), whereas the PFA is a technique for finding groups to create cell layout (Burbidge, 1989). Karvonen et al. (2017) concluded on the patient flow analysis to be a valuable additional tool in hospital design. The production flow analysis can be used to analyze transfer volumes between activities, which then can be taken into account in the layout planning and architectural design phases. However, although an ideal layout is the input to the starting point of a planning process, practical implications may prevent the ideal layout to take form. In the research of Karvonen et al. (2017), reducing transfer distances was the main objective. Many new and continuously developing technologies requires more space than previous methods, whereas longer transfer distances can be a consequence of the increased need for floor space (Karvonen et al., 2017). By reducing transfer distances, a non-value adding activity, patient and personnel movements can be reduced, which supports cross-professional teamwork, productivity improvement, and patient safety, i.e. patient movement is a potential source of adverse effects on patient safety (Karvonen et al., 2017). One assumption made by Karvonen et al. (2017) was that the less the patients move, the less doctors and nurses move between different activities and departments (Karvonen et al., 2017). One of the key factors to reduce patient transfers in the study by Karvonen et al. (2017) was to locate the X-ray department in the interface between the outpatient department and the inpatient ward, which allowed for reduced patient transfers and facilitated communication between nurses and the X-ray department. (Karvonen et al., 2017)

The study by Amladi (1984) is mainly concerning facility planning and sizing of an outpatient surgical facility, i.e not layout. However, Amladi (1984) pointed out that if capacity is insufficient in an area, in this case pre-/post-surgery room, it can lead to an activity or service taking place in a different area than planned, i.e. the planned layout of services can change. In the case of Amladi (1984), the pre-surgery treatment was in some cases delivered in a chair instead of a cart, while post-surgery treatment was sometimes delivered in the hallway. I.e. care may be delivered in undesirable conditions due to lack of capacity (Amladi, 1984). Similarly, the study by Iskander and Carter (1991) is also mainly concerning facility and capacity planning. In their study the capacity of an outpatient care center under construction was simulated, which showed not to be sufficient. Some of the outpatient care services was then proposed to be moved to the main hospital, so that the planned layout of services was rearranged to balance capacity (Iskander and Carter, 1991). Finally, in the study by Sepúlveda (1999), rearranging the layout of services in an outpatient cancer treatment center was simulated, whereof two departments within the center was moved from the fourth floor to the first floor, near related departments. The aim was to reduce transportation distances and improving the patient flow within the facility and increase the capacity. The simulations identified patient flow bottlenecks, and provided insights on how to improve the patient flow and resource utilization by adding capacity. In addition, the rearrangement of layout of services showed some improvement for some patient types before adding capacity (Sepulveda et al., 1999).

3.4 Preliminary Framework for Layout Design Supporting Patient Flow in Outpatient Departments

Based on the literature study, a preliminary framework for layout design supporting patient flow in outpatient departments was created, and is presented in Table 9. The framework does not represent all the information presented in the literature study, but contains the most essential information extracted from it, regarding how layout should support patient flow in outpatient departments. Supporting patient flow is to facilitate high patient throughput volume, short patient throughput time, low patient waiting time, high personnel utilization, low personnel overtime (Koo et al., 2010), and short travel distances for patients and personnel (Karvonen et al., 2017). The framework is divided into three sections.

In the first section, a definition of patient flow and layout is presented. The patient flow definition is based on statements from Medina-León et al. (2014), Zhao and Lie (2010), Côté (2000), Hall et al. (2013) and Koo et al. (2010), as seen in the start of chapter 3.1. The layout definition is based on literature by Stevenson (2014) and Slack et al. (2010), whereas the transformed resources are patients. In the second section, constraints of patient flow are presented, divided into components of a system, and components of a layout, that can affect the patient flow. The reasoning behind including components of a system that can affect the patient flow, is to give insight to patient flow constraints of a system, whereas the layout should support the patient flow. The content of the second section will be elaborated below. Lastly, in the third section, how layout should support patient flow are presented. These are based on the layout objectives of Slack et al. (2010) and Stevenson (2014), as well as inputs from Karvonen et al. (2017) and Arnolds and Nickel (2015).

Firstly, in the second section, components that can affect the patient flow of a system is presented, which is based on statements from Koo et al. (2010). However, as the first two components given by Koo et al. (2010) concern demand and supply for services, these are merged together to 'available capacity', thus the components are 'available capacity' and 'variability'. Further, inputs from other authors (see chapter 3.1.1.1 and 3.1.1.2) are given to elaborate on these components. For available capacity, it is divided between resources and patient flow constraints. For variability, based on inputs from Koo et al. (2010) and Slack et al. (2010), it is divided between variation in arrival and variation in processing times. In addition, for variability, patient flow constraints are given as well.

Secondly, in the second section, components of layout that can affect the patient flow are presented. From the literature, the framework is only concerned with the components of layout that affect the flow. For example, the framework does not include safety and welfare as it is not concerning flow, although it is an important consideration in layout design in general. The components are divided into length of flow, clarity of flow, predictability of flow, flexibility, and coordination capabilities. Flexibility is included as inflexibility of layout can affect the future flow. Coordination capabilities is included as it entails managing flow. The components are mostly based on the literature by Slack et al. (2010) and Stevenson (2014), such as layout objectives (see Table 6). However, inputs from Karvonen et al. (2017) and Arnolds and Nickel (2015) are used as well.

Table 9: Preliminary framework for layout design supporting patient flow in outpatient departments

	Patient flow	**Layout**
Definition	The movement of patients through a set of locations in a healthcare facility.	Physical arrangement of transforming resources, determining how patients and some transforming resources, such as staff, move.
Patient flow constraints	*Components of a system that can affect the patient flow:* **Available capacity** *Resources*: health personnel, rooms, equipment, etc., whereof scarce resources are doctors and to some extent nurses. *Patient flow constraints*: capacity shortage, lack of coordination of capacity, underutilization of capacity, patient waiting time. **Process variabilities** *Variation in arrival*: patients, doctors, nurses, information, equipment, material, etc. *Variation in processing times*: Time to serve a patient, waiting for support services, room and equipment setup or down time. *Patient flow constraints*: causes underutilization of resources, patient wait time, staff overtime.	*Components of a layout that can affect the patient flow:* **Length of flow** Long distances and complex flows causes long flows, and is affected by how related activities are located relative to each other. Long flows increase transportation distances for patients (risk of adverse effects, throughput time) and staff (lost service time). **Clarity of flow** To what degree it is clear for both patients and staff where to move within a facility. **Predictability of flow** To what degree operational workflows are considered in layout design, and unpredicted flows are avoided. **Flexibility** To what degree the layout has taken future needs into consideration, which can affect potential future flows. **Coordination capabilities** To what degree supervision and coordination of activities are facilitated by layout.
How layout should support patient flow	*To support patient flow in outpatient departments, a layout should:* • Co-locate related patient activities to reduce distances traveled by patients, reduce risk of adverse effects and allow for short throughput times. • Facilitate for efficient use of workers, rooms, and equipment, especially scarce resources, by shortening distances, allowing for more time spent on care. Shortening distances between related activities also facilitates communication, coordination, teamwork and productivity. • Have a well-signposted flow, clear and evident to patients and staff alike. • Understand operational workflows before deciding on a layout to avoid unpredictable flows. • Take potential future needs and flows into account to allow for flexibility. • Support supervision and coordination of activities.	

4 Case Study

This chapter presents the case OPDs. General information about the case companies is presented in chapter 4.1. More extensive information concerning the outpatient department at St. Olavs Hospital is presented in chapter 0, while supplementary information from the outpatient departments at Levanger- and Vesterålen is presented in chapter 4.3.

Figures explaining the layout of the different OPDs, as well as the figures explaining where related activities to the OPDs take place, have different color codes to represent different areas. The color codes are shown in Figure 6.

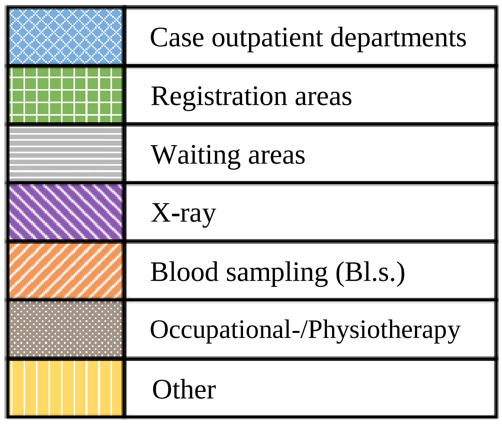

Figure 6: Color codes representing different areas

4.1 Case Companies

This chapter shortly introduces the main case companies, the orthopedic OPD at St. Olavs Hospital (OPD1), the surgical-orthopedic OPD at Levanger Hospital (OPD2), and the surgical-orthopedic OPD at Vesterålen Hospital (OPD3). However, some information collected on the OPDs was similar, and is thus presented here. Firstly, all of the OPDs receive acute patients. If acute patients arrive outside opening hours, they are going to the emergency department instead.

For all of the OPDs, both doctors and nurses, depending on the patients' needs, can perform patient consultations. The doctors' main functions are to examine, evaluate, and diagnose. The nurses' main functions are to assist doctors, ensure coordination of patients, and conduct wound treatments, remove stiches, and lay or remove casts and bandages. Patients can receive consultation from both a doctor and a nurse during a visit.

The number of doctors and nurses present during a day in the OPDs may vary from day to day. Regarding doctors, it varies from day to day which doctors are present in the OPDs, while nurses are of the same staff. The doctors have different specializations as well as duties other places in the hospital, such as participating in operating theatres, visiting the ward, morning meetings and attending educational lectures. Also, the number of elective patients who are treated during a day, depends on the time duration of the appointments, number of doctors and nurses that are in the OPD that day, and if the doctors and nurses have full- or half-day OPD schedule.

Patients going to the case OPDs may require services from other departments in addition to the ones provided in the OPDs during a visit, as the OPD services are related to other services. These services are pre-examinations such as blood sampling and medical imaging (X-ray, MRI, CT, ultrasound, etc.) that may be required before an OPD consultation, and occupational therapy (OT) and physiotherapy (PT) after consultation at an OPD. Normally X-ray results are ready the same day, while it normally takes between one to two weeks to receive the results from the other remaining medical imaging services. For the medical imaging services, the pictures are ready soon after being taken, but must be interpreted and described by radiologists. However, if urgent, it is possible to expedite the results by choosing a higher degree of urgency when placing an order. Blood sample results are also ready the same day. Most patients going to OT after an OPD1 consultation do so the same day, whereas patients going to PT normally do so another day, and are mostly referred to external physiotherapists.

4.1.1 St. Olavs Hospital Orthopedic Outpatient Department (OPD1)

St. Olavs Hospital is one of the largest hospitals in Norway and is an own health enterprise (HF), where most of the activities are located at Øya in Trondheim municipality, Norway. In 2017, St. Olavs Hospital had 453.059 somatic outpatient consultations (St. Olavs Hospital HF, 2018b). The orthopedic OPD at St. Olavs Hospital (henceforth OPD1) is located in the west wing first floor in the Movement Center (Bevegelsessenteret) at St. Olavs Hospital at Øya. The Movement Center is about 19300 square meters, and was taken into use in July 2009 (St. Olavs Hospital HF, 2018a). Location of the Movement Center at St. Olavs Hospital at Øya can be seen in Figure 7.

An X-ray and a blood sampling department are located closely to OPD1 in the Movement Center. Besides these departments in the Movement Center, patients may go to departments in other centers for similar or other services than the ones provided in the Movement Center. Related departments to OPD1 patients outside the Movement Center and the centers they are located in are presented in Table 10, whereas the centers referred to in this table can be seen in Figure 7. However, the table does not represent a complete picture over all possible buildings where related services to OPD1 take place, but the most commonly used.

Figure 7: The Movement Centers' (Bevegelsessenteret) location in St. Olavs Hospital at Øya. Source: St. Olavs Hospital and NTNU (2013)

Table 10: Related departments to Outpatient Department 1 outside the Movement Center, and what centers they are located in.

Related departments	**Center**
Occupational- and Physiotherapy	1902-bygget
Medical imaging	Gastrosenteret, Kvinne-barn-senteret
Blood sampling	Gastrosenteret, Akutten

Regarding X-ray, the orthopedists in OPD1 can interpret this type of medical imaging and must therefore normally not wait for the X-ray descriptions. However, in some situations they do need to order a description of the X-ray, which are normally ready within the same day. In addition, sometimes the orthopedists may choose to interpret CT scans depending on the situation, which makes it possible for a patient to receive both CT and OPD1 consultation(s) within the same day.

Further, some key information regarding OPD1 is presented in Table 11, which entails what type of patients are going to OPD1, OPD1's doctors' medical disciplines, staffing, consultation types, planned time duration of consultations, and opening hours of OPD1 and the X-ray and blood sampling department closely located OPD1.

Table 11: Key Information about Outpatient Department 1

Key Information About Outpatient Department 1	
Type of patients	Mostly elective patients, and about none to six acute patients per day. Acute patients in the context of OPD1 are patients who have urgent post-surgery matters, such as casts not fitting, increase in pain, concerns about a wound or bone fracture.
Doctors' medical disciplines	Mainly doctors within orthopedics (orthopedist), but also some doctors within plastic surgery (plastic surgeon). The orthopedists are specialized within sub-disciplines, such as foot, hand, knee, hip, shoulder, back, or a combination of foot and diabetes.
Staffing	On a typical day there are about 5-8 doctors and 7 nurses. In addition, there is an orthopedic technician whose main function is to adjust orthoses and laying casts, but besides this function as a nurse. Out of the nurses, 4 work full time, 2 has working weekends on the ward every fourth week (and gets two days off in the OPD), and one works half time in the OPD1 and half time on the ward. On Mondays, Thursdays and Fridays respectively, there are normally 2, 1, and 2 plastic surgeons present in OPD1.
Consultation types	*Consultation types for Elective Patients* • Post-surgery consultations • Minor surgeries • Pre-assessment consultations • Diabetes foot wound consultations • Acute consultations
Planned time durations of consultations	• 15, 30, 45 or 60 minutes for orthopedists. • 15 or 30 minutes for nurses • 20 or 40 minutes for plastic surgeons
Opening hours for OPD1 and closely located and related departments	Outpatient department 1, elective and acute patients: 8:30-15:30 X-ray department (close to OPD1): 8:00-15:00 Blood sampling department (close to OPD1): Monday to Thursday 7:45-14:30, and Friday 8:00-10:00

4.1.2 Levanger Hospital Surgical-Orthopedic Outpatient Department (OPD2)

Levanger Hospital is a smaller hospital, located in Levanger municipality in Norway, and is a part of Health Nord-Trøndelag HF. In 2016, Health Nord-Trøndelag HF had 126.620 somatic outpatient consultations (Helse Nord-Trøndelag HF, 2017). Previous data from Nord-Trøndelag HF (2011) showed 114.712 somatic consultations, whereof 69.921 took place at Levanger Hospital (Helse Nord-Trøndelag HF, 2013). I.e. it is natural to assume that Levanger Hospital has about 60% of Helse Nord-Trøndelag HFs' outpatient consultations, which in 2016 would be about 75.972 outpatient consultations.

The surgical-orthopedic OPD at Levanger Hospital (henceforth OPD2) is located on the first floor in Levanger Hospital, close to the main entrance. OPD2 was previously located in another building, and is now located in an area that was originally not built for the process of an OPD. The approximate location of OPD2, the main entrance, and related departments can be seen in Figure 8.

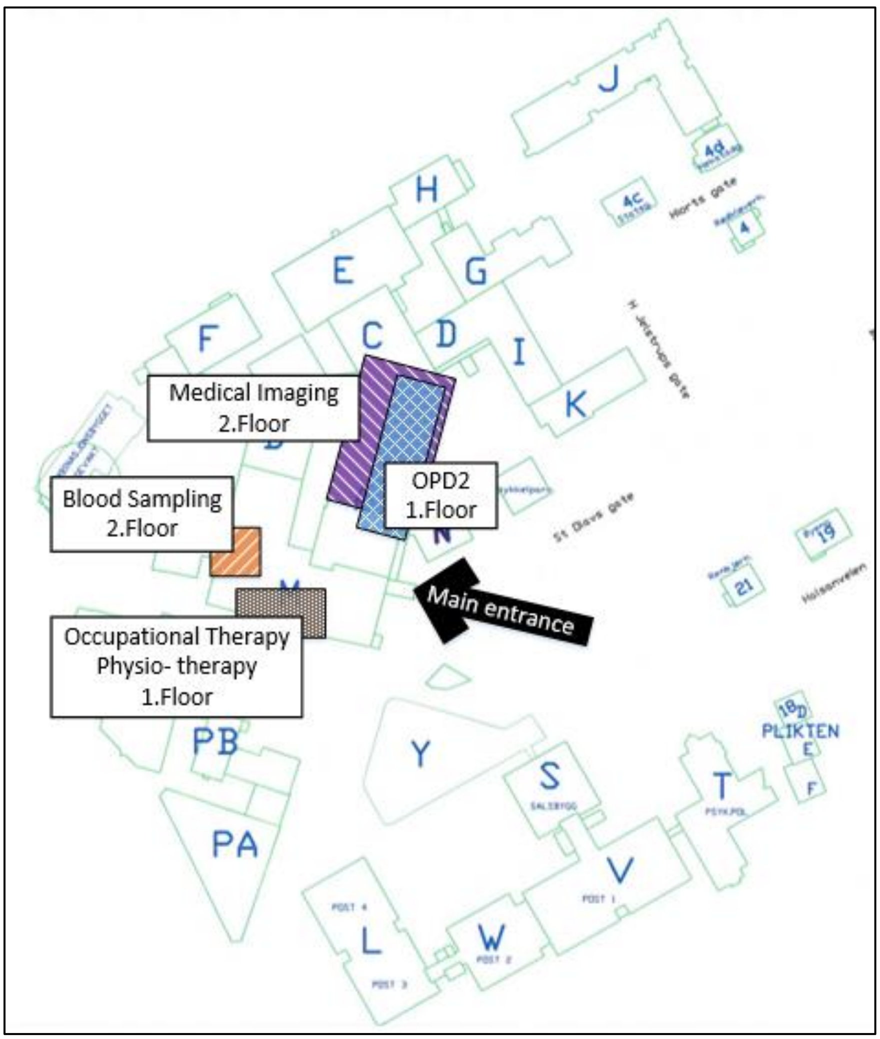

Figure 8: Levanger Hospital floor plan, with approximate location of Outpatient Department 2, main entrance, and related departments.
Source: Levanger Hospital. Adapted from original floor plan.

Further, some key information regarding OPD2 is presented in Table 12, which entails what type of patients who are going to OPD2, OPD2's doctors' medical disciplines, staffing, consultation types, planned time duration of consultations, and OPD2's opening hours.

Table 12: Key Information about Outpatient Department 2

Key Information About Outpatient Department 2	
Type of patients	Elective and acute patients. About 30 acute patients per day, sometimes up to 60. Acute patients in OPD2 context are for example patients with fresh bone fracture, or patients with urgent post-surgery matters.
Doctors' medical disciplines	Mainly orthopedics, but also gastroenterology, urology, general surgery, and vascular surgery.
Staffing	On a typical day there are about 5-6 doctors treating elective patients, and 1 doctor treating acute patients within a day, and about 5-10 nurses and 1 nurse assistant.
Consultation types	• Post-surgery consultations • Minor surgeries • Pre-assessment consultations • Acute consultations • Other treatments/examinations/consultations
Planned time durations of consultations	• 15, 20, 30, or 60 minutes
Opening hours for OPD2	Elective patients: 8:00-15:30 Acute patients: 8:00-22:15

4.1.3 Vesterålen Hospital Surgical-Orthopedic Outpatient Department (OPD3)

Vesterålen Hospital (Nordlandssykehuset Vesterålen) is a smaller hospital located in Hadsel municipality in Norway, and is a part of Nordlandssykehuset HF. In 2016, Vesterålen Hospital had 27.444 somatic outpatient consultations (Mathisen, 2018). The surgical-orthopedic OPD at Vesterålen Hosptial (henceforth OPD3) is located on the first floor, close to the main entrance. The Vesterålen Hospital building is relatively new. The building was taken into use in 2014. The location of OPD3, the main entrance, and the approximate location of the related departments are shown in Figure 9.

Further, some key information regarding OPD3 is presented in Table 13, which entails what type of patients who are going to OPD3, OPD3's doctors' medical disciplines, staffing, consultation types, planned time duration of consultations, and OPD3's opening hours.

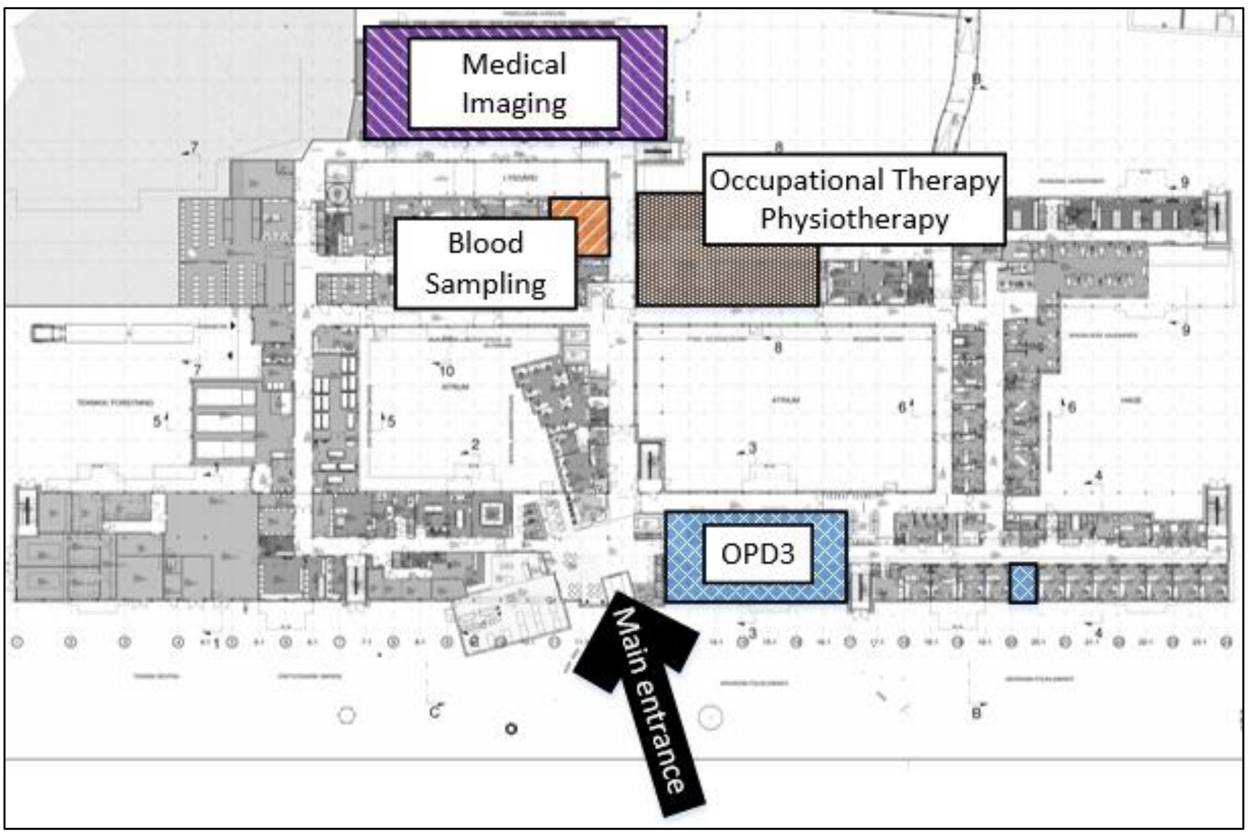

Figure 9: Vesterålen Hospital floor map, with the location of Outpatient Department 3, the main entrance, and approximate location of related departments. Source: Vesterålen Hospital. Adapted from original floor plan drawn by Boarch Arkitekter

Table 13: Key Information about Outpatient Department 3

Key Information about Outpatient Department 3	
Type of patients	Mostly elective, and about none to 15 acute patients per day. Acute patients in the context of OPD3 can for example be patients with bone fracture or urgent post-surgery matters.
Doctors' Disciplines	Mainly orthopedics, but also gastroenterology, urology, and general surgery.
Staffing	On a typical day, there are about 2-6 doctors in OPD3, sometimes as many as 7, and 3-4 nurses.
Consultation types	• Post-surgery consultations • Minor surgeries • Pre-assessment consultations • Acute consultations • Other treatments/examinations/consultations
Planned time durations of consultations	• 15, 20, 30, 45, or 60 minutes
Opening hours for OPD3	Elective and acute patients: 8:00-15:30

4.2 Outpatient Department 1

In this chapter, information regarding the OPD1 layout is presented first. Secondly, the patient flow in OPD1 is presented, for so presenting information regarding patient flow constraints in OPD1.

4.2.1 Layout in Outpatient Department 1

The floor plan over OPD1 and surrounding areas are shown in Figure 10. OPD1 is closely located to other departments and areas, such as an X-ray department, blood sampling department, pre-surgery OPD, rheumatology, physiology, toilets, and cafés. In Figure 10, the different areas are divided into different groups by color and names (see Figure 6 for color codes representing different areas). The different groups are further explained in the text below.

The blue colored areas in Figure 10 are rooms belonging to OPD1. An overview of the different OPD1 rooms and related departments' rooms, their main purpose, secondary purpose (if any), who uses them, and comments can be found in Table 14. However, a further explanation of the different rooms is given in the text below. Although it is stated that a room is used either by a doctor or a nurse, it is important to point out that nurses can assist in doctors' or other nurses' rooms, while doctors can supervise nurses in the nurses' rooms. Doctors can also perform their consultations alongside nurses' consultations in the nurses' rooms.

As explained, the blue colored areas (in Figure 10) are rooms used by OPD1. However, the rooms named TOV1 and TOV2 are allocated to Trøndelag Orthopedic Workshop (Trøndelag Ortopediske Verksted, henceforth TOV), which uses the rooms once a week, but besides that, OPD1 are allowed to use the rooms. Room 5 is a shared room between the OPD1 and the surrounding departments, whereof the room is allocated to an OPD1 doctor about one to two times a week.

As seen in Table 14, OPD1 rooms have different main and secondary purposes. Room 5 to 11, and 16 are general consultation rooms (GCRs), i.e. standardized rooms, which contain computers and other necessary equipment the doctor needs, that can be used for multiple purposes. However, room 16 is normally used as a nurse consultation room (NCR), i.e. NCR includes all equipment necessary for nurses' needs. All GCRs can be used as NCRs when not allocated to a doctor. Unlike doctors who are allocated rooms, nurses use the remaining rooms available.

Figure 10: Floor plan over Outpatient Department 1 and surrounding areas. Source: St. Olavs Hospital. Adapted from original floor plan.

Room 12 and 13 are surgery rooms. When surgeries are performed, a doctor and a nurse are present in the room. Room 12 can be used as GCR when not used for surgeries, however the risk of infection should be low. Room 12 is used for four to five surgeries Mondays and Fridays, i.e. half day, while eight to nine surgeries on Thursdays, i.e. full day. Room 13 is normally only used for surgeries because it should be as clean as possible due to risk of infections. I.e. the type of surgery performed in room 13 can go down to the bone, and an infection in the bone, versus for example in the skin as in room 12, is more critical due to antibiotics not going into the bone as it is driven by blood. It is attempted not to use the room for other purposes than surgeries, but if highly necessary, it can be used as a NCR when the risk of infection is low. No doctor is allocated room 13 throughout a day, i.e. a doctor and a nurse gather at room 13 when a patient requires surgery.

Room 14 and 15 are plaster cast rooms (PCRs), i.e. used for laying and removing casts, used by nurses and the orthopedic technician. Besides this, room 14 and 15 can be used as a NCR. In addition to this, the orthopedic technician also use the PCRs to adjust orthoses, whereof the orthopedic technician has an orthopedic workshop with connecting doors to both room 14 and 15. Regarding the rooms allocated to TOV, TOV1 is used as a NCR when TOV is not using it, while TOV2 can be used as a resting room for some patients if required, but cannot be used as a NCR.

In addition to the rooms used by OPD1, the X-ray and the blood sampling department are seen in context with OPD1, as patients may require these services before they go to OPD1, in addition to that these departments are closely located to OPD1. The X-ray department (purple color in Figure 10) consists of two X-ray rooms and a processing area. The workers in the X-ray department are radiographers, who prepare for and take X-ray pictures. If X-ray picture descriptions are required, the pictures are sent electronically to a radiologist for analyzation. The blood sampling department (orange color in Figure 10) consists of two blood sampling rooms, and a processing area. The workers in the blood sampling department are bioengineers. Blood samples are taken in the blood sampling rooms, while the results are either being analyzed in the processing area or sent to "Laboratoriesenteret" (see Figure 7) for analyzation, dependent on type of blood sample.

Further, there are three registration areas (green color in Figure 10), a self check-in machine, a counter, and a blood sampling queue ticket machine. For the observation, the waiting areas (gray color in Figure 10) were divided into five areas as (see chapter 2.2.1). W1 is the waiting area close to the registration counter. W2 close to the X-ray rooms. W3 and W4 is waiting area right outside a consultation room in OPD1, and W5 is the waiting area close to blood sampling department.

The remaining surrounding areas (yellow in Figure 10) closely located to OPD1, are the pre-surgery OPD, rheumatology and physiology, educational areas belonging to Norwegian University of Science and Technology (NTNU), a café, toilets and elevators. In addition to the two X-ray rooms belonging to the X-ray department, there is another X-ray room, belonging to NTNU, which are only used for educational purposes, i.e. the X-ray department does not utilize the educational X-ray room. In addition to the surrounding areas shown in in Figure 10, there is another café and more toilets located on the same floor. OPD1 patients may go to the surrounding areas.

Table 14: Overview of Outpatient Department 1 rooms and related departments' rooms, their main and secondary purpose, who uses them, and comments.

Room	Main purpose	Secondary purpose	Main users	Secondary users	Comments
Outpatient Department 1 rooms					
5	GCR	NCR	Doctor	Nurse	Shared between OPD1 other departments
6, 7, 8, 9, 10, 11	GCR	NCR	Doctor	Nurse	
16	NCR	GCR	Nurse	Doctor	GCR mainly used as NCR
12	Surgery	GCR/NCR	Doctor	Nurse	Used for GCR when risk of infection is low
13	Surgery	(NCR)	Doctor and nurse (combined)	(Nurse)	Used for NCR only when highly necessary, and risk of infection is low
14	Plaster cast room (PCR)	NCR	Orthopedic Technician and Nurse		
15	PRC	NCR	Nurse		
TOV1	TOV	NCR	TOV	Nurse	When not used by TOV, OPD1 uses it as a GCR
TOV2	TOV	(Resting room)	TOV	(Patient)	When not used by TOV, it can in some cases be used as resting room for patients
Related departments' rooms					
X-ray (1&2)	X-ray		Radiographer		
Blood sampling (1&2)	Blood sampling		Bio-engineer		

Finally, regarding location of personnel, if a doctor is in OPD1, the doctor is assigned a GCR in OPD1, so that the doctor has a fixed room for that clinic session. However, a doctor does not have a fixed room from day to day. Further, two of the nurses have a specialization so that they can work with reconstructive prostheses. These nurses are also allocated a GCR the times they are performing reconstructive prosthesis work. Besides this, all nurses are using the remaining available rooms, but each nurse is not allocated a specific room.

4.2.2 Patient Flow in Outpatient Department 1

4.2.2.1 Main patient flow

Normally, patients going to OPD1 enters through the Movement Center's main entrance (see Figure 10). There are also some other doors that the patient can enter through, as well as stairs and lifts from other floor levels. After entering, the patients check-in.

Where to check-in (register) depends on what services the patient requires. Elective patients with planned OPD1 appointments can choose between registering on the self check-in machine or registering at the counter. Acute patients must register at the counter. Patients with an X-ray appointment must register at the counter, and patients going to the blood sampling department must draw a blood sampling queue ticket as there are no appointments for blood sampling.

If a patient has both an X-ray and OPD1 appointment, the OPD1 appointment can be registered at the self check-in machine, but the patient will then get a message on the self check-in machine to contact the counter regarding their X-ray appointment. Similarly, if a patient is taking a blood sample and having an OPD1 appointment, the patient can also register their OPD1 appointment at the self check-in machine, but in such a case the patient does not get any message reminding about the blood sample. However, in advance of their OPD1 appointment, they have received information regarding blood sampling. Blood samples must be taken in advance of the OPD1 appointment, and can be taken wherever blood sampling is offered, e.g. at the general practitioners office. Nurses can see in their information system if a patient has blood test results, so if the patient has no blood test result when checking in, a nurse contacts the patient and ask them to take a blood sample.

When checking in, elective patients with an OPD1 appointment can choose between being called up by a nurse, or receiving a call-in SMS close to their consultation. The call-in SMS makes it possible for patients to go to cafés and other surrounding areas while waiting for their appointment. A patient is then sent a call-in SMS close to the appointment and which room to wait outside. Acute patients only get this option if they have to wait for a while. SMS call-ins are not possible for X-ray appointments and blood sampling, where the patients must be called up from the respective waiting areas.

After registering, patients wait for their consultation. Ideally, the patients wait in the respective area for their next step. Patients waiting for OPD1 appointments wait in W1, those waiting for X-ray appointments wait in W2, and those waiting for blood sampling wait in W5. For patients waiting in W1, when time is closer their OPD1 appointment, the patients move from W1 to W3/W4, i.e. right outside their consultation room. The next step after W3/4, W2 or W5 is then for the patients to move into their respective consultation rooms, i.e. OPD1, X-ray or blood sampling room. The patients may undergo one or multiple consultations during a visit.

For the check-out, patients only receiving X-ray do not need to check out, as they have already paid when checking in at the counter. All patients going to OPD1, e.g. only receiving OPD1 consultation, or both X-ray/blood sampling and OPD1 consultation during a visit, pay collected when checking out. After checkout, the patient exits the OPD1. There are different areas to exit. In most cases, the patient exits the OPD through the main entrance. Patients that go to OT or PT after their consultation, exits the building in the opposite direction of the main entrance, close to room 1 in Figure 10.

4.2.2.2 Multiple Consultations

Further, as patients may take multiple consultations during a visit, the reasoning behind some of them will be explained to give a better understanding of the operation of the OPD. The different routes during a patient visit identified, are presented in chapter 5.1.1. "Main routes" will be used while explaining, whereas main routes are the combination of health care services and their sequence (further explained in 5.1). Examples of main routes are "GCR" if only receiving care in one GCR room during a visit, or "X-ray→GCR" if the patient first gets an X-ray picture taken, and then afterwards has an OPD1 consultation in a GCR.

In the case of "X-ray→GCR", the patient is seeing an orthopedic doctor afterwards and no surgery is performed. Thus, in the case of "X-ray→GCR(ROOM12)", room 12 is not used for surgeries. A similar main route "PCR→X-ray→GCR", the patient is to remove their cast(s) at a PCR, as X-rays with casts on often have poor quality. To remove a cast, some casts do not require a PCR, while thicker casts (often foot casts) require to be removed in a PCR. Following, main route "PCR→X-ray→GCR→PCR" is similar to the latter main route mentioned, however laying of a new cast is required which takes place in a PCR.

Main route "Blood sampling→GCR" can occur either due to that a patient was supposed to get a blood sample before going to OPD1 and has not got one, or that it is an acute patient, where it is necessary with a blood sample before patients can be consulted by OPD1 personnel in a GCR. In the opposite case, "GCR→Blood Sampling", the patient is supposed only to go to a GCR, but due to concerns of potential infections, the patient gets a blood sample taken before he/she leaves. The patient will then receive a phone consultation with the OPD1 doctor a later day. Another similar route is "GCR→Blood Sampling→GCR" which is similar to the latter main route mentioned, but the patient is consulted by OPD1 personnel in a GCR afterwards.

For main route "X-ray→GCR→X-ray" the X-ray is taken first, then the patient goes to their OPD1 consultation in a GCR, but the doctor is not satisfied with the X-ray picture, so the patient needs another X-ray picture taken, and the doctors order an urgent X-ray. An urgent X-ray is when a doctor orders an X-ray, and the X-ray picture(s) is taken the same day as it is ordered. A similar main route is "GCR→X-ray", but where the first X-ray has been taken in a day or more in advance, i.e. not during the same visit. Another example of urgent X-rays, are the main route "GCR→X-ray→GCR", which occurs when a doctor has forgotten to order an X-ray appointment for the patient in advance of the OPD1 appointment. I.e. the patient goes to a GCR, the doctor finds out that there is no X-ray picture taken, and the patient must take an urgent X-ray, and then return to the doctor in the GCR.

Main route "GCR→TOV1" is either an OPD1 consultation followed by the patient going to TOV1 to receive services from the TOV personnel, or it could be in case of an OPD1 doctor consultation followed by a nurse consultation. Main route "GCR→TOV2" is seldom, but if it happens, it is first an OPD1 consultation, followed by the patient going to TOV2 to receive services from the TOV personnel. Another seldom route, main route "GCR→GCR" is in the case of health personnel needing to consult with each other, i.e. the patient moves outside the room to wait. However, in most cases where health personnel must consult with each other, the personnel can do so in front of the patient, or the personnel moves outside the room.

Some patients may require both blood sampling and X-ray before going to OPD1, as in main route "Blood sampling→X-ray→GCR". In such a case, it is recommended by the staff that the patient take their blood sample first, and then X-ray, as one must wait for blood sample results, while the doctors normally interpret the X-ray pictures on their own.

4.2.3 Patient Flow Constraints

4.2.3.1 Available Capacity

The amount of health personnel available in OPD1, affects the number of patients it is possible to consult during a day. The patient may require only a doctor or nurse, or a combination of the preceding. In addition, a nurse may need supervision by a doctor, i.e. the doctor has to go to the nurse's room. Also, a doctor or a nurse can require assistance from a nurse, i.e. the nurse must move to a consultation room.

Two to three nurses share a nurses' patient list that contains the patients that are to be consulted by these nurses within that day, while each doctor have their respective patient list. The patients served by one doctor or a nurse may vary from day to day, depending on the planned duration of consultation. Doctors' schedules are fully booked, while nurses may have some available time on their schedule. For example, a nurses' patient list can contain 10-20 patients, and even more in busy periods. Regarding room capacity, doctors are assigned rooms, while nurses must use the remaining available rooms.

Workload on the nurses depends on the amount of surgeries performed. Enough nurses are required to meet the demand of patients after surgeries, as patients requiring nurse consultations should not wait too long. For example, patients with a wound, must receive wound treatment within a certain time period. Also, on Wednesdays, the main patient group treated is patients with diabetes foot wounds, which also requires nurse consultations.

For doctors, an internal deadline for consultation is set for each patient. The internal deadline is a date set which the patient should receive treatment within, and is different from patient to patient. It depends on the degree of urgency, and can be up to multiple months. Ideally, patients should not wait longer than the internal deadline. All patients coming to OPD1 within a day, both elective and acute, are treated the same day, unless they show up unreasonably late.

A patient may also require X-ray or blood sampling, thus radiographers and bioengineers may be required resources as well. The X-ray and blood sampling department are shared resources between OPD1 and the rest of the hospital. The patients who are not going to OPD1, but using these departments, are in most cases related to the Movement Center. Regarding patients having multiple appointments, for example going to both X-ray and OPD1, they may have their appointments on the same day, or different days. Before the appointments, the patient receives a notice with the respective time of both appointments.

4.2.3.2 Variability

There is variation taking place in OPD1, which affects the flow of patients. Doctors and nurses may cause variation to the process by arriving late, use longer time than planned on a patient consultation or related activities, or have a sudden sick leave. Also, the interruption of doctors and nurses, i.e. all activities that requires the doctors or nurses attention may lead to variation, such as supervision by doctors, or assistance by nurses. Patients can also arrive late, not show up, arrive as an acute patient, or have patient slowness. Acute patients are not scheduled, and must be taken in-between the elective patients. Patient slowness (further explained in 5.2.2), as described by the OPD1 nurses, is that a patient can require more time than normal, or planned time duration used to consult a patient. There is also variation related to the support services such as X-ray and blood sampling. Elaboration on variation can be found in the respective chapter in the analysis (see chapter 5.2.2).

4.3 Outpatient Department 2 and 3

The information collected on OPD2 and OPD3 is less extensive than on OPD1. However, the information from OPD2 and OPD3 gives valuable complementary understanding of OPDs. This chapter mostly concerns the presentation of the layouts of OPD2 in chapter 4.3.1, and OPD3 in chapter 4.3.2. However, some additional comments regarding the patient flow and constraints are given here.

Regarding patient flow in OPD2 and OPD3, if only looking at the main routes (see chapter 5.1), the flows are much similar to the patient flow in OPD1. However, in OPD2, a patient may go from one urology room to another, or one gastroenterology room to another. In OPD3, if a patient requires proctoscopy, the patient is first consulted in OPD3’s room 1, but if a proctoscopy is needed, this is conducted in OPD3’s room 7. In addition to this, looking at the route for acute patients in OPD2, they must deliver a form before waiting for their consultation. The acute patients are first to register at the counter, then deliver a form from the counter to the work room, before going to W8 (see Figure 11). Although the main routes are similar to OPD1, the patient route numbers (explained in 5.1) would be different in each case OPD, due to route differences regarding registration and where to wait. The PRNs will not be stated for OPD2 and OPD3. Regarding the patient flow constraints, similar to OPD1, the amount of health personnel available in OPD1 affects the number of patients it is possible to consult during a day. Regarding X-ray, similar to OPD1, many patients from OPD2 and OPD3 require X-ray pictures in relevance of their OPD consultation.

4.3.1 Layout in Outpatient Department 2

The floor plan over OPD2 and surrounding areas are shown in Figure 11. OPD2 is located on the first floor, and is closely located to amongst other the emergency department, the main entrance, and a kiosk. The registration area, X-ray department and blood sampling department are placed on the second floor, which is accessed by some stairs close to the kiosk. The different areas on the first floor were divided into groups by color and names, as shown in Figure 11, whereas the second floor is not included, but the approximate location of OPD2 and related departments can be seen in Figure 8.

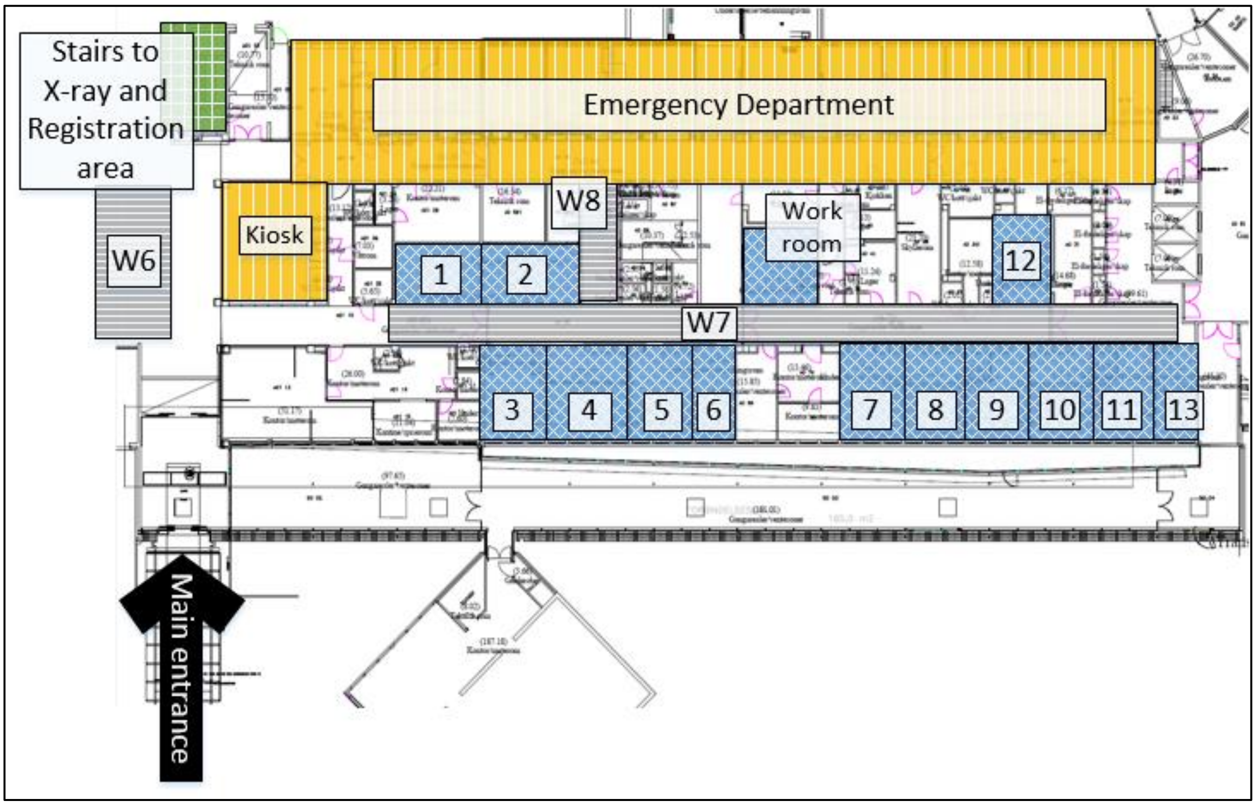

Figure 11: Floor plan over Outpatient Department 2 and surrounding areas. Source: Levanger Hospital. Adapted from original floor plan.

The black arrow explains where the main entrance is located. The blue areas in Figure 11 are rooms belonging to OPD2. The green area is the stairs leading up to the registration area, the medical imaging department, and the blood sampling department. The registration area is just by the stairs, the medical imaging department is located above OPD2, and the blood sampling department is located close to the registration area. The yellow areas are the emergency department and the kiosk. The gray areas are the waiting areas, whereof for explanatory reasons, are divided into W6, W7 and W8. For elective patients W6, is the main waiting area, and W7 is the waiting area right outside the consultation room the patient is going into. W8 is the waiting area for acute patients.

OPD2 has 13 consultation rooms that are used for different purposes. The rooms in OPD2, their main and secondary purpose, and comments are shown in Table 15.

Table 15: Overview of Outpatient Department 2 rooms, their main and secondary purpose, and comments

Room	**Main purpose**	**Secondary purpose**	**Comments**
1	PCR		No doctor is assigned this room as it must be available for laying casts.
2	PCR/GCR (Acute)		PCR, which can also function as a GCR, always used for treating acute patients.
3, 5, 7	GCR		Room 3 can be used as supplementary room for acute patients in busy hours with many acute patients.
4 "the Clean room"	Surgery	GCR	Can be used as a GCR, but only when the risk of infection is low
6	NCR		Only used in busy hours, or if there is a suspicion about high risk of infection risk.
8, 9	Urology consultations	GCR	If urology doctors are in OPD2, they are assigned these rooms. When they are not in OPD2, these rooms can be used as GCRs.
10, 11	Gastroenterology consultations	GCR	If gastroenterology doctors are in OPD2, they are assigned these rooms. When they are not in OPD2, these rooms can be used as GCRs.
12 "the Urodynamic room"	Urodynamic consultations (Nurse)		Not used as a GCR, which is much due to size of the equipment in the room. Urodynamic consultations are performed by a nurse.
13 "the Buffer room"	NCR	External services (pre-surgery, or OT)	The last room to be used by OPD2 staff, only used in busy hours. However, sometimes the room is used for pre-surgery, OT and PT consultations.

Regarding doctor and nurse room allocation, it is similar to OPD1, however with a few differences. Urologists and gastroenterologists, if present in OPD2, are respectively only allocated room 8 to 9, and room 10 to 11. Room 2 is always allocated to a doctor treating acute patients, however, the doctor may vary. Also, doctors can be allocated in the surgery room (room 4). In addition, a nurse with specialization in wound treatment may be assigned room 6 during a day, whereof a doctor related to the wound treatment patients are located in room 5 in such a case, as the rooms have a door between them, which makes communication and collaboration easy between the nurse and the doctor.

4.3.2 Layout in Outpatient Department 3

The first floor in Vesterålen Hospital, with the location of OPD3, and related departments (medical imaging, blood sampling, and OT, and PT) were presented in Figure 9. Further, a closer section of the floor plan over OPD3 and surrounding area are shown in Figure 12. OPD3 is closely located to amongst other the main entrance and the medical OPD. The different areas were divided into groups by color and names, as shown in Figure 12. The black arrow explains where the main entrance is located. The blue area in Figure 12 are rooms belonging to OPD3. The green areas are the different registration areas: counter for OPD, counter for X-ray, and self-service machines. The yellow areas are rooms belonging to the medical OPD and toilets. The gray areas are the waiting areas, whereof for explanatory reasons, are divided into W9 and W10. W9 is where most patients wait, while W10 is a secondary waiting area where it is possible to wait, however most patients wait in W9.

OPD3 has seven consultation rooms that are used for different purposes. The rooms in OPD3, their main and secondary purpose, and comments are shown in Table 16.

Table 16: Overview of Outpatient Department 3 rooms, their main and secondary purpose, and comments

Room	**Main purpose**	**Secondary purpose**	**Comments**
1	Surgery	GCR	Used as GCR when not for surgeries.
2	PCR	GCR (Acute)	PCR, but used as GCR for acute patients in busy hours during a day.
3	GCR (Acute)		GCR assigned to a doctor who treats both acute and elective patients
4	GCR (Orthopedist)		GCR mostly used by orthopedist.
5	Urology consultations	Surgery, GCR	If urology doctors are in OPD3, they are assigned this room. When not in OPD3, these rooms can be used as a surgery room or as a GCR.
6	NCR	GCR	NCR, however, if needed it can be allocated to a doctor.
7	GCR		GCR shared between OPD3 and the medical OPD. If an OPD3 doctor is to conduct proctoscopy, it only takes place in this room.

Regarding doctor and nurse room allocation, it is similar to OPD1, however with a few differences. In OPD3, similar to OPD2, doctors can be allocated rooms based on their specialization or treatment they are to conduct. If an urologist are in OPD3 one day, the urologist is always assigned room 5. Further, room 3 is always assigned to the doctor treating acute patients. If there are many acute patients, an additional doctor may be summoned to consult acute patients. If so, the additional doctor is always assigned room 2.

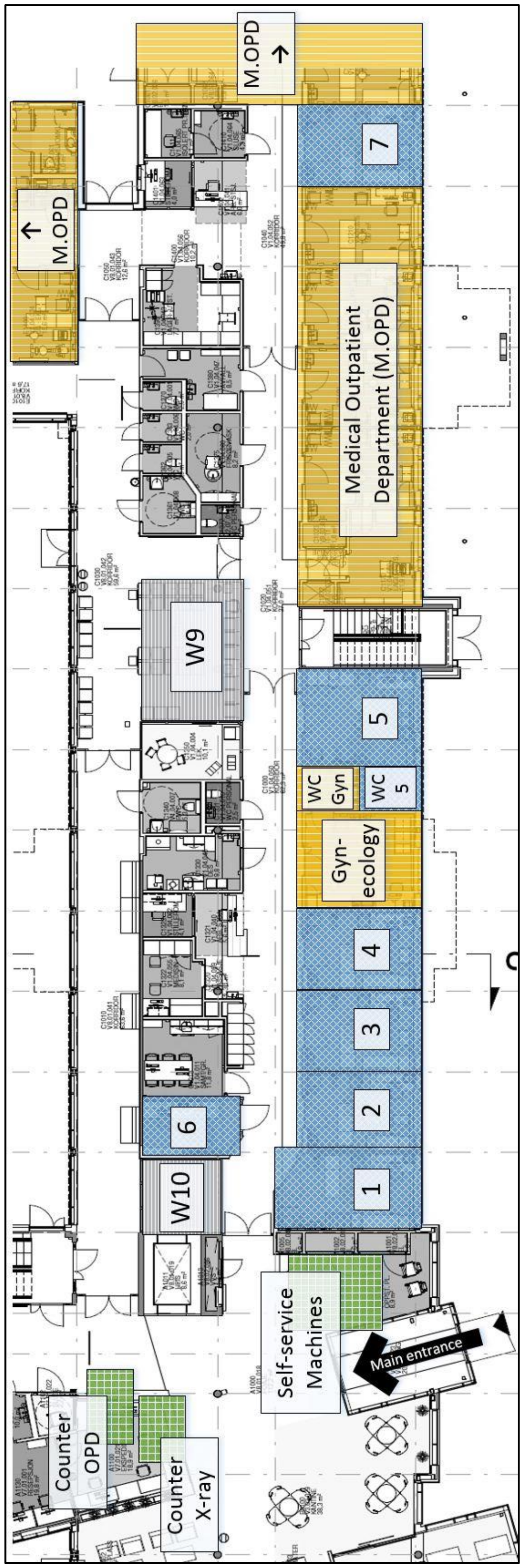

Figure 12: Floor plan over Outpatient Department 3 and surrounding areas.
Source: Vesterålen Hospital. Adapted from original floor plan drawn by Boarch Arkitekter.

5 Analyzation

The analyzation takes into account information provided in the case study, and presents findings concerning patient flow in OPD1, patient flow constraints in OPD1, and layouts of the three case OPDs. The case study is seen in the light of the literature study, in addition to the numerical observation data from the case study, concerning patient flow in OPD1, is structured using PFA (see chapter 2.3). Information from the literature study is taken into account when found appropriate. Firstly, findings concerning patient flow in OPD1 is presented in chapter 5.1. Secondly, findings concerning patient flow constraints in OPD1 is presented in chapter 5.2. Thirdly, the findings concerning the layouts of the case OPDs are presented in chapter 5.3. Finally, a summary of the analyzation is presented in chapter 5.4.

5.1 Patient Flow in Outpatient Department 1

As explained in chapter 2.3, PFA is used to structure and get a better understanding of the patient flow in OPD1. Throughout the patient flow, patients take different routes based on their needs. A route consists of route stations, e.g. registration is one route station, waiting is another, and so on. It is distinguished between planned patient movement and actual patient movement. Planned patient movement is the movement a patient is thought to take, given a certain route, whereas actual patient movement is the actual movement of a patient in a facility, which may deviate from the different planned patient movements.

Further, for explanatory reasons, it is distinguished between “route names”, “patient route numbers (PRNs)”, “main route stations”, and “main routes”. Firstly, each route is given a route name, e.g. route A, to make it easier to refer to. Secondly, a PRN is a code number which lists all the route stations (numbered) which a patient is to go through, given a certain route, in the sequence they are used. The PRNs are based on the planned patient movements. Thirdly, a main route station is a route station where health care services are delivered, such as OPD1 consultation, X-ray, or blood sampling, and not registration or waiting. Lastly, a main route is a shortened form of a PRN, however not numbered, and does only include the main route stations of a PRN. For example “X-ray→GCR” is a main route where the patient first goes to X-ray, then goes to a GCR in OPD1. Main routes are the same, regardless of whether it is planned patient movements or actual patient movement.

Information regarding the processing of the observation data can be found in chapter 2.2.2. Planned patient movements are presented in chapter 5.1.1, while actual patient movements are presented in chapter 5.1.2.

5.1.1 Planned Patient Movements

This chapter concerns the planned patient movements. First, numbering of the different route stations is presented in Table 17. Secondly, the different PRNs with frequency and with no observation data are presented. Thirdly, the FROM/TO table is presented. Finally the patient flow network is presented.

PRNs were defined based on a combination of extracted data from the sub-categories AB1, AB2 and AB3 (see chapter 2.2.2), and follow up questions to the OPD1 staff to identify additional routes, and to ensure correct information about the different planned patient movements identified (see chapter 2.2). PRNs observed and PRNs with no observation data (n.o.) are shown in Table 18, divided into sub-category AB1, AB2 and AB3. The PRNs in Table 18 use the numbering shown in Table 17, whereof the main route stations' numbers in the PRNs are highlighted in gray. As can be seen in Table 17, route station 7 consists of room 5 to 11, and 16 compiled. This is because all of these rooms are GCRs, whereas there is no difference between their functionality. However, as room 12 also can function as a GCR, all routes with a GCR can in fact also use room 12. Thus, in Table 18, all PRNs including a GCR can in fact be either room 5, 6, 7, 8, 9, 10, 11, 12, or 16. Anyway, in Table 18, route C and route R are the PRNs where room 12 has been observed being used. In the case of route C, it can either be that the room was used for surgery, or was used as a GCR. Further, Route R is in fact similar to route Q, as in this type of main route the room is not used for surgeries, but used as a GCR (see chapter 4.2.2.2).

Table 17: Numbering of route stations

Route station	**Numbering**
Entrance/Exit	0
Self-check-in	1
Counter	2
W1	3
W2	4
W3/W4	5
X-ray	6
GCR (Room 5 to 11, and 16)	7
GCR/Surgery (Room 12)	8
Surgery (Room 13)	9
PCR (Room 14)	10
PCR (Room 15)	11
TOV1	12
TOV2	13
Blood sampling queue ticket	14
Blood sampling waiting area	15
Blood sampling	16

In addition, some of the planned patient movements are simplified versions of the reality. In reality, patients only going to OPD1 are to choose between the self check-in machine and the counter for registration. However, for the planned patient movements, it is assumed that patients only going to OPD1, are supposed to register at the self check-in machine. Similarly, patients with a scheduled X-ray appointment can register their OPD1 appointment at the self-service machine, and their X-ray appointment at the counter. However, for the planned patient movements it is assumed that the patient is supposed to register at the counter. Thus, if a PRN is starting with registration at the self check-in machine combined with an X-ray main route station, it indicates an urgent X-ray (see chapter 4.2.2.2).

Table 18: Route names, PRNs, with frequency and with no observation data (n.o.)

ROUTE NAME	**MAIN ROUTE**	**PATIENT ROUTE NUMBER (PRN)**												**#**
Sub-category AB1: Only OPD1 consultation														
A	GCR	1	3	5	7	2								**47**
B	PCR (ROOM14)	1	3	5	10	2								**7**
C	GCR/Surgery (ROOM12)	1	3	5	8	2								**5**
D	NCR/TOV (TOV1)	1	3	5	12	2								**4**
E	PCR (ROOM15)	1	3	5	11	2								**1**
F	GCR→TOV1	1	3	5	7	5	12	2						**1**
G	Surgery (ROOM13)	1	3	5	9	2								**1**
H	Blood sampling→GCR	1	14	15	16	3	5	7	2					**1**
I	GCR→GCR	1	3	5	7	5	7	2						**n.o.**
J	GCR→TOV2	1	3	5	7	5	13	2						**n.o.**
K	GCR→Blood sample	1	3	5	7	14	15	16	2					**n.o.**
L	GCR→Surgery	1	3	5	7	5	9	2						**n.o.**
M	GCR→PCR (ROOM 14)	1	3	5	7	5	10	2						**n.o.**
N	GCR→PCR (ROOM 15)	1	3	5	7	5	11	2						**n.o.**
O	GCR→Blood sample→GCR	1	3	5	7	14	15	16	3	5	7	2		**n.o.**
Sub-category AB2: Only X-ray consultation														
P	X-ray	2	4	6										**26**
Sub-category AB3: Both OPD1 and X-ray consultation														
Q	X-ray→GCR	2	4	6	3	5	7	2						**16**
R	X-ray→GCR (ROOM12)	2	4	6	3	5	8	2						**3**
S	PCR (ROOM15)→X-ray→GCR	2	3	5	11	4	6	3	5	7	2			**3**
T	GCR→ X-ray→ GCR	1	3	5	7	4	6	3	5	7	2			**1**
U	PCR (ROOM15)→ X-ray→GCR→PCR	2	3	5	11	4	6	3	5	7	5	11	2	**1**
V	PCR(ROOM14)→ X-ray→GCR→PCR	2	3	5	11	4	6	3	5	7	5	10	2	**n.o.**
W	PCR (ROOM14)→X-ray→GCR	2	3	5	10	4	6	3	5	7	2			**n.o.**
X	PCR (ROOM14)→GCR→X-ray	1	3	5	10	5	7	4	6	2				**n.o.**
Y	PCR (ROOM15)→GCR→X-ray	1	3	5	11	5	7	4	6	2				**n.o.**
Z	Blood sample→X-ray→GCR	2	14	15	16	4	6	3	5	7	2			**n.o.**
Æ	GCR→X-ray	1	3	5	7	4	6	2						**n.o.**
Ø	X-ray→GCR→X-ray	2	4	6	3	5	7	4	6	2				**n.o.**
SUM:														**117**

As can be seen from Table 18, the main routes “GCR”, “X-ray", and ” X-ray→GCR”, i.e. routes A, P and Q, occur most often, whereof route A and P only consist of one main route station each, i.e. single-stage system, while route Q consists of two main route stations, i.e. multistage system with two stages. Other than that, route B, C, D, R and S respectively have a frequency of 7, 5, 4, 3 and 3 from the observation data. Out of these B, C and D only have one main route station, while R and S have two and three respectively. The remaining routes with frequency, C, E, G, H, K, and M, have a frequency of 1, whereof route K and M have three and four main route stations respectively. The remaining routes, with no observation data, are all multistage systems. As can be seen in Table 18, all routes where a PCR is included, the PCR can be either room 14 or 15. However, the room used is different, based on the type of patients, as the larger PCR room, room 14 is used when laying or removing a foot cast, while room 15 is normally used for laying or removing hand/arm casts. Thus, the functionality of these two rooms are similar, but not entirely. The more complex a route is, i.e. the more main route stations a patient goes to, the more a patient will move. However, most routes observed, have either only one or two main route stations.

Further, based on the information presented in Table 18, a FROM/TO table was created (see chapter 2.3) for the PRNs, and are presented in Table 19. The FROM/TO table displays the frequency of movement from one route station to another. E.g. from route station 1 (self check-in machine) to route station 3 (W1), the frequency of movements is 67. In Table 19, movements belonging to the planned patient movements are marked gray. The movements with frequency show their respective frequency, while the movements with no observation data show “n.o.”.

Table 19: FROM/TO table based on Patient Route Numbers (PRNs) with frequency and with no observation data (n.o.)

FROM↓/TO→	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	SUM
0	0	68	49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	117
1	0	0	0	67	0	0	0	0	0	0	0	0	0	0	1	0	0	68
2	91	0	0	4	45	0	0	0	0	0	0	0	0	0	n.o.	0	0	140
3	0	0	0	0	0	96	0	0	0	0	0	0	0	0	n.o.	0	0	96
4	0	0	0	0	0	0	50	0	0	0	0	0	0	0	n.o.	0	0	50
5	0	0	0	0	0	0	0	71	8	1	7	6	5	n.o.	0	0	0	98
6	26	0	n.o.	24	0	0	0	0	0	0	0	0	0	0	0	0	0	50
7	0	0	68	0	1	2	0	0	0	0	0	0	0	0	n.o.	0	0	71
8	0	0	8	0	n.o.	n.o.	0	0	0	0	0	0	0	0	n.o.	0	0	8
9	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
10	0	0	7	0	n.o.	n.o.	0	0	0	0	0	0	0	0	0	0	0	7
11	0	0	2	0	4	n.o.	0	0	0	0	0	0	0	0	0	0	0	6
12	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
13	0	0	n.o.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
16	0	0	n.o.	1	n.o.	0	0	0	0	0	0	0	0	0	0	0	0	1
SUM	117	68	140	96	50	98	50	71	8	1	7	6	5	0	1	1	1	720

Based on the FROM/TO table in Table 19, a patient flow network of planned patient movements was created (see chapter 2.3), which is shown in Figure 13. The patient flow network includes both the PRNs with frequency and with no observation data. In addition, the respective movements between each route station are shown. For example, from route station 1 to route station 3, the frequency of movements is 67. The patient flow network in Figure 13 is a means of visualizing the information displayed in Table 19.

From the patient flow network, it is possible to see that there are more movements between some route stations than others. Although this patient flow network may indicate an approximate share of movement volumes between the different route stations, it is not giving a complete realistic picture of the patient flow in OPD1. However, some movement volumes are elaborated on below.

Route station 7, as seen in Table 17, is actually room 5 to 11, and 16 (GCRs) compiled, which makes the average number of movements through one of these GCRs 8,5. From the observation data, most of the OPD1 rooms, or route stations, have a frequency of movements higher than 5. However, looking at route station 9, which is room 13 (surgery room), the frequency of movements observed is 1. This may indicate that this room is not as frequently used as the GCR/NCR.

Regarding X-ray, with a total number of 50 patients out of 117 receiving X-ray, X-ray seems to be a major part of the patient flow in OPD1. However, 26 of these did only receive X-ray, whereas it is natural to assume that some of these patients are belonging to other departments and centers (see chapter 5.2.1). Besides this, based on the observation data, the blood sampling department is not very frequently used by OPD1 patients, as only 1 patient was observed to receive blood sample. Another thing to point out is that patients normally enter and exit the same place, leading to a backward flow. This is unlike materials, whereas materials often start at a raw material inventory and end up at a finished goods inventory, making it possible to avoid backward flow.

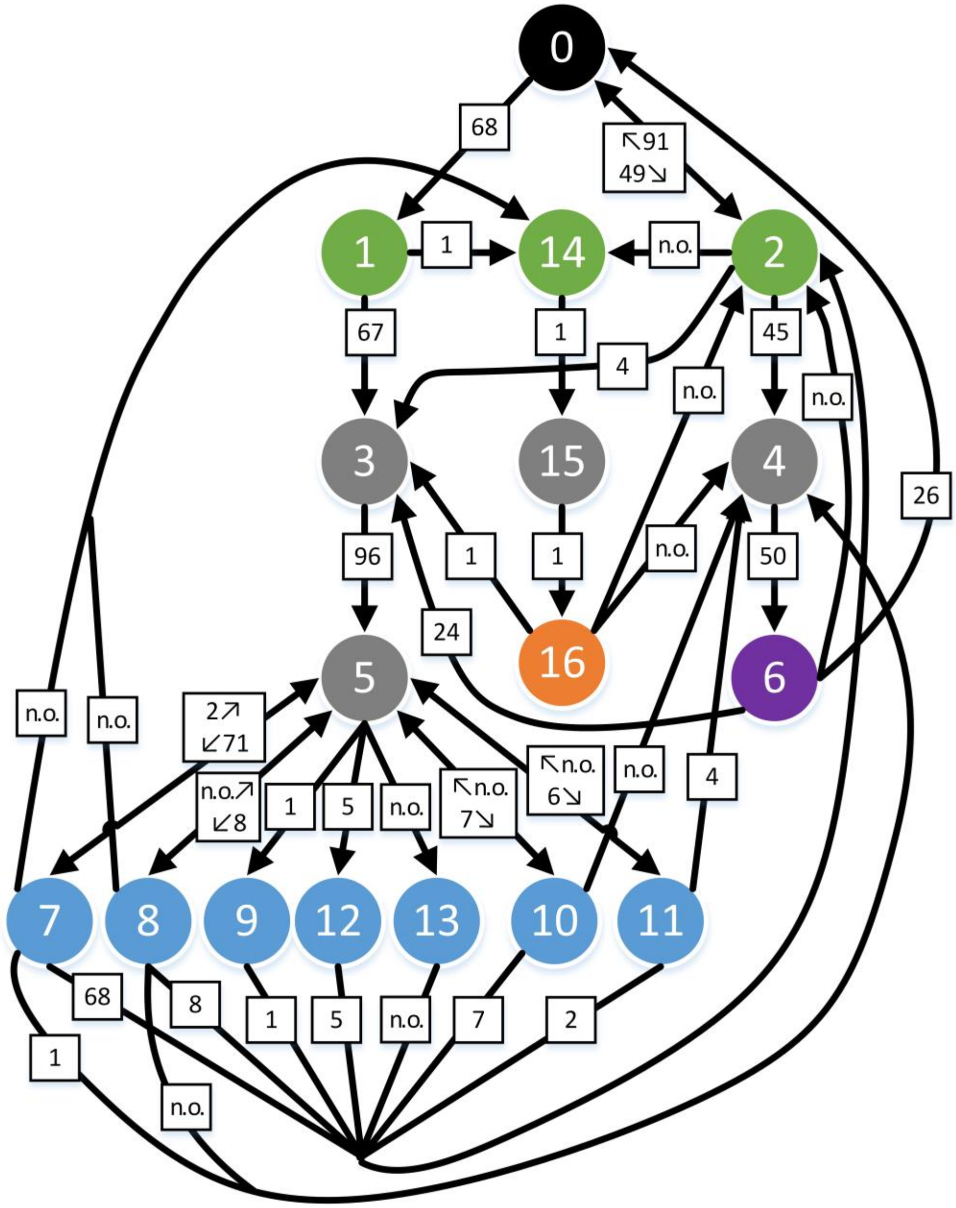

Figure 13: Patient flow network for planned patient movements, with frequencies between route stations. (n.o.=no observation data)

5.1.2 Actual Patient Movements

Deviation from the planned patient movements can occur of different reasons. For example, patients, unlike materials, have their own free will. Patients may wander off to areas outside their planned patient movements for different reasons. Firstly, patients can get confused, curious or restless, causing them to move around. Secondly, they may choose to use facilities such as toilet and cafés.

A FROM/TO table containing the sum of all actual patient movements are presented in Table 20. Besides this, FROM/TO tables containing the sum of actual patient movements divided into the sub-categories AB1, AB2, and AB3 (see chapter 2.2.2), can be seen in Appendix F. Table 20 does not use the numbering from Table 17 as it contains other areas than the planned patient movements' route stations. Instead, text is used to describe the respective route stations.

Table 20: FROM/TO table: Actual patient movements

FROM↓ / TO→	Entrance/Exit	Self check-in	Counter	W1	Rheuma/Physio	Other areas	Waiting Bl.S.	Blood Sampling	W2	WC	X-ray	W3	5	6	7	8	9	13	14	15	W4	10	11	12	16	TOV1	TOV2	SUM
Entrance/Exit	0	39	74	3	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	117
Self check-in	0	0	19	19	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	40
Counter	87	0	0	44	1	6	2	0	51	5	0	4	0	0	0	0	2	0	1	2	4	0	0	0	1	0	0	210
W1	5	1	10	0	0	5	1	0	3	0	2	26	0	1	5	3	3	1	5	1	15	1	1	1	5	2	0	97
Rheuma/Physio	1	0	2	0	0	0	0	0	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
Other areas	0	0	1	13	0	0	0	0	2	1	0	1	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	20
Waiting Bl.S.	0	0	2	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Blood Sampling	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
W2	8	0	7	4	2	5	1	0	0	8	49	2	0	0	1	0	0	0	0	0	2	0	0	0	0	0	0	89
WC	1	0	1	3	0	1	0	0	7	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14
X-ray	15	0	7	8	0	0	0	0	17	0	0	3	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	51
W3	0	0	0	0	0	1	0	0	2	0	0	0	2	11	8	8	7	0	0	0	0	0	0	0	0	0	0	39
5	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
6	0	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12
7	0	0	12	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14
8	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	11
9	0	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12
13	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
14	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7
15	0	0	4	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7
W4	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2	0	2	7	7	1	2	0	22
10	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	3
11	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	8
12	0	0	7	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8
16	0	0	7	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8
TOV1	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
TOV2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SUM	117	40	210	97	6	20	4	1	89	14	51	39	2	12	14	11	12	1	7	7	22	3	8	8	8	5	0	808

Comparing Table 20 to Table 19, it can be seen that the actual patient movements deviate from the planned patient movements. For example, patients can have the main route "X-ray→GCR", however, they may have other movements compared to the planned patient movements. A comparison between the actual patient movements (Table 20) and the planned patient movements (Table 19), with explanations can be found in Table 21.

Table 21: Comparison between actual and planned patient movements.

Route stations	Sum of frequencies of planned patient movements (Table 19)	Sum of frequencies of actual patient movements (Table 20)	Explanation
Entrance/ Exit	117	117	Same number of patients enters and exit the system.
Self check-in	68	40	Less patients register the self check-in machine than planned. However, the current process are meant to allow for patients only going to OPD1 to choose between the self check-in machine and the counter, although in this analysis it is assumed that they should use the self check-in machine. Also, out of the 40, 5 are patients only going to x-ray, which can't use the self check-in machine for check-in anyway.
Counter	140	210	The counter is visited more frequently than planned. This can be due patients asking questions at the counter meanwhile waiting for an appointment, or that patients have questions regarding directions in-between activities. This may indicate confusion regarding where to go, or curiousness regarding waiting time, or other concerns.
W1	96	97	The number of visits to W1 is almost the same as planned. However, looking further into the individual patient observations in Appendix E, it can be seen that patients may be using W1 after a consultation, or visiting W1 more times than planned as they move to surrounding areas for so returning to W1. It also happens that some patients move directly from registration to either W3/4 or a consultation room, without going to W1. Besides this, one patient waiting for an X-ray consultation was observed to wait in W1, which can cause the X-ray personnel to take in other patients before, in addition to the X-ray personnel having to walk to W1 to find the patient.
Rheuma/ Physiology	Not part of planned route	6	Some patients go to areas outside the planned patient movements, such as rheumatology and physiology. This movement indicates that the patient is either confused, curious or restless.
Other areas	Not part of planned route	20	Patients also go to other areas such as the cafés to spend time there while waiting for their appointment. Two patients were observed moving directly from these areas, to a consultation room, which may indicate that they noticed their appointment call-in SMS late.
Waiting Bl.S.	1	4	More patients than planned wait in the waiting area for blood sampling. This may indicate that there is not a clear enough distinction between W1 and this waiting area. However, out of the patients not waiting for blood sampling, only one patient waited for an OPD1 appointment, while the remaining two were just having a look while waiting for an available counter.

Table 21 Continued

Route stations	**Sum of frequencies of planned patient movements (Table 19)**	**Sum of frequencies of actual patient movements (Table 20)**	**Explanation**
Blood sampling	1	1	Same number of patients requiring blood sampling as the number of patients entering a blood sampling room.
W2	50	89	A significant larger number moves to W2 than planned. This are in most cases due to patients gathering their stuff after an X-ray appointment, or that patients are curious or confused, and ask questions to the counter, for so moving back to W2. In addition, one patient who were to wait in W1, was observed waiting in W2 and being called directly into consultation from W2, which may indicate that the nurses had been waiting for this patient.
WC	Not a part of planned route	14	The toilets was used 14 times. An interesting observation was that many of the patients utilizing the toilets were the patients waiting in W2, just close to the toilets. This may indicate that it is more likely that patients use toilets if the toilets are placed in front of them.
X-ray	50	51	One patient, only going to X-ray, was observed leaving the X-ray, for so coming back some minutes later, and this time in a wheelchair. This was a very rare case and not a part of the planned patient movements.
W3/4	98	39+22=61	Less patients wait in W3/4 than planned. For one, this can indicate that a patient either moves from one room to another without waiting in between. However, in most of these cases, patients go directly from W1 to the consultation room. Also, in some cases patients were observed to move directly from the registration area to the consultation room. The two latter may indicate that the patient have arrived late, or that the staff is available before planned appointment time.
OPD1 rooms Room 5-15, and TOV1 and TOV2	Sum=98	Sum=98	No difference between the planned patient movement and the actual patient movements when it comes to OPD1 consultation rooms.

5.2 Patient Flow Constraints in Outpatient Department 1

This chapter entails the analysis of patient flow constraints in OPD1, divided into available capacity in chapter 5.2.1 and variability in chapter 5.2.2.

5.2.1 Available Capacity

The OPD1 nurses stated that there is a capacity shortage of health personnel and GCRs. According to OPD1 staff, doctors' schedules are often fully booked a long time ahead. The doctors have long waiting times, which makes it difficult to find early appointment dates. Waiting times are especially long for doctors within the orthopedic sub-disciplines back, foot, hand, and the combination of foot and diabetes. Many patients receive appointments close to their internal deadline. Sometimes, the internal deadline (see chapter 4.2.3.1) of appointments is exceeded. However, if the internal deadline is exceeded, the patient often gets quick access afterwards. Patients waiting long times in access of OPD1 appointments, as well as the internal deadline being exceeded from time to time, indicates a capacity problem regarding doctors. It is also important to point out that doctors are not only in OPD1. As they have other duties in the hospital, such as being in the operating theatre and the inpatient ward, the doctors' time must be balanced between their different activities. The doctors are the bottleneck resource in OPD1, which determines the number of patients treated in OPD1, and thus how long the waiting lists are.

Further, it is not so difficult to make time for patients requiring consultations by nurses. In the case of busy periods, the nurses' patient lists are overbooked. It is easier to overbook the nurses' patient list than the doctors' as two to three nurses are sharing a list of patients which makes the nurses more flexible. In addition, for most of the nurses, the nurses' responsibilities, lies in the OPD, not different places in the hospital such as for the doctors. As patients are not to wait long to get access to a nurse consultation, the amount of nurses available to OPD1 can be seen as in balance with demand.

Regarding rooms in OPD1, capacity shortage of GCRs/NCRs occurs only in busy hours. Thus, there is not a constant capacity shortage of GCRs/NCRs. It is especially the nurses who perceive the capacity shortage of rooms. Busy hours where there is need for more GCRs/NCRs than available, occurs about one to two times a week, whereof there are about one to two periods during these days that there is a peak in demand leading to lack of rooms. Lack of rooms can lead to patients waiting longer for their consultation than planned. On Wednesdays, the nurses' patient lists are quite full, whereof the main patient group this day is diabetes patients, which on average has a high degree of patient slowness (see chapter 4.2.3.2). Due to the volume of treatments and patient slowness congestion on Wednesdays, shortage of GCRs is more prominent this day.

Minimizing the walking of doctors and nurses can lead to the health personnel being able to spend more time on patients (Skeldon et al., 2014), as well as support improvement in productivity (Karvonen et al., 2017). Nurses may need supervision by a doctor, so that a doctor has to go to a nurse's room. Also, a doctor or a nurse can require assistance from a nurse, so that a nurse must move to a consultation room. Supervision or assistance from one health personnel to another thus leads to walking between rooms in the OPD, and takes of the time possible to serve patients.

Regarding the X-ray and blood sampling department, especially the X-ray department has limited access, as they normally are fully booked, and patients going to OPD1 must frequently have their X-ray appointment at other centers in the hospital. One staff member assumed this to be the case in 1 out of 10 patients requiring X-ray before their OPD1 appointment. Similarly, patients from other centers with own X-ray departments, go to the X-ray department in the Movement Center. In addition, regarding X-ray appointments taking place the same or a different day than the OPD1 consultation, although efforts are made to schedule the appointments into one patient visit, it is not always possible, leading to patients having split appointments. A split appointment is for example when a patient has an X-ray appointment, and then must come back to OPD1 later that day, or another day, to have their OPD1 appointment. In addition, out of the patients receiving both of these services the same day, several patients were observed to wait one to two hours in-between the X-ray appointment and OPD1 appointment. One patient was also observed to wait about four to five hours, however this patient left after the X-ray consultation, and came back later the same day. Thus, due to high demand for X-ray and how the available capacity is coordinated, the X-ray department can be seen as a bottleneck that determines the time between X-ray and OPD1 appointments, which causes waiting time in-between appointments during a visit, or split appointments, or that patients have to go to another building to take X-ray.

Regarding the blood sampling department, the blood sampling may close earlier than planned during all days depending on demand and available capacity in the overall hospital. If there is a shortage of bioengineers, the bioengineers that are normally in the Movement Center are gathered at the emergency department instead. If so, patients must go to the emergency department or the gastro center (Akutten and Gastrosenteret in Figure 7) to take a blood sample.

5.2.2 Variability

In the case of OPD1 doctors arriving late, it is often due to morning meetings and/or educational lectures taking longer times than planned. According to the OPD1 staff, late arrival of doctors affect the schedule more than late arrival of patients. However, late arrival of patients is more frequent than late arrival of doctors.

Late arrival of patients can be caused by external factors, such as weather and traffic conditions leading to delay. Patients may also arrive late due to being unobservant while waiting for their appointment call-in SMS (after registering). However, the staff pointed out that this does not affect the schedule much, as the information, either in form of call-in SMS or calling the patient up from W1 happens in good time before the appointment with the doctor. In addition a patient may be using surrounding facilities such as cafés and toilets meanwhile waiting to receive their appointment call-in SMS, so that they are further away, and the staff must wait for the patient to find out about the call-in SMS received. Late arrival of patients was assumed by the staff to only lead to slight delay in the schedule. However, if a patient is very late to an appointment, the doctors and/or nurses must see if they still have time available to consult the patient. It is more likely that a very late patient can receive consultation if a next patient on the schedule has arrived earlier than planned and has received consultation earlier than planned. Also, it can depend on the length of consultation required. Finally, if a late patient arrives close to the OPD closing hours, e.g. 5 minutes to closing, it can be that the patient does not receive consultation.

As a measure to reduce variation in the schedule, the staff can let in other patients first. In scenario A, the first patient on the list may be late, and if more than 5-10 minutes late, the second patient, if present, is let in for consultation first. In scenario B, if the second patient on the schedule is present in OPD1 before the first patient and his/her's appointment time, combined with the staff being free, the second patient may be taken in for consultation first. However, for the latter case, the staff considers whether it is feasible depending on the planned duration of the second patient's appointment, i.e. how much waiting it will cause for the first patient on the schedule. For doctors, the most likely scenario to occur is scenario A. For nurses, there is more of a combination of scenario A and B. This is much due to nurses being more flexible than the doctors, due to multiple nurses sharing a nurses' patient list. Also, one nurse can in some cases work on 2-3 patients at the same time in the case of needing supervision by a doctor. While waiting for supervision for some patient(s), the nurse can give consultation to another patient.

Patients can also not show up (no-shows), which in most cases is because the patient has forgotten about the appointment, or forgotten to cancel. Seldom, the patient has not received the appointment notice letter which makes the patient unaware of their appointment. During one typical day in OPD1, there is about none to three no-shows. In addition, in rare cases, patients can show up to wrong appointment time, either during the day or arriving another day than planned, due to misconception of their appointment time.

Late arrival of patient's and no-shows does not only lead to variability in the schedule throughout the day, but may also cause health personnel to walk around looking for them, i.e. time lost that could have been used on delivering care. In OPD1, in most cases, nurses do this rather than doctors, as it is the nurses' responsibility to coordinate patients. However, if it is an X-ray appointment, the radiographers may move around looking for the patient as well. The reason why personnel moves around, is that in some cases the patient has registered, but have wandered off somewhere else than the respective waiting area. Also, some patients forget to register, so that the staff has to check whether or not the patient is present.

Arrival of acute patients cause variation as they interrupt the schedule, and are sequenced in between elective patients. This can lead to delay in the schedule of elective patients, however, the doctors and nurses put their efforts to avoid this. Similarly, interruption to the X-ray schedule happens when doctor's request for urgent X-ray for acute patients. Especially in the case of acute patients, a nurse may consult two to three patients at a time, as the acute patients require supervision by a doctor. In such a case the patients are placed in individual rooms, the doctor is called in for supervision, and while the nurse waits for the doctor to be ready to give supervision for some patient(s), the nurse consults another patient who is ready to receive nurse consultation. This work method makes the nurses not to wait for doctors to be available.

Regarding variation in processing time, patient slowness (described in chapter 4.2.3.2) is often the cause to this. Patients can have various degrees of patient slowness. Patient slowness can be caused by one or a combination of factors. Patient slowness factors and description are given in Table 22. Patient slowness can cause variation, and may result in a consultation room being occupied until the patient has left the room. Patients going to both a doctor and a nurse consultation, are therefore often only led into the nurse consultation room, and the doctor comes by that room to give their consultation as well. This is a measure to prevent the doctor's room being occupied, to avoid delay in the doctor's schedule. A patient may also be led into the nurse consultation room because of the consultation delivered by the nurse will take longer time than the doctor's consultation. For example, some wound treatments, performed by a nurse, take longer time than the doctor's consultation time. As mentioned, many patients with a high degree of patient slowness are treated on Wednesdays, which may in particular cause delay in the schedule this day.

Table 22: Patient slowness factors and description

Patient Slowness Factor	Description
Reduced mobility	Patients can have reduced mobility, i.e. reduced movement ability and/or reduced walking speed. It can be due to walking difficulties, age, use of crutches or wheelchairs, etc. In addition, reduced mobility may also cause movement and walking discomfort.
Heaviness	Patients can be heavy to lift, or heavy to assist lifting, e.g. if the patient needs assistance in moving into a chair due to reduced mobility, this may require help from the health personnel (one or multiple).
Faints and blackouts	If the patient faints or has a blackout, it can take time to get the patient conscious again. While unconscious, the patient will occupy the room.
Difficulty	The patient prevents the staff to perform something easily. I.e. the patient will not do as the doctor/nurse says.
Perception	The patient requires more time to understand information given, e.g. instructions for how the patient must treat their wound.
Questions	The patient has many questions that the staff must set aside time to answer.
Uncertainty	The patient may need more extensive consultation than first planned.

Delay in doctor schedules may arise due to patient slowness, variation in duration of taking notes after consultation, or that the doctor has to supervise in another room in OPD1, another department, or the emergency department. Regarding supervision, nurses may need to ask for a doctor's supervision, which will interrupt the doctor and take of their time. However, this is necessary to provide the right treatment. Sometimes, a nurse may know what to do, but due to different levels of position authorities, they need the doctor to authorize the treatment before they conduct it. In addition, there are some treatments that only the doctors are authorized to conduct. Also, in some cases, a doctor has predetermined that he/she wants to have a look at the patient. Supervision required from the doctor happens about none to five times during a day. In addition to this, most of the time, acute patients require a doctor's supervision.

Due to the variation in arrival times and processing times taking place in OPD1, doctors and nurses from time to time must work overtime, with a varying degree of length. Also, the variations may cause delays in the schedule, causing waiting for patients while being in the OPD. Finally, variation may cause staff underutilization, in the case of patients not showing up, or the patient arriving late.

Regarding the patient flow taking place in a multistage system, when a patient has both an X-ray and an OPD1 appointment, the patient in most cases have to wait between each service (see chapter 5.2.1). This makes the different appointment schedules of the different stages less prone to variation in another stage of the multistage system. Thus, when patients have multiple appointments, the patients wait in-between each service, and thus the health personnel are less likely to wait for a patient due to variability elsewhere, such as the patient arriving late, or that the schedule of another service is delayed. However, waiting time can cause patient dissatisfaction.

Regarding the X-ray department, there are different variations that can occur. As they have a schedule, their schedule can be delayed due to variation in arrival and processing times of the different patients. As explained in chapter 4.2.2.2, an urgent X-ray is when a doctor orders an X-ray, and the X-ray picture(s) is taken the same day as it is ordered. Regarding X-ray pictures, the radiographers receive X-ray requirements from the doctors concerning what the X-ray picture(s) should include. The radiographers must prepare for each X-ray requirement of the respective patients they are to receive, such as what body part, from what angle, etc. Sometimes the X-ray requirements from the doctors are incomplete, or the radiographer interprets the requirements wrongly, causing the X-ray pictures not to display the information the doctors require. It is also possible that an X-ray picture has poor quality, such as not being clear enough. In the case of X-ray pictures not displaying the information it should, or being of poor quality, retaking of X-ray occurs. Retaking an X-ray picture can either happen the same day (urgent X-ray), or are taken a later day. Acute patients may also require X-ray, which is thus an urgent X-ray as it takes place the same day. Urgent X-rays disrupts the schedule of the X-ray department. For urgent X-rays, if a patient has X-ray as their last main route station (see chapter 5.1), normally the patient has been assessed for the need of a surgery, whereof surgery is necessary, and the doctor finds it more desirable to have a new and clearer/more detailed picture to prepare for the surgery. The patient then gets an urgent X-ray appointment the same day so that the patient does not need to come back for another consultation before a possible surgery.

Regarding the blood sampling department, the time to receive blood sample results varies between 1,5 to 5 hours. However, processing of blood samples can be rushed forward, e.g. nurses can put the degree of urgency to high, to receive the blood sampling results faster, at fastest 1,5 to 2 hours.

Resource pooling, which is that a patient waits for multiple servers instead of a single server, can be used to reduce variation in queues (Walley et al., 2006). For the doctors, this is not possible, as each doctor has their respective specialization, i.e. the patient must see a certain doctor. For nurses, two to three nurses work together on a nurses' patient list, which makes a patient waiting for the first available nurse out of these. The nurses are thus more flexible and their schedules are less prone to variation, which is of benefit for patients. For the X-ray, each X-ray room have their own schedule, however, if the schedule of one X-ray room is ahead, and the other is behind, the X-ray with some free time may take some of the other X-ray room's patients. As stated by a radiographer, one single queue is difficult to achieve, as the radiographers prior to the X-ray appointments have prepared for the x-ray requirements of the respective patients they are to receive. For the blood sampling department, there is only one queue, either waiting for one or two bioengineers, as this may vary.

5.3 Layout

This chapter presents the analysis of the layouts of the case OPDs. The analysis concerning layout of OPD1 is presented in 5.3.1, while the analysis concerning layout of OPD2 and OPD3 is presented in 5.3.2.

5.3.1 Layout of Outpatient Department 1

If looking at OPD1 from a hospital perspective (macro level), OPD1 is almost a cell as it contains almost all services required for the patient group visiting OPD1 during a visit. A few patients require other services, such as medical imaging before an OPD1 consultation, OT or PT after an OPD1 consultation. In most cases, the medical imaging services located elsewhere (CT, MR, ultrasound, etc.) take place at least one to two weeks before the OPD1 visit, thus it will not affect the patient flow during a visit to OPD1. Also, patients are normally referred to external physiotherapists, and will thus in most cases neither be affected by the location of the PT department. However, the patients going to OT after an OPD1 consultation, normally receive so within the same day as the OPD1 appointment, whereas OT and PT services are located in the building “1902-bygget”, closely located to the Movement Center.

Looking at OPD1 from a department perspective (micro level), Figure 14 shows the patient flow network from Figure 13 mapped onto the current floor plan of OPD1. Looking at OPD1 from a hospital department perspective, but taking the X-ray department and blood sampling department into account as they are closely related and located, the way the different services are laid out in the building, shows that the similar functionalities are located together. Thus, the OPD1 rooms, X-ray rooms, and blood sampling rooms are located together respectively, which resembles a functional layout. However, as stated by Burbidge (1991), companies of small size may in effect already be a single group, i.e. a cell (Burbidge, 1991). Anyway, the layout of OPD1 is looked further into.

In Figure 14, circles with numbers are representing the route stations with the respective numbering (see Table 17). As route station 7 consists of GCR 5 to 11, and 16, the circle representing route station 7 are placed approximately in the middle of these. The actual location of all GCRs which are compiled into route station 7, are mapped with blue rectangles displayed with the number 7. Figure 14 displays four different arrows, whereof the respective arrows symbol a range of movement frequencies between the route stations: no observation data and up to 2, 3 to 10, 11 to 45, and 45 to 96. The arrows symbolling each movement frequency range are also presented in Figure 14. The main movements (frequency range of 45 to 96) are between the entrance and the different registration areas, the respective registration areas to W1 or W2, W1 to W3, W2 to an X-ray room, W3 to a GCR, a GCR to the counter, and from the counter to the exit.

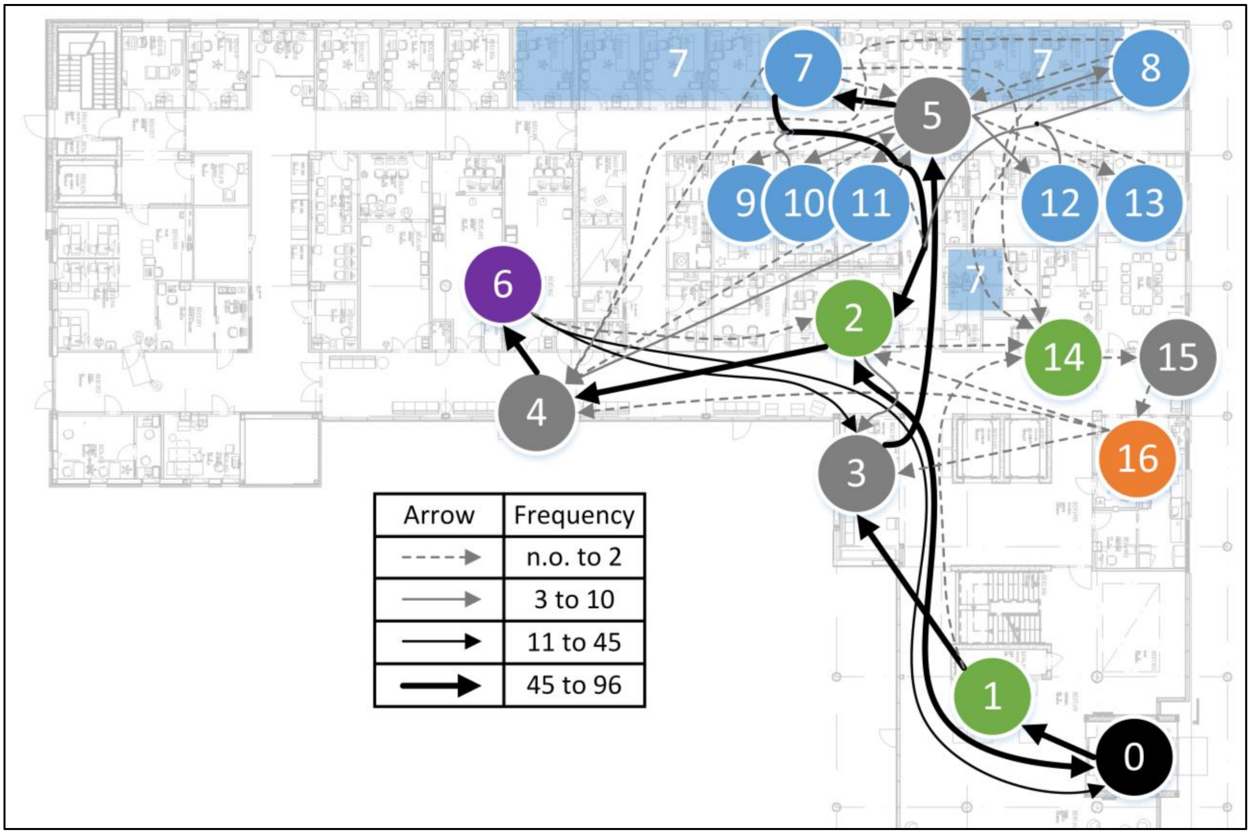

Figure 14: Patient flow network for planned patient movement mapped onto the current layout of Outpatient Department 1.
Source: St. Olavs Hospital. Adapted from original floor plan.

Out of the OPD1 rooms, the GCRs are placed along a line, besides room 16 which is located closer to the counter. The PCRs are located together, TOV rooms are located together, whereas the surgery rooms are not. The PCRs are connected by a room (orthopedic workshop) which is related to both the PCRs. The TOV rooms are located together as the TOV personnel mostly use one room as office (TOV2) and the other one to see patients (TOV1). However, TOV is only in the OPD1 one day a week. Anyway, it is more beneficial for patients going to TOV, that the TOV personnel are present in OPD1, so that these patients do not need to move between different buildings. Further, the surgery rooms are not related to each other. Room 13 is not utilized fully (only used for surgeries which do not take place all the time), and in addition, it cannot be allocated to a doctor. Patients going to room 13, also have a less extensive PRN, i.e. the patient must not walk much back and forth. Despite the room not being a very active room, it has a location in the middle of OPD1 and the X-ray rooms.

Regarding placement of health personnel in OPD1, what room a doctor is allocated affects the layout of competence, as doctors are specialized within sub-disciplines, and that they receive patients within their specialization. Since the doctors do not have a fixed room, the layout of competence can vary from day to day. The nurses use the PCRs, TOV1, and the remaining available GCRs.

There are three registration areas, located separately, which may confuse the patients. For example, most patients going to the blood sampling, go to the counter first. In addition, some patients that cannot use the self check-in try to do so. Also, many patients that have both an OPD1 appointment and an X-ray appointment register their OPD1 appointment at the self check-in machine, and their X-ray appointment at the counter. The location of the three registration areas may not cause additional walking for the patients, but may take of the patients' time, and consequently the health personnel's time.

Waiting areas close to the consultation rooms in OPD1 ensure in most cases that patients are right outside the consultation room, waiting for their doctor to be ready to take them in, so that the doctors do not have to wait for the patients to arrive the room. However, from W1 to W3, nurses many times call-up the patients from W1, which causes walking for the nurses to have such an arrangement.

The most common main routes taking place in the layout is "GCR", "X-ray→GCR" and "X-ray". For patients only going to either a GCR or an X-ray room, the route is quite simple and does not cause much walking back and forth. For patients going to "X-ray→GCR", the route causes patients some back and forth movement. For somehow more complex routes, the patient must move more back and forth, such as patients having routes including both X-ray rooms, GCRs and PCRs, due to the location of these rooms, for example, route S, U, V, W, X, and Y (see Table 18). Combined, these routes constitute 5 out of 117 routes observed, thus not a major part of the flow. For patients with reduced movement ability, it may be beneficial to have shorter walking distances. For the somehow more complex routes such as the ones mentioned, shorter walking distances could be achieved by locating PCRs closer to the X-ray rooms.

Besides this, the OPD1 staff stated that the OPD1 layout is characterized by one long corridor, causing much walking back and forth for patients and staff, but besides that, the staff is satisfied with the current layout. Previously, OPD1 was located in another building and had an H-shaped layout, which made coordination and cooperation between the staff cumbersome and caused much walking back and forth.

5.3.2 Layout of Outpatient Department 2 and 3

Looking at OPD2 and OPD3, from a hospital perspective (macro level), they are located in a more functional way. OPD2 and OPD3 patients requiring X-ray and blood sampling must walk longer distances in these OPDs, than compared to patients in OPD1 who have these services located closely. Patient walking distances will thus be affected more if these services are located other places in the hospital. The layout of services on a hospital level will thus have a greater impact on the movement of patients, than the layout of services in a single department. If possible, locating an X-ray department close to the OPD is beneficial for the patients. However, if such solutions are feasible, will probably depend from hospital to hospital due to size and available resources to allocate.

Looking at OPD2 and OPD3 from a hospital department level (micro level), where both layouts, especially the layout of OPD2, are characterized by a long corridor, causing unnecessary walking for patients and staff. For both OPD2 and OPD3, most patients only visit one room in the OPDs during their visit, however there are some exceptions. In OPD2, the exceptions are patients going from either a gastroenterology- or urology- room to another, whereas they use a door between the rooms. In OPD3, the exception is that patients who receive a proctoscopy examination are first consulted in room 1, and moved to room 7 if proctoscopy is necessary, whereas room 1 and room 7 are the two rooms located furthest apart in OPD3. Regarding room 7, the gynecologists did not receive a room with a toilet (WC) in the medical OPD, although their patient group requires so. Thus, as room 7 contains WC, the gynecologists got the room located in the middle of OPD3, which led to OPD3 being allocated room 7, which causes more back and forth walking for patient and staff. The gynecologists use the room located in the middle of OPD3 every day, and the room is thus not assigned to OPD3 doctors. Besides this, the rooms in OPD2 and OPD3 are mostly located along a line, besides room 1, 2 and 12 in OPD2, and room 6 in OPD3, which are located on the opposite side of the corridor.

Regarding registration areas, in OPD2 it might not be as evident where it is located, as it is located on the second floor. Thus, it needs to be well signed for a patient to find it. For OPD3, there are several registration areas, which may confuse patients regarding where to register. Regarding waiting areas, similar to OPD1, nurses in OPD2 call patients up from W6 to go and wait in W7, outside the consultation room, which causes unnecessary walking for nurses. Also, in OPD2, acute patients must deliver a register form to the work room (see Figure 11) before waiting in W8. For OPD3, there is only one main waiting area W9, as W10 is rarely used. W9 is located between room 5 and the start of the Medical OPD. Due to the location of W9, it can cause unnecessary back and forth flow of patients as they go to the waiting area, for so going back the same direction when going to a consultation room in OPD3.

Finally, the OPD2 staff pointed out that OPD2 previously was located in another building, where the consultation rooms where located in a U-shaped layout. The staff stated that this type of room arrangement was much more convenient and caused less walking.

5.4 Summary of Analyzation

The summary of the information provided in the analyzation is presented in this chapter. The summary of the analyzation is divided into, and presented in, three tables: Table 23 concerns patient flow in OPD1, Table 24 concerns patient flow constraints in OPD1, and Table 25 concerns layout.

Table 23: Summary of the analyzation concerning patient flow in OPD1

Summary of the Analyzation Concerning Patient Flow in Outpatient Department 1
Planned Patient Movements • Most routes taking place are either single stage or two stage systems, which does not cause very much back and forth walking • A few routes have three or four main route stations, causing some more walking, which may be disadvantageous for patients with reduced movement ability • X-ray is frequently used by OPD1 patients • Blood sampling is not very frequently used by OPD1 patients • Few patients seem to go to room 13, which may indicate low utilization rate *Actual Patient Movements Compared to the Planned Patient Movements* • Patients unlike materials have their own free will, and will thus move around due to being confused, curious, or restless. • Patients do not always follow the planned patient movements. In some cases, it causes more movement than necessary, such as patients going multiple times to the counter for asking questions, for so going back to their waiting area. In other cases, it causes less movement, such as patients going directly from W1 or the counter to a consultation room. However, the latter can indicate late arrival of patient. • A few patients misunderstand where to wait, causing health personnel to wait or look for them, which can lead to lost consultation time.

Table 24: Summary of the analyzation concerning patient flow constraints in OPD1

Summary of the Analyzation Concerning Patient Flow Constraints in OPD1
Available Capacity • Capacity shortage of doctor's is the bottleneck determining throughput volume. • There can be busy periods with high workload for nurses, however, the available capacity can be seen as in balance with demand. • Capacity shortage of rooms where nurse consultations can take place are prominent on Wednesdays due to many patients with patient slowness being in the OPD1 that day. • Poor coordination of X-ray schedules can lead to long patient waiting time, sometimes days, in-between X-ray and OPD1 appointments. In addition, an OPD1 patient may go to another center for X-ray, although patients from other centers likewise go to the X-ray department in the Movement Center. • If capacity shortage of bioengineers, the blood sample department in the Movement Center is closed, and patients receive blood sampling in another center. *Variation* • No-show patients and patients arriving late, affect the utilization of doctors and nurses the most. However, sometimes the next patient has arrived earlier and can be taken in, avoiding delay in schedule in the case of late patients. • Acute patients, and patients arriving late may lead to the OPD1 staff working overtime. • Patient slowness is a characteristic of patients going to OPD1, which can lead to delay in the schedule. It also makes it difficult to predict the actual time duration of consultations. • Supervision from doctors and assistance from nurses may lead to interruption of these staff members, whereas walking distance to the room they must supervise or assist in, is a part of the interruption time. • Long times in-between appointments make the process less prone to variation, however, it can cause patient dissatisfaction. • Urgent X-rays are often due bad quality or incorrect information in the X-ray pictures. • It is not possible to reduce variation of doctors by resource pooling, as patients are allocated a specific doctor, based on the patient's condition and the doctor's specialization. • Nurses are more flexible than doctors due to two to three nurses sharing a patient list, which supports reducing variation in the schedule. • Blood sampling results take 1,5 to 5 hours. If urgent, it takes 1,5 to 2 hours.

Table 25: Summary of the analyzation concerning layout

Summary of the Analyzation Concerning Layout
OPD1 • From a macro level perspective, OPD1, X-ray and blood sampling are grouped together, and resembles a cell. From a micro level perspective, the different departments and rooms are located separately, resembling a functional layout. Among the OPD1 rooms, the GCRs are mostly placed along one line. • Room 13, is located in the middle of OPD1, and close to the X-ray rooms, but is not related to the X-ray department, and is also relatively less utilized than the remaining rooms in OPD1. • The PCRs in OPD1 are related to the X-ray department, and could maybe be located closer to the X-ray department, due to that the patients having the most complex routes in OPD1, have routes with a combination of the main route stations PCR, GCR, and X-ray. • Three registration areas seem to confuse patients were to go, however, it does not cause much additional walking, but may take of the patients' time, and consequently time of health personnel. • Waiting area close to the consultation rooms ensure efficient utilization of doctors, but may cause walking for the nurses. *Additional Inputs from OPD2 and OPD3* • Long corridors lead to unnecessary walking for patients and staff • Lack of attention to capacity requirements may affect the layout of services after the building is built, which can cause unpredicted, and consequently long flows • Location of registration area is more beneficial if located close to the entrance, causing less backward flow. • U-shaped layout of rooms may be more convenient than rooms located in one long corridor, causing less walking.

6 Discussion

The input to the discussion is relevant information presented in the literature study (chapter 3), the case study (chapter 4), and the analyzation (chapter 5). The research objective of this thesis is to develop a framework that combines patient flow in outpatient departments and how layout can support patient flow. Based on the literature study, a preliminary framework was developed (see chapter 3.4). The discussion will focus on answering the research objective and present a revised framework for layout design supporting patient flow in outpatient departments. To do so, the different components of a layout are discussed toward how they can affect, and support, the different aspects of patient flow.

The different aspects of patient flow are movement distances of patients which poses risk of adverse effects, and efficient patient flow. The first may be particularly of interests to orthopedic OPDs, as this type of OPD has a large share of patients with reduced movement ability. In addition, by reducing distances, personnel movements can be reduced, which support cross-professional teamwork and productivity improvement (Karvonen et al., 2017). The second, efficient patient flow, consists of high throughput volume, short throughput time, low patient waiting time, and low personnel overtime combined with high personnel utilization (Koo et al., 2010). In addition, there are also different aspects of layout, where macro level is focused on the assignment of departments within a hospital, while the micro level is focused on the layout within one single department (Arnolds and Nickel, 2015). Further, different layout types are intended for different purposes and will affect how patients flow through a facility.

Discussion concerning layout types for patient flow in outpatient departments will be discussed in chapter 6.1. Further, a discussion concerning how layout can support patient flow in outpatient departments, is presented in chapter 6.2. Finally, a summary of the discussion and a revised framework for layout design supporting patient flow in outpatient departments are presented in chapter 6.3.

6.1 Layout Types for Patient Flow in Outpatient Departments

Choice of layout type is influenced by process types, although a process type does not necessarily imply one specific layout type (Slack et al., 2010). Process types are the general approaches to designing and managing processes and activities (Slack et al., 2010). Patient flow belonging to one outpatient department, and the services required by these patients, is henceforth synonymous with outpatient process. As described (see chapter 1.2), patient flow in outpatient departments is not only limited to the movement inside an OPD, but the movements of the outpatients as they may require related services during a visit to an OPD, which may lay outside an OPD as well. Looking at the service process types and their characteristics, an outpatient process resembles a service shop, illustrated in Figure 15, and explained below.

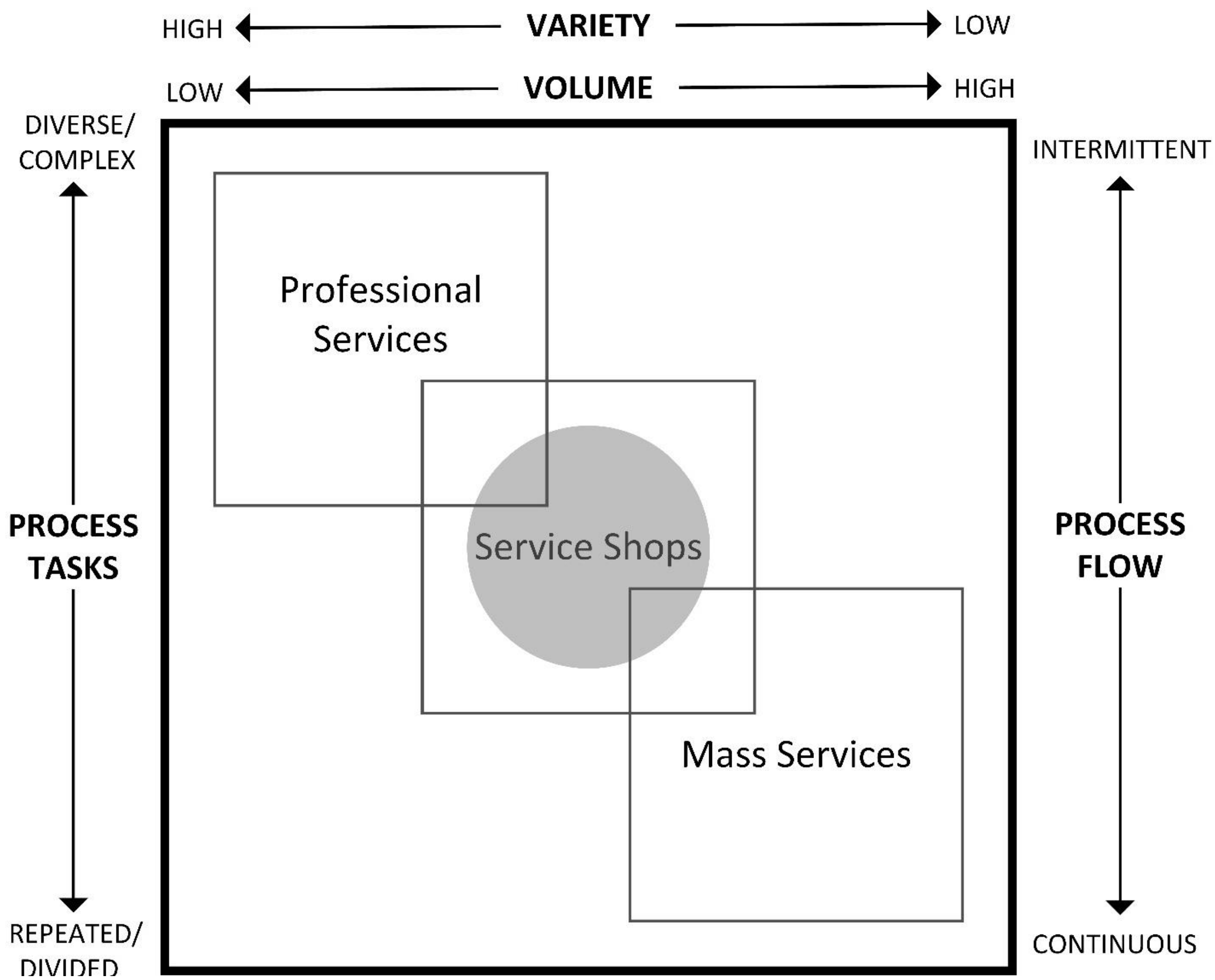

Figure 15: Outpatient process' process type. Adapted from Slack et al. (2010)

Service shops have fairly standardized services, but the service is customized to each customer's individual need (Slack et al., 2010). Based on the case OPDs, each OPD has a set of doctors, each specialized within a medical discipline, whereas it is predetermined which doctor a patient is to receive consultation from, based on the patient's requirements. In addition, some patients require multiple services during a visit, whereof some of these may lay inside or outside an OPD. The services required in an outpatient process is fairly standardized, but yet customized to each individual patient's need, and the outpatient process thus resembles a service shop. It is assumable that the preceding descriptions of the case OPDs, can be the case for other outpatient processes as well. As seen in Figure 15, service shops are characterized by medium complexity of process tasks, medium variety and volume of patients, and medium continuous flow. However, it will probably depend from one OPD's outpatient process to another, where it will be placed within the service shop range, as different OPDs will have different activities depending on the practiced field of medicine and services they provide (Froehle and Magazine, 2013). Thus, it is assumable that the characteristics may vary some from one outpatient process to another.

With a basis in the outpatient process being a service shop, according to Slack et al. (2010), service shops do normally imply that functional layout and cell layout are basic layout types that can suit this process type (Slack et al., 2010), illustrated in Figure 16.

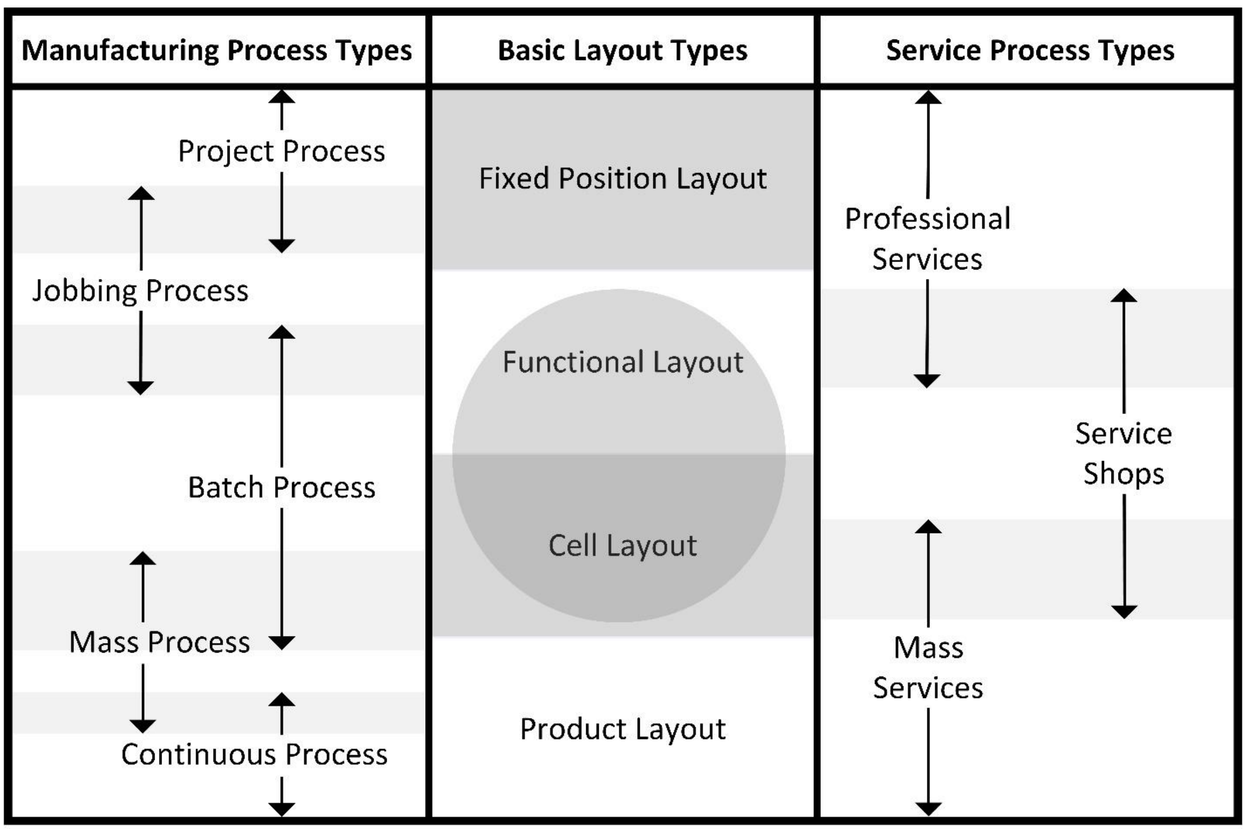

Figure 16: Outpatient process' choice of layout type. Adapted from Slack et al. (2010)

Functional and cellular layout have different advantages and disadvantages (see chapter 3.3.1, Table 8). Depending on the placement of an outpatient process in Figure 15 within the service shop range, it may change whether or not it is functional or cell layout that is the best option. Of functional and cell layout, the lower volume and higher variety a process has, the more it leans towards functional layout, as one of the advantages of functional layout is that it provides high mix and product flexibility (Slack et al., 2010, Stevenson, 2014).

As presented in the literature study (see chapter 3.3.1, Table 7), in functional layout similar processes are located together, whereas the customer have to take different routes according to their needs (Stevenson, 2014, Slack et al., 2010). As also presented, in cell layout, workstations are grouped together according to processing requirements for a set of similar customers to be worked on which require similar processing (Stevenson, 2014). In addition, cell layout is an attempt to create order to the complex flow which characterizes functional layout (Slack et al., 2010, Burbidge, 1991). Further, outpatients may undergo one or multiple consultations (Cayirli and Veral, 2003, Côté, 2000). The illustration of patient flow in outpatient departments presented in the literature study, is presented anew in Figure 17, for the reader's convenience.

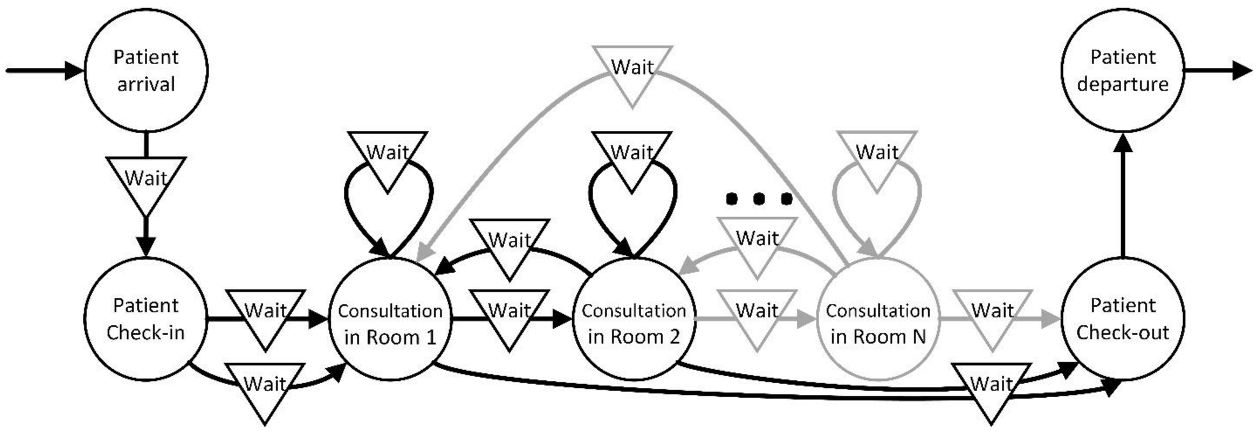

Figure 17: General illustration of patient flow in outpatient departments.
Adapted from Côté (2000), Swisher et al. (2001), Mardiah and Basri (2013), Pan et al. (2015), Chand et al. (2009), and Cayirli and Veral (2003).

In the case of only one consultation during a visit, it is limited to how complex the flow can get, although the patient most likely is to go to areas for check-in and checkout, as well as waiting areas, where the locations of these areas also affect the flow. Anyway, if a patient requires multiple consultations, it is to assume that the flow complexity can increase. From the findings, the patients in OPD1 may require as many as four 4 consultations during a visit, however the most common routes only include one or two consultations. Anyway, in other OPDs, multiple consultations, and consequently complex flows, may be a major part of the outpatient process. As cell layout is a means of creating order to the complex flows which characterize functional layouts (Slack et al., 2010, Burbidge, 1991), for patients with multiple consultations, cell layout could reduce the complexity of a flow by grouping related activities together. However, for patients with simpler flows, functional layout does not affect the flow of patients as much. As different basic layout types can be combined in one layout, or can be used in different parts of an operation (Slack et al., 2010), an outpatient process may have benefit of using a combination of functional and cell layout. From the findings, the distances patients must move will be longer if related hospital departments are located functionally rather than grouped together, than if rooms within a department are located functionally rather than grouped together. However, this may vary depending on the size of an OPD, if the patient flow takes place only within the OPD or also in related departments, the location of related activities, as well as the overall patient flow complexity. Again, this may vary from one outpatient process to another. Besides flow implications of the different layout types, there are other advantages and disadvantages to consider when deciding on layout. For instance, functional layouts are relatively robust in the case of disruption (Stevenson, 2014, Slack et al., 2010). Also, cell layout may imply more plant and equipment (Slack et al., 2010), and it must be considered if it is cost efficient to group the related activities. For example, on a macro level, if services of a related department are required by the patients of an outpatient process to a large extent, as well as the volume of patients being sufficient enough to allow for cost-efficiency, it may be beneficial to co-locate the OPD and the related department to allow for reduced length of patient flow.

6.2 Layout Supporting Patient Flow in Outpatient Departments

As presented, efficient patient flow consists of high patient throughput volume, short patient throughput time, low patient waiting time, and low personnel overtime combined with high personnel utilization (Koo et al., 2010). From the findings, there are indications that the layout may not affect the throughput volume of OPD1, and thus the waiting time in access of services in OPD1. This is due to that all patients with elective treatments are allocated specific time slots with a doctor, the doctors do not move much within the facility while being in OPD1, combined with the doctor being the bottleneck resource determining how many patients it is possible to treat. Doctors being a bottleneck resource is consistent with what is found in the literature (Erhard et al., 2018, Koo et al., 2010). From the findings, although capacity of nurses seems to be in balance with demand in the access of nurse consultations, nurses can have busy hours during the OPD working hours, that can cause waiting time for patients during a visit. Accordingly, Koo et al. (2010) stated that nurses are also important resources in healthcare systems, and found for their case scenario, sometimes during the week, capacity of nurses was not sufficient (Koo et al., 2010). Thus, in terms of facilitating high throughput volume, and also reducing patient waiting time during a visit, a layout should not only facilitate doctor utilization, but the utilization of other health personnel as well. However, whether or not throughput volume is affected by layout, depends on the process of each OPD, and the respective layouts that these processes take place within.

Utilization of doctors affects how many patients it is possible to consult. According to Stevenson (2014), a layout should support the utilization of staff (Stevenson, 2014). As doctors seem to be the bottleneck determining the throughput volume, a layout should particularly facilitate utilization of doctors. Reducing distances, and thus movement of health personnel, allows for more time spent consulting patients (Skeldon et al., 2014), and supports productivity improvement (Karvonen et al., 2017). From the findings, in OPD1 and OPD2, patients wait right outside the doctors' rooms, that makes the doctors not wait for the patients, which is supporting the utilization of doctors. In OPD3 patients do not wait directly outside the doctor's room, but move directly from the waiting area after being called up by a nurse, that causes walking for the nurse and waiting for the doctor. Nurses calling up patients from waiting areas are seen in all three case OPDs, which causes walking for the nurses. In addition, patients in the orthopedic OPDs have various degrees of patient slowness, including reduced movement ability, which can affect the time a patient requires to move from one area to another. However, as this thesis has studied the patient flow, and not health personnel flow nor utilization, it is difficult to say how much of an impact these distances have in the case OPDs. Anyway, from a larger perspective, if health personnel have distances to walk, or if they must wait for patients to walk from one area to another, this can affect the utilization of health personnel. For example, depending on the size of an OPD and the location of different activities and waiting areas within it, long flows for patients and health personnel may occur, which can result in low personnel utilization.

Regarding reduction in length of patient flow on a macro level, locating related departments close to each other, for example locating an X-ray department close to an orthopedic OPD, reduces the patient movement in a facility (Karvonen et al., 2017). Reducing patient movement distances can be done by using group technology (Karvonen et al., 2017), where a group is equipped with the processing facilities required to complete all products or services the group is to process (Burbidge, 1991). In addition, co-locating related activities supports teamwork and productivity (Karvonen et al., 2017, Burbidge, 1991). From the findings, an X-ray- and a blood sampling department are closely located to OPD1. For OPD1 patients, as these departments are closely located to OPD1, the patients are saved from unnecessary movement, and reduces the risk of adverse effects of transportation (Karvonen et al., 2017). Also, when looking at OPD2 and OPD3, where the X-ray and blood sampling department are not as closely located, it is evident that it is not given that these departments are located right next to an OPD. However, as X-ray is the most prominent of the related services required by the orthopedic OPD patients, it could be seen as a benefit to have an X-ray department and orthopedic OPD closely located, as layouts should avoid complex and long flows for patients (Slack et al., 2010, Karvonen et al., 2017). In addition, locating an X-ray department and an orthopedic OPD closely, facilitates communication between the nurses and the X-ray department (Karvonen et al., 2017). Anyway, locating related departments, can probably be applied for other outpatient processes as well, where benefits could include such as reduced length of patient flow as well as increased communication between the related departments, supporting teamwork and productivity.

Regarding reduction in length of patient flow on a micro level, the length of flow will depend on the size of an OPD, and the complexity of the patient flow taking place within it. For the case OPDs, if the rooms were arranged differently, it is uncertain how much of an impact it would have on the length of patient flow and the risk of adverse effects. However, some findings related to OPD1 are discussed, as it may be of importance, when it comes to other OPDs. An X-ray department is closely located to OPD1, and is thus discussed in the context of OPD1. As stated, most routes in the OPD1 only have one or two main route stations (see Table 18), not causing very complex flows. Anyway, some patients going to the main route stations PCR, X-ray, and GCR, have a somehow longer flow, due to the location of these route stations. Complex flows, and thus length of flow, can be reduced by reducing cross- and backward flow (Burbidge, 1991). To reduce the length of flow for patients going to the main route stations PCR, X-ray, and GCR, it could be beneficial to locate the PCRs and GCRs closer to the X-ray rooms. For OPD1, only 5 out of 117 observations had these main route stations, implying that it is not a major part of the patient flow in OPD1. However, in other OPDs, complex flows may be a major part of the patient flow. Another related finding is that OPD1 patients going to room 13 do not have a very complex route during a visit, combined with this room not being fully utilized due to restrictions for use, as it should remain as sterile as possible. Unless highly necessary, the room should not be used for other consultations than surgeries. Anyhow, the room is located in the center of OPD1, close to both GCRs and closer to the X-ray rooms than the PCRs. To allow for other rooms being closer to the X-ray department, room 13 could have been placed further away from the X-ray rooms. Again, grouping related activities supports teamwork and productivity (Karvonen et al., 2017, Burbidge, 1991). However, locating rooms in different ways may have other implications for the operation that has not been identified in this thesis. Anyway, patient flow analysis is a valuable tool in designing hospitals (Karvonen et al., 2017). For both the reduction of transfer distances between departments, and the transfer distances within one department, as discussed in this section and the section above, patient flow analysis can be used to identify possible patient routes, their volume, their complexity, and consecutive length of flow.

Further, regarding layout supporting teamwork and productivity among staff on a micro level, the arrangement of rooms can affect this. In all three case OPDs, the departments' layouts are characterized by one long corridor. The arrangement of rooms should facilitate the utilization of staff (Stevenson, 2014). For instance, when doctors must supervise a nurse, and when nurses must assist a doctor or another nurse, this leads to walking. As mentioned by the OPD2 staff, a U-shaped was more convenient and caused less walking, than having the rooms arranged along one long line. According to Stevenson (2014), a U-shaped layout is more compact than one straight line, and allows for increased communication because the workers are grouped together, which facilitates teamwork (Stevenson, 2014). It also allows for flexibility, as workers can handle stations on the opposite side of the line (Stevenson, 2014). Thus, the use of U-shaped layout in OPDs may increase communication, teamwork and flexibility, since the doctors and nurses can easily access consultation rooms on the opposite side of the corridor. This would also help in reducing the walking distances, compared to having most of the rooms allocated along one long line. In the case of larger OPDs, multiple areas divided into U-shapes, could perhaps be more beneficial than one single U-shape. However, it would depend on the operation of each individual OPD whether or not it is feasible to arrange the rooms in such a way. Anyway, how to arrange rooms within one OPD, should take into account the movement of doctors and nurses between rooms, so that short walking distances between these rooms can be facilitated, and thus decrease the length of health personnel flow.

Further, change in layout of services delivered due to capacity shortage was observed by Amladi (1984). Similarly, the findings from OPD3 indicate that lack of attention to capacity requirements when locating resources can lead to changes in planned layout of services. For example, even though capacity may be in balance, the planned layout of services may change due to inefficient location of resources. In the case of OPD3, a room with WC in OPD3 was allocated to gynecologists, as they needed a room with a WC for their patient group, while the OPD3 was allocated room 7 (see Figure 12) further down the hall as a replacement. This change in layout leads to unpredicted and longer flows than planned, which is undesirable (Slack et al., 2010). A measure to prevent unpredictable flows could be to carefully consult with the OPD staff regarding room requirements needed for their type of consultations. This can make it more likely to avoid change in planned layout of services due to capacity requirements not being met. In addition, as seen by Iskander and Carter (1991), rearranging services between centers can also happen due to lack of capacity (Iskander and Carter, 1991). Thus, capacity planning and allocation can affect the planned layout of services, both on a micro and a macro level. Changes in planned layout of services can affect the length of patients and personnel flow, which has been elaborated on in the above sections.

Regarding throughput time of patients in the OPDs, long distances can make it necessary to schedule appointments with some time in-between, causing longer throughput times than necessary (Morinaga et al., 2016). Grouping related activities can allow for fast throughput times (Slack et al., 2010). However, activities can also be closer located than needed for scheduling (Morinaga et al., 2016). For OPD1, an X-ray department and a blood sampling department are closely located to OPD1, which facilitates the possibility of scheduling appointments closer to each other. Regarding X-ray, in OPD1 doctors can interpret X-ray pictures, but the appointments seem to be scheduled with some time in-between, which may be due to lack of coordination between scheduling of the different services. In OPD2 and OPD3, doctors have to wait for the X-ray descriptions given by the radiologists, which may also be the case in OPD1 sometimes. Regarding blood sampling, there is no appointments scheduled, but a queue ticket system. In addition, the blood sampling results have a waiting time of at least 1,5 to 2 hours. Thus, the throughput time in the case of waiting for results, is an inherent characteristic of the process, while the throughput time in the case of waiting time in-between appointments due to lack of coordination, seems to be more of a scheduling problem. Anyway, in terms of facilitating a shorter throughput time, a layout should support the possibility of scheduling appointments close to each other when possible to do so, by reducing the distances of related services. For example, if doctors of an OPD are able to interpret X-ray pictures, to enable scheduling of appointments close to each other, an X-ray department could be located closely to the OPD. Further, for services where a patient anyway must wait for the results, in regards of achieving shorter throughput times, the activities do not necessarily need to be as closely located. However, locating related activities can have benefits for patients and staff, as discussed in the above sections.

The throughput time of a patient is also affected by variations that causes waiting time. Waiting time is the time a patient waits in-between appointments, which is affected by scheduling as mentioned above, but also variation causing delay in the planned appointment schedule. From the findings, it is difficult to say how much of an impact layout has on this. Anyway, confusion about where to go, such as for registration, can cause variation (Chand et al., 2009). From the findings, if a patient waits in a wrong waiting area, the health care personnel may wait some for this patient, let in the next patient(s) on the schedule before this patient, or walk around to look for them. If the health personnel takes in the next patient(s) on the schedule, it will cause waiting for the patient in the wrong waiting area. Also, if the health personnel either waits for the patient to arrive or walk around to look for the patient, the schedule may be delayed as well. In addition, patient slowness can also cause variation, because if patients have reduced movement ability, they may require longer time walking to rooms, as described in the second section of the discussion, which can lead to delay in the schedule. Further, staff overtime is related to patient waiting time and staff utilization (Koo et al., 2010). In the case OPDs, delay in the schedule can cause overtime work as all patients arriving during a day is treated, unless they show up unreasonably late. Where to go should be well signposted, clear and evident to workers and patients alike (Slack et al., 2010). Thus, in regards of reducing patient waiting time and staff overtime, a layout should avoid confusion regarding where to go, support staff utilization, as well as shorten length of patient flow.

6.3 Framework for Layout Design Supporting Patient Flow in Outpatient Departments

Regarding layout types for patient flow in outpatient departments, the outpatient process indicates that the layout should use either functional layout or cell layout. The relative location of registration areas, waiting areas, rooms and departments affects how a patient moves throughout the facility. As cell layout is a means of reducing complexity of flow, grouping related activities when feasible to do so, would be beneficial to reduce the distances travelled by patients, both on a macro and micro level layout perspective. Grouping related activities to reduce complexity of flow can be especially advantageous for outpatient processes where patients require multiple consultations. A layout may also combine different layout types. Anyway, choice of layout also depends on other considerations than flow, such as volume and variety characteristics of the process, cost implications, and relative robustness to disruption.

Further, regarding layout supporting patient flow in outpatient departments, the findings discussed in chapter 6.2, are discussed towards the preliminary framework presented in the literature study (see chapter 3.4, Table 9). Most of the elements from the preliminary framework has been touched upon in the discussion, although not all. The discussion has mainly concerned patient and health personnel flow, and how taking these into consideration in layout design of rooms and departments can help support the different aspects of patient flow. The reason why there has been much emphasis on health personnel flow, although the main focus of this thesis is on patient flow, is because health personnel, especially doctors, are seen as scarce resources, which determines the throughput volume that is a part of efficient patient flow. Thus, to support patient flow in outpatient departments, the flow of health personnel is important to consider as well. From the preliminary framework, the definition of patient flow and the definition of layout remain the same, as these are included for informative purposes, and have not been discussed. Anyway, in the below sections, the other elements of the preliminary framework, whether or not they have been touched upon in the discussion, and changes to the framework are discussed below.

Firstly, from the preliminary framework, "components of a system that can affect the patient flow" remains unchanged in the revised one, although not all elements have been touched upon, such as available capacity of equipment. As also mentioned for the preliminary framework, the reasoning behind including components of a system that can affect the patient flow, is to give insight to patient flow constraints of a system, whereas the layout should support the patient flow, such as supporting utilization of available capacity, and reduction of process variabilities, which also affects utilization of available capacity. In addition, from the case study, health personnel, especially doctors, but also nurses, are scarce resources, which is consistent with information from the preliminary framework, and thus this information remains unchanged as well.

Secondly, from the preliminary framework, "components of a layout that can affect the patient flow", remains unchanged in the revised one, although not all of the components have been brought up in the discussion. Concerning the components that have been brought up, the emphasis lies mostly on reducing length of flow, by reducing long distances and complex flows, for the benefits of reducing the risk of adverse effects, allow for short throughput times and more time spent on care, as well as facilitate communication, coordination, teamwork and productivity. In addition, clarity and predictability of flow have been brought up, whereas unclear and unpredicted flows can lead to longer flows than initially planned. Further, inflexibility has not been discussed, as neither the literature study nor the case study has provided examples of this. However, this will still be included, as flexibility is an important objective of layout. In the case of outpatient processes, what services delivered may change over time, leading to new layout requirements. This is natural to assume as treatments that previously were inpatient treatments are more often done on an outpatient basis (Wiig and Hedum, 2001). Regarding coordination capabilities, this component has been discussed partly, in terms of grouping related activities together, which supports coordination of activities, communication, teamwork and productivity. However, how easy it is for the management to supervise plant or equipment, has not been brought up, whereas a functional layout is relatively easy to supervise, as similar processes are grouped together (Slack et al., 2010). Coordination capabilities remain the same as in the preliminary framework, as both ease of supervision and coordination of activities are desired in layout design, however are also dependent on layout type (Slack et al., 2010, Stevenson, 2014). Also, it may vary from one case to another regarding what is necessary for good coordination capabilities. Grouping related but different activities (cell layout) allow for coordination of activities and flow, while grouping similar processes (functional layout) allow for easy supervision of plant or equipment (Slack et al., 2010). A common feature of the components of a layout that can affect the patient flow, is that to support the different aspects of patient flow, all of the components more or less concern reducing length of flow, both for patients and staff.

Finally, from the preliminary framework, "how layout should support patient flow" include some changes, based on inputs from the discussion. The inputs from the discussion included in the revised framework is that related patient activities, such as such as departments and rooms, but also registration and waiting areas, should be co-located when feasible, and that one way to reduce unpredictable flows are to pay close attention to capacity requirements when locating resources. Besides this, some elements have not been brought up for discussion, such as facilitating for efficient use of equipment, or supervision of activities, as also mentioned in the above sections. As these can be important as well, they are retained in the revised framework.

Thus, there are few changes from the preliminary framework to the revised framework, however a few changes in the section "how layout should support patient flow" are made. Also, some elements of the framework are retained, although they have not been discussed, which lays a basis for further research. Thus, the framework presented is on a superficial level, and dependent on each case there may be several constraints of the operational workflows that has not been discussed, that can constrain whether or not different suggestions on how layouts should support patient flow are feasible. Anyway, the different components of layout that can affect the patient flow are: length of flow, clarity of flow, predictability of flow, flexibility and coordination capabilities, are all important to consider to support the different aspects of patient flow in outpatient departments. As mentioned, the revised framework is presented in Table 26. Lastly, as the framework presented is mostly based on general layout objectives, it may be applicable for other patient flows than patient flow in outpatient departments as well.

Table 26: Revised framework for layout design supporting patient flow in outpatient departments

<table>
<tr><th></th><th>Patient flow</th><th>Layout</th></tr>
<tr><td>Definition</td><td>The movement of patients through a set of locations in a healthcare facility.</td><td>Physical arrangement of transforming resources, determining how patients and some transforming resources, such as staff, move.</td></tr>
<tr><td>Patient flow constraints</td><td>Components of a system that can affect the patient flow:

Available capacity
Resources: health personnel, rooms, equipment, etc., whereof scarce resources are doctors and to some extent nurses.
Patient flow constraints: capacity shortage, lack of coordination of capacity, underutilization of capacity, patient waiting time.

Process variabilities
Variation in arrival: patients, doctors, nurses, information, equipment, material, etc.
Variation in processing times: Time to serve a patient, waiting for support services, room and equipment setup or down time.
Patient flow constraints: causes underutilization of resources, patient wait time, staff overtime.</td><td>Components of a layout that can affect the patient flow:

Length of flow
Long distances and complex flows causes long flows, and is affected by how related activities are located relative to each other. Long flows increase transportation distances for patients (risk of adverse effects, throughput time) and staff (lost service time).

Clarity of flow
To what degree it is clear for both patients and staff where to move within a facility.

Predictability of flow
To what degree operational workflows are considered in layout design, and unpredicted flows are avoided.

Flexibility
To what degree the layout has taken future needs into consideration, which can affect potential future flows.

Coordination capabilities
To what degree supervision and coordination of activities are facilitated by layout.</td></tr>
<tr><td>How layout should support patient flow</td><td colspan="2">To support patient flow in outpatient departments, a layout should:
• Co-locate with related patient activities, such as departments and rooms, but also registration and waiting areas, when feasible, to reduce distances traveled by patients, reduce risk of adverse effects and allow for short throughput times.
• Facilitate for efficient use of workers, rooms, and equipment, especially scarce resources, by shortening distances, allowing for more time spent on care. Shortening distances between related activities also facilitates communication, coordination, teamwork and productivity.
• Have a well-signposted flow, clear and evident to patients and staff alike.
• Understand operational workflows before deciding on a layout, such as close attention to capacity requirements when locating resources, to avoid unpredictable flows.
• Take potential future needs and flows into account to allow for flexibility.
• Support supervision and coordination of activities.</td></tr>
</table>

7 Conclusion

The conclusion addresses how the research objective was answered, and the thesis' limitations and future research. For the reader's convenience, relevant information is repeated. The research objective and questions, the research approach used to answer the research objective, how the research objective has been answered, and contributions to research, is presented in chapter 7.1. Limitations and future research is presented in chapter 7.2.

7.1 Research Objective

The objective of this thesis was to develop a framework for layout design supporting patient flow in outpatient departments. To support patient flow is to facilitate high patient throughput volume, short patient throughput time, low patient waiting time, high personnel utilization, low personnel overtime (Koo et al., 2010), and short travel distances for patients and personnel (Karvonen et al., 2017). In addition, patient flow in outpatient departments is not only limited to the movement inside an OPD, but the movements of the outpatients as they may require related services during a visit to the hospital, which may lay outside an OPD as well. To answer the research objective, two research questions were developed:

RQ1: What are the characteristics of patient flow in outpatient departments?

RQ2: How can layout support patient flow?

The topics investigated in this thesis are patient flow in outpatient departments, patient flow constraints, and layout. The research design consisted of a literature study and case study. The literature study was conducted to find relevant research with the aim of providing insight on the topics studied, and to develop a preliminary framework. The case study was performed, including three case OPDs, with the aim of gaining a deeper insight on the topics studied with real world examples. Analyzation was done by seeing the case information in the light of the literature study, as well as using patient flow analysis, with a basis in Burbidge's production flow analysis, to structure and better understand the patient flow in OPD1. Further, in the discussion, the findings from the analysis was discussed towards the literature, and the findings were seen in a broader context than just the case OPDs. The discussion ends with presenting a revised framework.

To answer the research objective, the two research questions created the groundwork for the development of the framework. The first research question concerned investigating patient flow in outpatient departments and patient flow constraints. Some outpatients require only one service during a visit, while other patients require multiple services during a visit. In addition to the services delivered, the patient may have to register and wait for the different services. The amount of activities, and the different activities' respective location, will have an implication of how patients move throughout a facility. Concerning patient flow constraints, health personnel, especially doctors, are seen as scarce resources, and thus the bottleneck determining the throughput volume in OPDs. The second research question concerned gaining insight on how layout can support patient flow. General layout objectives concerning flow, combined with the information gathered from research question one, found that layout should consider the following components of a layout to support patient flow: length of flow, clarity of flow, predictability of flow, flexibility and coordination capabilities. The different components more or less concern length of flow. As health personnel are seen as scarce resources, it is just as important to consider flow of personnel, as flow of patients, to support patient flow. Grouping of rooms and departments with related activities when feasible, can be beneficial for both patients and health personnel as it can reduce the length of flow. For patients, reducing length of flow allows for reduced risk of adverse effects and shorter throughput times. For health personnel, reducing length of flow allows for more time spent on care, and facilitates communication, coordination, teamwork and productivity.

The result of the master's thesis is a framework for layout design supporting patient flow in outpatient departments, as a means of answering the research objective. It provides a structured overview, and entails a definition of patient flow and layout, components of a system and of a layout that can affect the patient flow, and how layout should support the patient flow in outpatient departments. Concerning contribution to research, the thesis adds to the research on layout combined with patient flow in outpatient departments, as well as introducing a framework for layout design supporting patient flow in outpatient departments. The proposed framework is seen in a general context, for not to be only relevant for the case OPDs studied. As the proposed framework is mainly based on general layout objectives, the framework may be applicable for other patient flows in hospitals as well. For Sykehusbygg HF, the main contact company, the framework can be used as a supportive tool in layout design, in terms of arranging departments, rooms, and registration and waiting areas within hospitals, to support the patient flow in outpatient departments.

7.2 Limitations and Further Research

A limitation of the thesis is the small number of case OPDs. Three case OPDs provide an indication of the patient flow in OPDs and the layout it takes place in, however, do not give a complete picture for all OPDs. In addition, the case OPDs are all orthopedic outpatient departments, whereas other OPDs have different flows, depending on the services required. Also, when collecting information, only nurses and medical secretaries were interviewed, which may not represent all possible viewpoints, such as doctors' and patients' viewpoints. Also, the thesis is mainly focused on the physical flow of patients throughout a facility, although other flows, such as health personnel, material, and equipment flow, can have an impact on the different aspects of patient flow. Thus, there may be other important considerations for how layout can support patient flow, which has not been covered in this thesis, which lays the basis for further investigation, such as a more in-depth understanding of health personnel flow.

Another limitation is the use of samples in the production flow analysis used to study the current patient flow in OPD1. For such an analysis, samples can lead to incomplete results, as they do not ensure to find all patient route numbers and all their inter-process transfers (Burbidge, 1989). For instance, the observation in the case study only concerned the movement of patients that took place close to OPD1, and not patients going to other related activities to OPD1, such as occupational therapy, which leads to an incomplete picture of the patient flow.

Another limitation is that the literature study had to be ended due to timely constraints. For instance, further investigations concerning patient flow and layout could have been conducted, such as studying other types of hospital departments' patient flow and the layout it takes place within, and extract relevant information for layout design supporting patient flow in outpatient departments. Further research concerning layout and patient flow in outpatient departments thus may undertake an investigation of layout and patient flow in other hospital departments.

Besides this, the findings from the analysis indicate that there are other areas than layout that should be considered for the case OPDs, which may be studied further. For OPD1, there seems to be an improvement area regarding coordination of the scheduling of OPD1 and X-ray appointments. Also, it would be beneficial to reduce no-show patients to facilitate a higher throughput volume. Thus, further improvements for the case OPDs should focus on topics such as improving scheduling and reducing no-show patients. This can also be topics for future research, however, several studies are already concerning such topics in the literature (Hong et al., 2013).

Finally, the proposed framework is on a superficial level, and does not concern specific in-depth layout design considerations. It does provide an overview of how layout can support patient flow, but not specific suggested solutions, and what effects these will have. For example, the thesis does not cover to what extent it is possible to serve more patients with an appropriate layout. Thus, further research should focus on to what degree different layout considerations can support patient flow when it comes to the arrangement of departments, rooms, and registration and waiting areas within hospitals. This type of research may be more of a quantitative analysis, to be able to measure the effects of different scenarios. In addition, it should be investigated whether or not different solutions are feasible from an economical perspective.

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Appendix A

Tabell 3.1 Andelsvis fordeling av nyhenviste, ordinært avviklede og ventende på omsorgsnivå. 2. tertial 2012–2014

Sektor/omsorgsnivå			Nyhenviste		Ord. Avviklede			Ventende (31.08)		
		2. tert 2012	2. tert 2014 2. tert 2013	2. tert 2012	2. tert 2013	2. tert 2014	2. tert 2012	2. tert 2013	2. tert 2014	
Somatikk	Poliklinikk	88	89	90	88	89	90	88	89	90
	Dagbehandling	6	6	5	6	6	5	6	6	6
	Innleggelse	5	5	4	5	5	5	5	4	4
PHV-V	Poliklinikk	90	91	93	90	91	92	90	90	94
	Dagbehandling	1	0	1	1	0	1	1	0	1
	Innleggelse	9	8	6	9	8	8	9	10	5
PHV-BU	Poliklinikk	98	99	99	98	99	99	98	99	99
	Dagbehandling	1	1	1	1	1	1	1	1	1
	Innleggelse	1	1	1	1	1	1	1	1	0
TSB	Poliklinikk	59	63	74	59	63	69	59	52	58
	Dagbehandling	1	1	0	1	1	1	1	1	0
	Innleggelse	40	36	25	40	36	31	40	48	41

(Helse- og omsorgsdepartementet, 2015)

Appendix B

From: Helse- og omsorgsdepartementet (2015), SHEET 1/3

Tabell 3.2 Antall ordinært avviklede etter ventetid, andel med ventetid over tre måneder og andel etter somatiske fagområder. 2. tertial 2014

Fagområde	<1 mnd	1–2 mnd	3–5 mnd	6–11 mnd	1–4 år	>4 år	Totalt	Antall over 3 mnd	Andel over 3 mnd
Patologi	2	1	2	0	0	0	5	2	40 %
Anestesiologi	365	523	346	234	3	0	1471	583	40 %
Ortopedisk kirurgi	7314	15328	10105	2676	459	8	35890	13248	37 %
Kjevekirurgi og munnhulesykdom	644	877	510	300	63	1	2395	874	36 %
Øre-nese-hals sykdommer	6906	9852	6467	2216	199	5	25645	8887	35 %
Yrkes- og arbeidsmedisin	54	222	120	18	2	0	416	140	34 %
Plastikkkirurgi	1635	1387	865	485	162	11	4545	1523	34 %
Karkirurgi	1327	1529	761	433	214	0	4264	1408	33 %

From: Helse- og omsorgsdepartementet (2015), SHEET 2/3

Tabell 3.2 Antall ordinært avviklede etter ventetid, andel med ventetid over tre måneder og andel etter somatiske fagområder. 2. tertial 2014

Fagområde	<1 mnd	1–2 mnd	3–5 mnd	6–11 mnd	1–4 år	>4 år	Totalt	Antall over 3 mnd	Andel over 3 mnd
Øyesykdommer	3847	6159	2655	1166	358	4	14189	4183	29 %
Thoraxkirurgi	123	110	66	23	5	0	327	94	29 %
Nevrologi	2547	5525	2080	646	254	15	11067	2995	27 %
Nevrokirurgi	513	1024	465	79	13	6	2100	563	27 %
Lungesykdommer	2713	2600	1580	349	14	0	7256	1943	27 %
Urologi	3400	6075	2568	516	112	8	12679	3204	25 %
Immunologi og transfusjonsmedisin	2	1	0	1	0	0	4	1	25 %
Generell indremedisin	687	532	200	152	38	0	1609	390	24 %
Barnekirurgi	207	550	211	18	2	0	988	231	23 %
Endokrinologi	1662	2804	831	441	69	0	5807	1341	23 %
Generell kirurgi	4087	3461	1318	721	192	4	9783	2235	23 %
Gastroenterologisk kirurgi	4170	4289	1632	604	184	4	10883	2424	22 %
Habilitering barn og unge	80	382	116	15	1	0	594	132	22 %
Fysikalsk medisin og (re)habilitering	2178	4301	1612	194	32	0	8317	1838	22 %
Hud og veneriske sykdommer	3470	3737	1617	334	59	4	9221	2014	22 %
Habilitering voksne	120	339	100	26	2	0	587	128	22 %
Revmatiske sykdommer	2555	4341	1262	507	138	1	8804	1908	22 %
Transplantasjon, utredning og kirurgi	10	27	10	0	0	0	47	10	21 %
Nukleærmedisin	1	3	1	0	0	0	5	1	20 %
Nyresykdommer	524	674	221	46	12	0	1477	279	19 %
Geriatri	337	751	220	22	4	0	1334	246	18 %
Hjertesykdommer	5398	10185	2630	516	206	7	18942	3359	18 %
Barnesykdommer	2909	5755	1517	286	21	1	10489	1825	17 %
Klinisk nevrofysiologi	1770	2602	805	76	9	0	5262	890	17 %
Medisinsk genetikk	773	458	146	60	40	0	1477	246	17 %
Fordøyelsessykdommer	6820	7751	1837	442	94	3	16947	2376	14 %

From: Helse- og omsorgsdepartementet (2015), SHEET 3/3

Tabell 3.2 Antall ordinært avviklede etter ventetid, andel med ventetid over tre måneder og andel etter somatiske fagområder. 2. tertial 2014

Fagområde	<1 mnd	1–2 mnd	3–5 mnd	6–11 mnd	1–4 år	>4 år	Totalt	Antall over 3 mnd	Andel over 3 mnd
Kvinnesykdommer og elektiv fødselshjelp	17188	13114	3263	658	66	0	34289	3987	12 %
Infeksjonssykdommer	1376	590	207	9	3	1	2186	220	10 %
Blodsykdommer	1012	747	150	15	2	0	1926	167	9 %
Radiologi	22	11	1	0	0	1	35	2	6 %
Onkologi	1780	540	83	23	8	2	2436	116	5 %
Mamma- og para-/ tyreoideakirurgi	1479	731	74	30	4	0	2318	108	5 %
Rehabilitering	11	6	0	0	0	0	17	0	0 %
Klinisk kjemi	1	0	0	0	0	0	1	0	0 %
Habilitering	0	0	0	0	0	0	0	0	
Klinisk farmakologi	0	0	0	0	0	0	0	0	
Medisinsk mikro-biologi	0	0	0	0	0	0	0	0	
Totalt alle fagområder	92019	119894	48654	14337	3044	86	278034	66121	24%

Appendix C

PRESTUDY REPORT SHEET 1/10

Principles for efficient capacity utilization of outpatient rooms

Pre-Study Report – 23.02.18
Student: Nathalie B. Madsen
Supervisor: Marco Semini
Co-supervisor: Aili Biriita Hætta Stangeland

Introduction

Background

There have been several trends when it comes to infrastructure and organization of the Norwegian health sector. Since the end of the 1980s, the policy has aimed at replacing relatively expensive hospitalizations with less costly outpatient and day treatments. This has led to a decrease in the number of hospital beds and an increase in the use of outpatient- and day treatments, often thanks to new treatment options (Ringard et al., 2013). The ratio between outpatient- and inpatient treatment increased from 4:1 in 1990 to 6:1 in 2011 (Rønningen and Helsedirektoratet Norge, 2016). The number of patients receiving outpatient treatments increased with 4,3% in the period 2011-2015, and only in the period 2014-2015 the increase was by 2,2% (Rønningen and Helsedirektoratet Norge, 2016). Also, the average waiting time for the somatic sector has increased with 5 days from 2006 to 2013, and in the time period 2008 to 2012 the budgeted activity growth barely kept up with the increased demand for specialist health care services (Helse- og omsorgsdepartementet, 2015).

The waiting times for elective treatment, i.e. non-acute planned treatment, in Norwegian hospitals are long (Ringard et al., 2013). Outpatients are the majority type of patients waiting for elective treatment (Helse- og omsorgsdepartementet, 2015), see Appendix B. The waiting time is an important indicator on availability and quality in the health care services, as long waiting times can reduce the patients' opportunities to achieve maximum health outcomes of the treatment and can also indicate a capacity problem in the hospitals (Helse- og omsorgsdepartementet, 2015). In 2014, the somatic disciplines orthopedic surgery and ear-nose-throat illnesses were among the top three disciplines with the highest number of elective patients, and among top five disciplines with the highest percentage of waiting times above 3 months for elective treatment (Helse- og omsorgsdepartementet, 2015), see Appendix C.

Historical figures show that there has been a low capacity utilization of outpatient departments and day units in many hospitals (Myrbostad et al., 2006). Several hospitals informed about 990 000 performed outpatient consultations in 910 outpatient rooms in 2005. Within the planned opening hours, the room capacity available should have made it possible to perform approximately 1,6 million consultations if fully utilized, however the actual utilization was approximately 62% (Myrbostad et al., 2006).

In outpatient departments, it is distinguished between two types of treatment rooms. General rooms with standardized equipment, meant for most examinations and treatments; and specialized rooms with specialized equipment, meant for particular treatments or procedures. Some outpatient departments require more specialized rooms than other departments (Lauvsnes and Myrbostad, 2004). The low utilization could be explained by specialized rooms being more difficult to use full-time (Myrbostad et al., 2006, Lauvsnes and Myrbostad, 2004). However, it shows a potential for more efficient organization of outpatient departments (Myrbostad et al., 2006). Some outpatient departments that require specialized rooms are Eye, Neurology, Ear-Nose-Throat, Gynecology and Orthopedic (Lauvsnes and Myrbostad, 2004, Vestre Viken HF, 2014). One possible way of achieving a higher utilization of specialized rooms is by using them for general examination in addition to their special purpose (Lauvsnes and Myrbostad, 2004).

A study by Konstante and Tradin (2015) identified several reasons for lack of areas for examination and treatment rooms in the outpatient departments at St. Olavs Hospital. These reasons were changes in treatment and new treatment methods, changes in work processes (an increase in number of procedures conducted by nurses), and an increased activity in outpatient departments while the dimensioned degree of utilization was not reached (Konstante and Tradin, 2015). Adaption to changes in treatment and work processes requires that outpatient departments are planned with a high degree of generalism and flexibility (Konstante and Tradin, 2015). When planning area, variation of patient load must be considered and give flexibility to how the area should be utilized (Vestre Viken HF et al., 2015).

Long-term perspectives on resource and capacity planning are in the focus of the design of hospitals (Arnolds and Nickel, 2015). Although decisions made on a strategic (long term) and operational (short term) level are made by different decision makers, the hierarchical structure and interdependencies among such decisions impose restrictions and limitations on the success of a system (Vandatzad et al., 2016). For instance, the strategic decisions will significantly influence tactical and operational activities (Vandatzad et al., 2016, Arnolds and Nickel, 2015), e.g. scheduling is performed under the fixed layout (Morinaga et al., 2016). Further, tactical and operational decisions will also affect the resource utilization and accessibility of care services (Ahmadi-Javid et al., 2017).

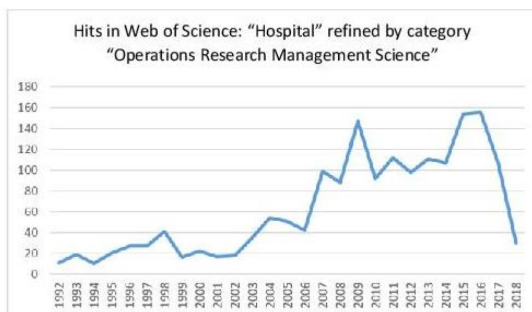

Figure 1: Increase in hospital operations management literature

In 1996, Butler et al. stated that there is a wealth of research in both operations management and strategic planning in hospitals, but that there is little research on the integration of these two topics (Butler et al., 1996). There has been an increase in science combining hospital subjects and operations management in the last 20 years, see Figure 1. Accodring to Xie and Lawley (2015) major operations research (OR) and industrial engineering (IE) journals are increasingly publishing more papers in healthcare. "Innovative operations research (OR) techniques have been developed for a wide range of healthcare applications such as operating room planning, emergency department staffing, breast cancer screening, radiotherapy treatment planning, home healthcare planning, long-term care planning and scheduling" (Xie and Lawley, 2015). According to Vandatzad et al. (2016), very few studies focusing on patient flow consider integrating strategic, tactical and/or operational decisions in one framework. It is crucial to develop a holistic framework in order to integrate the architectural aspects with the flow of patients, providers and goods (Vandatzad et al., 2016).

The literature indicates that there are challenges related to outpatient room utilization and that there is a need for holistic frameworks on patient flow that considers decisions on strategic, tactical and operational level. Specialized rooms seems to be utilized less than generalized rooms in outpatient departments. However, there is a need for flexibility, and the utilization of outpatient rooms could be higher. Decisions on strategic, tactical and operational level will each influence the facilitation for efficient outpatient room utilization.

Problem description

The number of outpatient treatments are increasing, waiting times for outpatient treatment are long, and there is a potential to increase the utilization of outpatient departments in Norwegian hospitals. Specialized rooms are being utilized less than general rooms. Adaption to changes in treatment and work processes requires that outpatient departments are planned with a high degree of generalism and flexibility. The literature indicates that there is a need for a holistic framework that considers aspects on strategic, tactical and operational level with regard to ensuring efficient utilization of outpatient rooms.

Research objective

The objective of the project is to identify challenges and opportunities regarding room utilization, and important aspects on strategic, tactical and operational level for an efficient room utilization in outpatient departments with general and specialized rooms. The outcome of the study will be a framework, consisting of principles on strategic, tactical and operational level, for ensuring efficient room utilization in outpatient departments with general and specialized rooms.

Preliminary research questions

1. What are the challenges and opportunities related to room utilization on strategic, tactical and operational level, in outpatient departments with general and specialized rooms?

2. What are the key principles on strategic, tactical, and operational level for ensuring sufficient room utilization in outpatient departments with general and specialized rooms?

Research methodology

As the research will consist of collecting both quantitative and qualitative data to answer the research objective, mixed methods research will be used in this master thesis. Mixed methods is a combination of qualitative and quantitative methods, and involve collection, analysis, and integration of quantitative and qualitative data in a single or multiphase study (Hesse-Biber, 2010). The study design is shown in Figure 2. For the multiple case study, an explanatory sequential design will be used, which is a two-phased mixed methods approach where quantitative data is used to provide a general picture, and then qualitative data is collected to explain the general picture (Creswell, 2012).

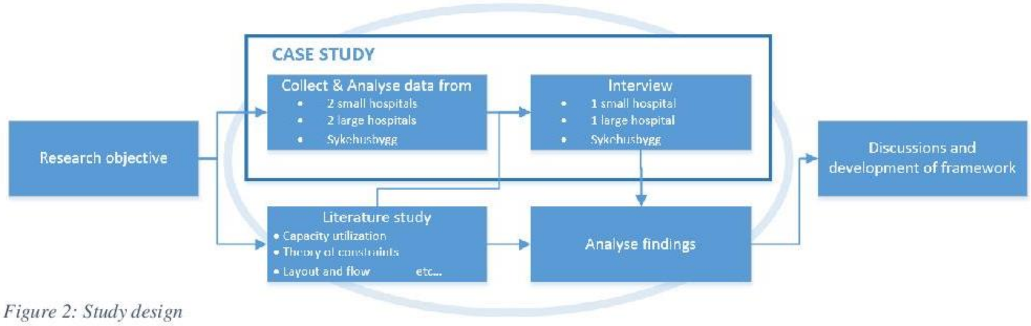

Figure 2: Study design

A literature study will be conducted to get knowledge on the topic within both operations management and service operations management. The literature study will be explorative, and will focus on topics relevant to utilization on a strategic, tactical and operational level: capacity utilization, resource utilization, theory of constrains, layout and flow planning, scheduling, etc.

Multiple cases will be studied. Although the case study consists of Sykehusbygg and multiple hospitals, it is not a cross-case study. Thus, the different cases will not be compared to each other. The reasoning for using multiple cases is to get a better understanding of similarities and differences, knowledge and insight of today's situation, to get a holistic view, and not rely entirely on one source, thus strengthening the findings.

Approach to answer research question one

Before finding out challenges and opportunities, degree of utilization of outpatient departments today will be investigated. Opening hours data from outpatient departments in 2 small and 2 large hospitals will be collected. To start with, one type of outpatient department and analyzed. Planned and actual capacity utilization will be compared.

To investigate the tactical and operational challenges and opportunities, interviews will be performed at one large and one small hospital, at predetermined type of outpatient department. Among the inputs to the interview guide will be degree of utilization. The interview will also try to identify the utilization of general versus specialized rooms.

To investigate strategic challenges and opportunities, documents from Sykehusbygg on planning of outpatient departments will be collected and analyzed. Based on the information retrieved from the documents, an interview guide will be developed and Sykehus will then be interviewed.

Information found so far in the literature study will also be a supplement to developing both interview guides (strategical and tactical/operational). If necessary, second or multiple interview rounds might take place.

Approach to answer research question two

The literature study will investigate relevant topics in operations management, and will focus on the aspects on strategic, tactical and operational level related to utilization. Findings from the literature study and research question one will be combined and analyzed to identify key principles on strategic, tactical and operational level, for ensuring sufficient room utilization in outpatient departments with general and specialized rooms. This will make the basis for discussion and development of the framework as discussed in the research objective.

Preliminary literature

The literature used for the pre-study report are health care documents, hospital building project reports, hospital operations management literature, operations management literature, and methodology literature.

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Project Plan

Description of tasks

Task	Description	Other information
Methodology	- Write methodology to be used in the thesis	Mixed methods, multiple case study, ….
Literature study	- Literature search and review - Writing summary	Layout planning, long term capacity planning, scheduling, resource utilization, link between strategic, tactical and operational planning
Collection and analyzation of data	- Collect data - Analyse data - Write summary of data findings	1. Hospital: Data on opening hours, number and duration of treatments, at one type of outpatient department with general and specialized rooms. Data from two small and two large hospitals. 2. Sykehusbygg: Documents on planning of outpatient departments.
Interview	- Arrange interview participants and time - Make interview guide - Conduct interview - Write summary of interview	HOSPITAL - Find possible and appropriate outpatient department with general and specialized rooms to conduct interview with. - One certain type of outpatient department at one small and one large hospital will be interviewed. - How is it done today, what works well, what are the challenges, important considerations, future needs, etc. SYKEHUSBYGG - Interview regarding considerations on strategic level
Analyze findings	- Combine and analyze findings from case study and literature	
Discussion	- Discussion of analyzed findings	
Development of framework	- Develop a framework based on findings	Size of rooms? Equipment? Use of specialized rooms for general purposes? Scheduling of appointments? etc.
Conclusion	- Write Conclusion of master thesis	
Revise	- Revise thesis for consistency, spelling errors, etc.	
Deliver	- Delivery and formalities (e.g. physical hand in, etc)	

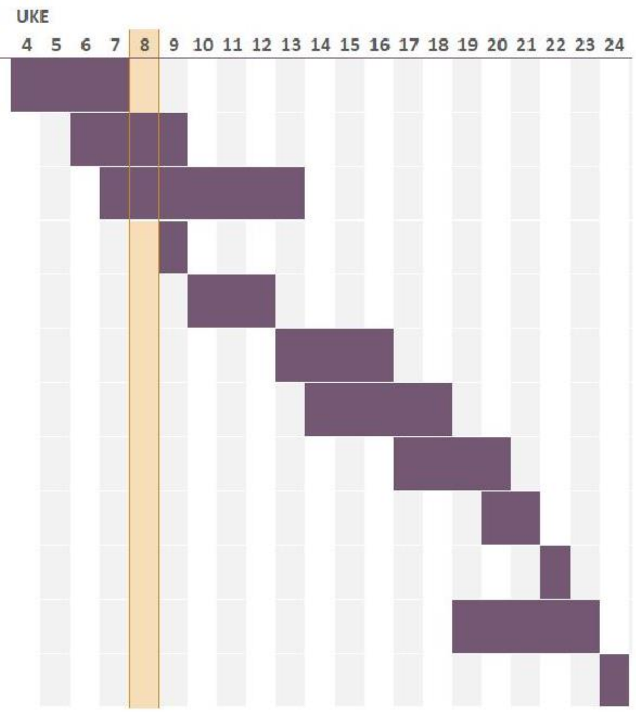
6

Estimated workload

For the project, the plan is to work for 8 hours a day, 5 times a week in the project period. The project period lasts for 21 weeks, but in the Easter holidays, one week break will take place in week 13. Sometimes the project might require more hours of work in certain periods due to deadlines and amount of work. In total, including the pre-study report, it is estimated that the project will use 800 hours, 100 days, and 20 weeks. The project started 22.january, and is planned to be finished 18.june 2018.

Schedule/Gantt diagram

ACTIVITY	START UKE	VARIGHET
Prelim. research	4	4
Method	6	4
Literature study	7	7
Data collection	9	1
Data analysis	10	3
Interview	13	4
Analyse findings	14	5
Framework	17	4
Discussion	20	2
Conclusion	22	1
Revise	19	5
Deliver	24	1



Appendix A

Tabell 8.1 Antall pasienter per 1 000 innbyggere etter behandlingsnivå og alder i 2011-2015.

		2011	2012	2013	2014	2015	Prosent endr. 2011-2015	Prosent endr. 2014-2015
Alle pasienter	Totalt	354	353	353	358	363	2,5	1,6
	67-79 år	536	537	537	541	548	2,3	1,4
	80 år og eldre	644	648	649	657	667	3,7	1,6
Innlagte pasienter	Totalt	118	117	115	114	113	-4,1	-1,1
	67-79 år	204	203	200	198	196	-3,6	-0,6
	80 år og eldre	346	349	346	346	348	0,6	0,6
Polikliniske pasienter	Totalt	321	321	322	328	335	4,3	2,2
	67-79 år	498	500	503	508	517	3,9	1,8
	80 år og eldre	520	528	532	544	558	7,3	2,6

(Rønningen and Helsedirektoratet Norge, 2016)

Appendix B

Tabell 3.1 Andelsvis fordeling av nyhenviste, ordinært avviklede og ventende på omsorgsnivå. 2. tertial 2012–2014

Sektor/omsorgsnivå			Nyhenviste			Ord. Avviklede			Ventende (31.08)	
		2. tert 2012	2. tert 2014 2. tert 2013	2. tert 2012	2. tert 2013	2. tert 2014	2. tert 2012	2. tert 2013	2. tert 2014	
Somatikk	Poliklinikk	88	89	90	88	89	90	88	89	90
	Dagbehandling	6	6	5	6	6	5	6	6	6
	Innleggelse	5	5	4	5	5	5	5	4	4
PHV-V	Poliklinikk	90	91	93	90	91	92	90	90	94
	Dagbehandling	1	0	1	1	0	1	1	0	1
	Innleggelse	9	8	6	9	8	8	9	10	5
PHV-BU	Poliklinikk	98	99	99	98	99	99	98	99	99
	Dagbehandling	1	1	1	1	1	1	1	1	1
	Innleggelse	1	1	1	1	1	1	1	1	0
TSB	Poliklinikk	59	63	74	59	63	69	59	52	58
	Dagbehandling	1	1	0	1	1	1	1	1	0
	Innleggelse	40	36	25	40	36	31	40	48	41

(Helse- og omsorgsdepartementet, 2015)

Appendix C

Tabell 3.2 Antall ordinært avviklede etter ventetid, andel med ventetid over tre måneder og andel etter somatiske fagområder, 2. tertial 2014

Fagområde	<1 mnd	1–2 mnd	3–5 mnd	6–11 mnd	1–4 år	>4 år	Totalt	Antall over 3 mnd	Andel over 3 mnd
Patologi	2	1	2	0	0	0	5	2	40 %
Anestesiologi	365	523	346	234	3	0	1471	583	40 %
Ortopedisk kirurgi	7314	15328	10105	2676	459	8	35890	13248	37 %
Kjevekirurgi og munnhulesykdom	644	877	510	300	63	1	2395	874	36 %
Øre-nese-hals sykdommer	6906	9852	6467	2216	199	5	25645	8887	35 %
Yrkes- og arbeidsmedisin	54	222	120	18	2	0	416	140	34 %
Plastikkkirurgi	1635	1387	865	485	162	11	4545	1523	34 %
Karkirurgi	1327	1529	761	433	214	0	4264	1408	33 %
Øyesykdommer	3847	6159	2555	1166	358	4	14189	4183	29 %
Thoraxkirurgi	123	110	66	23	5	0	327	94	29 %
Nevrologi	2547	5525	2080	646	254	15	11067	2995	27 %
Nevrokirurgi	513	1024	465	79	13	6	2100	563	27 %
Lungesykdommer	2713	2600	1580	349	14	0	7256	1943	27 %
Urologi	3400	6075	2568	516	112	8	12679	3204	25 %
Immunologi og transfusjonsmedisin	2	1	0	1	0	0	4	1	25 %
Generell indremedisin	687	532	200	152	38	0	1609	390	24 %
Barnekirurgi	207	550	211	18	2	0	988	231	23 %
Endokrinologi	1662	2804	831	441	69	0	5807	1341	23 %
Generell kirurgi	4087	3461	1318	721	192	4	9783	2235	23 %
Gastroenterologisk kirurgi	4170	4289	1632	604	184	4	10883	2424	22 %
Habilitering barn og unge	80	382	116	15	1	0	594	132	22 %
Fysikalsk medisin og (re)habilitering	2178	4301	1612	194	32	0	8317	1838	22 %
Hud og veneriske sykdommer	3470	3737	1617	334	59	4	9221	2014	22 %
Habilitering voksne	120	339	100	26	2	0	587	128	22 %
Revmatiske sykdommer	2555	4341	1262	507	138	1	8804	1908	22 %
Transplantasjon, utredning og kirurgi	10	27	10	0	0	0	47	10	21 %
Nukleærmedisin	1	3	1	0	0	0	5	1	20 %
Nyresykdommer	524	674	221	46	12	0	1477	279	19 %
Geriatri	337	751	220	22	4	0	1334	246	18 %
Hjertesykdommer	5398	10185	2630	516	206	7	18942	3359	18 %
Barnesykdommer	2909	5755	1517	286	21	1	10489	1825	17 %
Klinisk nevrofysiologi	1770	2602	805	76	9	0	5262	890	17 %
Medisinsk genetikk	773	458	146	60	40	0	1477	246	17 %
Fordøyelsessykdommer	6820	7751	1837	442	94	3	16947	2376	14 %
Kvinnesykdommer og elektiv fødselshjelp	17188	13114	3263	658	66	0	34289	3987	12 %
Infeksjonssykdommer	1376	590	207	9	3	1	2186	220	10 %
Blodsykdommer	1012	747	150	15	2	0	1926	167	9 %
Radiologi	22	11	1	0	0	1	35	2	6 %
Onkologi	1780	540	83	23	8	2	2436	116	5 %
Mamma- og para-/tyreoideakirurgi	1479	731	74	30	4	0	2318	108	5 %
Rehabilitering	11	6	0	0	0	0	17	0	0 %
Klinisk kjemi	1	0	0	0	0	0	1	0	0 %
Habilitering	0	0	0	0	0	0	0	0	
Klinisk farmakologi	0	0	0	0	0	0	0	0	
Medisinsk mikrobiologi	0	0	0	0	0	0	0	0	
Totalt alle fagområder	92019	119804	48654	14337	3044	86	278034	66121	24%

Helse- og omsorgsdepartementet, 2015)

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Appendix D

REK APPLICATION (REK SØKNAD) SHEET 1/2

REK
REGIONALE KOMITEER FOR MEDISINSK OG HELSEFAGLIG FORSKNINGSETIKK

Region:	Saksbehandler:	Telefon:	Vår dato:	Vår referanse:
REK sør-øst	Henriette Snilsberg	22845531	02.07.2018	2018/973/REK sør-øst B
			Deres dato:	Deres referanse:
			07.05.2018	

Vår referanse må oppgis ved alle henvendelser

Aili Biriita Bertnum
Norges teknisk-naturvitenskapelige universitet

2018/973 Pasientflyt i helsesystemet

Vi viser til søknad om forhåndsgodkjenning av ovennevnte forskningsprosjekt. Søknaden ble behandlet av Regional komité for medisinsk og helsefaglig forskningsetikk (REK sør-øst) i møtet 06.06.2018. Vurderingen er gjort med hjemmel i helseforskningsloven § 10.

Forskningsansvarlig: Norges teknisk-naturvitenskapelige universitet
Prosjektleder: Aili Biriita Bertnum

Prosjektomtale (original):
Prosjektets formål er å benytte logistikk og produksjonsledelse til å utvikle og forbedre kunnskap og kompetanse innen pasientflyt i det norske helsevesenet. Prosjektet er todelt. Det første delprosjektet fokuserer på regional pasientlogistikk der sykehus og kommunale helsevesen må samarbeide for å sørge for effektiv flyt og sikker behandling av pasienter. Funnene vil benyttes til å foreslå en effektiv struktur av sykehusene, kommunale helsevesen og distriktsmedisinske senter. Det andre delprosjektet fokuserer på materialflyt innad i sykehusene, der formålet er å undersøke barrierene for effektiv transport av materialer. Forskningen vil gjennomføres i samarbeid med Sykehusbygg, sykehus og kommunale helsetjenester. Det vil utføres casestudier i det norske helsevesenet for å få en forståelse av dagens helselogistikk, og for å kunne identifisere og analysere ineffektiviteter og flaskehalser i pasient- og materialflyt.

Komiteens vurdering
Hensikten med prosjektet oppgis å være at man skal undersøke logistikken og organiseringen av driften innen pasientflyt i helsevesenet.

Helseforskningsloven gjelder for medisinsk og helsefaglig forskning, det vil si «virksomhet som utføres med vitenskapelig metodikk for å skaffe til veie ny kunnskap om helse og sykdom», jf. helseforskningsloven § 2, jf. § 4. Komiteen anser dermed at prosjektet ikke omfattes av helseforskningslovens virkeområde. Det kreves ingen forhåndsgodkjenning fra REK for å gjennomføre prosjektet.

Det søkes om fritak fra taushetsplikt etter helsepersonelloven § 29. Slik REK forstår prosjektet, skal ikke prosjektet ha tilgang til pasientopplysninger. Man skal heller ikke observere behandlingen – kun gjøre observasjoner i gangområdet. Opplysningene skal være anonyme, og komiteen kan derfor ikke se at dispensasjon er nødvendig i dette forskningsprosjektet.

Vedtak
Etter søknaden fremstår prosjektet ikke som medisinsk eller helsefaglig forskning, og det faller derfor utenfor helseforskningslovens virkeområde, jf. § 2.

Prosjekter som faller utenfor helseforskningslovens virkeområde kan gjennomføres uten godkjenning av

Besøksadresse:
Gullhaugveien 1-3, 0484 Oslo

Telefon: 22845511
E-post: post@helseforskning.etikkom.no
Web: http://helseforskning.etikkom.no/

All post og e-post som inngår i saksbehandlingen, bes adressert til REK sør-øst og ikke til enkelte personer

Kindly address all mail and e-mails to the Regional Ethics Committee, REK sør-øst, not to individual staff

REK. Det er institusjonens ansvar på å sørge for at prosjektet gjennomføres på en forsvarlig måte med hensyn til for eksempel regler for taushetsplikt og personvern.

Komiteens avgjørelse var enstemmig.

Klageadgang
Du kan klage på komiteens vedtak, jf. helseforskningsloven § 10 og forvaltningsloven § 28 flg. Klagen sendes til REK sør-øst. Klagefristen er tre uker fra du mottar dette brevet. Dersom vedtaket opprettholdes av REK sør-øst, sendes klagen videre til Den nasjonale forskningsetiske komité for medisin og helsefag for endelig vurdering.

Med vennlig hilsen

Ragnhild Emblem
Prof. dr. med
Leder REK sør-øst B

Henriette Snilsberg
komitésekretær

Kopi til:aili.b.bertnum@ntnu.no;
Norges teknisk-naturvitenskapelige universitet ved øverste administrative ledelse: postmottak@adm.ntnu.no

Appendix E

INDIVIDUAL PATIENT MOVEMENT DATA

PATIENTS ONLY GOING TO OPD1 SHEET 1/5

		GCR										
CATEGORY →	A	A	A	A	A	A	A	A	A	B	B	B
WHAT ↓ #.→	43	17	40	41	93	95	102	185	193	11	45	83
Self check-in		1	1		1		1					1
Counter	1,6	5	5	1,5	4	1,5	5	2,5	1,4	1,7	1,6	5
W1	3	2	2	2	2,5	2	2	1		4	3	2
Rheuma/Physio								6				
Other areas	2									3	2	
Elevator												
Waiting Bl.S.												
Blood sampling												
W2										2		
WC												
Dressingroom												
X-ray												
LAB												
W3	4	3	3	3		3	3	3	2	5	4	3
2												
3												
4												
5	5											
6		4	4	4	3	4	4	4	3	6	5	4
7												
8												
9												
13												
14												
15												
W4												
10												
11												
12												
16												
TOV1												
TOV2												

INDIVIDUAL PATIENT MOVEMENT DATA

PATIENTS ONLY GOING TO OPD1 SHEET 2/5

	GCR											
CATEGORY →	A	A	B	B	B	A	A	A	A	A	A	B
WHAT ↓ #.→	129	159	10	19	73	12	54	56	90	167	177	98
Self check-in				1				1			1	
Counter	1,5	1,9	1,6	2,5,8	1,5,9	1,4	1,5	4,7	1,6	1,5	5	1,5
W1	2	2,4	2		7	2	2	2,5	3,7,9	2	2	
Rheuma/Physio												
Other areas		3		3	6							
Elevator												
Waiting Bl.S.												
Blood sampling												
W2		5,7			2,4			3				
WC		6		4					2,8			2
Dressingroom												
X-ray												
LAB												
W3	3		4	6	3		3		4	3	3	3
2												
3												
4												
5												
6												
7	4	8	5	7	8							
8						3	4	6	5	4	4	4
9												
13												
14												
15												
W4			3									
10												
11												
12												
16												
TOV1												
TOV2												

INDIVIDUAL PATIENT MOVEMENT DATA

PATIENTS ONLY GOING TO OPD1 SHEET 3/5

	GCR									
CATEGORY →	A	A	A	A	A	A	A	A	B	B
WHAT ↓ #.→	94	175	133	139	140	148	160	192	6	71
Self check-in		1		1		1				1
Counter	1, 3	2, 7	1, 5	4	1, 4, 6	5	1, 5	1, 4	1, 5	6
W1		4	3	2, 5	2	2	2	2	2	3
Rheuma/Physio										
Other areas			2							2
Elevator										
Waiting BI.S.					3					
Blood sampling										
W2										
WC		3								
Dressingroom										
X-ray										
LAB										
W3		5				3	3		3	4
2										
3										
4										
5										
6										
7										
8										
9	2	6	4	3	5	4	4	3	4	5
13										
14										
15										
W4										
10										
11										
12										
16										
TOV1										
TOV2										

INDIVIDUAL PATIENT MOVEMENT DATA

PATIENTS ONLY GOING TO OPD1 SHEET 4/5

	GCR												
CATEGORY →	A	A	A	A	A	A	A	A	A	A	A	A	A
WHAT ↓ #.→	9	37	77	190	194	14	57	62	67	85	118	169	176
Self check-in			1								1	1	
Counter	1,5	1,4	2,5	1,5	2,5	1,4	1,4	1,6	1,4	1,5	2,4	4	1,5
W1	2		3,6	2	1	2	2	2,4	2	2,4			2
Rheuma/Physio													
Other areas								3				2	
Elevator													
Waiting Bl.S.													
Blood sampling													
W2													
WC													
Dressingroom													
X-ray													
LAB													
W3													
2													
3													
4													
5													
6													
7													
8													
9													
13													
14													
15													
W4	3	2		3	3								3
10													
11	4	3	4	4	4								
12													
16						3	3	5	3	3	3	3	4
TOV1													
TOV2													

INDIVIDUAL PATIENT MOVEMENT DATA

PATIENTS ONLY GOING TO OPD1 SHEET 5/5

	ROOM 12					ROOM 13	ROOM 14							ROOM 15	TOV1				GCR→TOV1	BI.S.→GCR
CATEGORY →	A	A	A	A	A	A	A	A	A	A	A	A	B	A	A	A	A	A	A	A
WHAT ↓ #.→	78	100	113	166	183	120	22	34	80	127	138	146	68	103	20	64	55	188	50	179
Self check-in		1	1							1		1	1	1	1	1		1		1
Counter	1,5	4	5	1,3,7	1,5	1,4	1,4	1,4	1,6	2,4	1,4	5	4	6	2,4,8	5	1,4	2,5	1,6	3,11
W1	2	2	2	2,4	2	2	2	2	2,4		2	2	2	2,4	3,5	2	2	3	2	2
Rheuma/Physio																				6
Other areas									3			3		3						8
Elevator																				
Waiting BI.S.																				4
Blood sampling																				5
W2																				
WC																				
Dressingroom																				
X-ray																				
LAB																				
W3																				7,9
2																				
3																				
4																				
5																				
6																				
7																				10
8																				
9																				
13						3														
14							3	3	5	3	3	4	3							
15														5						
W4	3		3	5	3										6	3			3	
10																				
11																			4	
12	4	3	4	6	4															
16																				
TOV1															7	4	3	4	5	
TOV2																				

INDIVIDUAL PATIENT MOVEMENT DATA

PATIENTS ONLY GOING TO X-RAY SHEET 1/2

	X-RAY												
CATEGORY →	A	A	A	A	A	A	A	A	A	A	A	A	A
WHAT ↓ #.→	66	74	91	99	105	109	116	117	122	123	124	125	136
Self check-in	1				1			1					
Counter	2	1	1	1	2	1	1, 4	2	1	1	1	1	1, 6
W1					7								
Rheuma/Physio													
Other areas													5
Elevator													
Waiting Bl.S.													
Blood sampling													
W2	3, 5	2	2, 4	2, 4	4, 6	2	2	3, 5	2	2, 4	2	2, 4	2, 4, 7
WC	4				3, 5								
Dressingroom													
X-ray	6	3	3	3	8	3	3	4	3	3	3	3	3, 8
LAB													
W3													
2													
3													
4													
5													
6													
7													
8													
9													
13													
14													
15													
W4													
10													
11													
12													
16													
TOV1													
TOV2													

INDIVIDUAL PATIENT MOVEMENT DATA

PATIENTS ONLY GOING TO X-RAY SHEET 2/2

	X-RAY												
CATEGORY →	A	A	A	A	A	A	A	A	A	A	A	A	B
WHAT ↓ #.→	145	152	155	157	161	164	165	130	180	182	189	191	104
Self check-in						1				1			
Counter	1	1, 3	1	1	1	3, 5	1	1	1	2	1, 5	1, 4	1, 3
W1						2							
Rheuma/Physio													
Other areas											3		
Elevator													
Waiting Bl.S.		2											
Blood sampling													
W2	2, 4	4, 6	2, 4	2	2	4, 6	2, 4	2, 4	2	3, 5	2, 4, 6	2	2, 4, 6
WC	3	5	5										5
Dressingroom													
X-ray	5	7	3	3	3	7	3	3	3	4	7	3	7
LAB													
W3													
2													
3													
4													
5													
6													
7													
8													
9													
13													
14													
15													
W4													
10													
11													
12													
16													
TOV1													
TOV2													

INDIVIDUAL PATIENT MOVEMENT DATA

PATIENTS GOING TO BOTH OPD1 & X-RAY SHEET 1/3

	X-RAY→GCR						
CATEGORY →	B	A	A	A	A	B	B
WHAT ↓ #.→	4	132	137	16	92	69	156
Self check-in	1	1		1			
Counter	2,9	2, 8	1, 4, 8	8	1, 8	1, 7	1, 5, 10
W1	6, 10	5	5	2, 5	5	4	2, 7
Rheuma/Physio		7					9
Other areas							6
Elevator							
Waiting Bl.S.							
Blood sampling							
W2	3, 5	3	2	4	2, 4	2	3
WC							
Dressingroom							
X-ray	4	4	3	3	3	3	4
LAB							
W3	7		6	6	6	5	
2							
3							
4							
5	8						
6							
7		6	7	7	7	6	8
8							
9							
13							
14							
15							
W4							
10							
11							
12							
16							
TOV1							
TOV2							

PATIENTS GOING TO BOTH OPD1 & X-RAY SHEET 2/3

X-RAY → GCR

CATEGORY →	B	B	A	B	B	B	B	B	B
WHAT ↓ #.→	75	101	144	61	84	13	48	110	174
Self check-in				2	1				1
Counter	1, 10	1, 9	1, 7, 13	3, 8	2, 8	1, 10	1, 5, 9	2, 7	2, 7
W1	7		6, 10	1	5, 7		4, 6	5	5
Rheuma/Physio		5							
Other areas	6		5			6			
Elevator									
Waiting Bl.S.			9						
Blood sampling									
W2	2, 4	2, 4, 6	2, 4, 8	4	3	2,5,7	2	1, 3	3
WC	5								
Dressingroom									
X-ray	3	3	3	5	4	3	3	4	4
LAB									
W3	8	7	11	6		4			
2									
3									
4									
5									
6									
7								6 (?)	6 (?)
8	9	8							
9			12	7					
13									
14									
15									
W4						8	7		
10					6	9			
11							8		
12									
16									
TOV1									
TOV2									

PATIENTS GOING TO BOTH OPD1 & X-RAY SHEET 3/3

	X-RAY→ROOM 12			GCR→X-RAY→GCR	ROOM 15→X-RAY→GCR			ROOM15→X-RAY→GCR→ROOM15
CATEGORY →	A	B	B	A	A	A	A	B
WHAT ↓ #.→	47	15	76	33	163	49	58	18
Self check-in		1		1		1		1
Counter	1, 6	2, 8	1, 7	10	1, 9	2, 4, 9	1, 4, 6, 11, 14	2, 11
W1	4	3, 9		2	6			7
Rheuma/Physio							8	
Other areas					5			
Elevator								
Waiting Bl.S.								
Blood sampling								
W2	2	6	2, 4	6	3	5	5, 7, 9	5
WC								
Dressingroom								
X-ray	3	7	3	7	4	6	10	6
LAB								
W3				3, 8	7		12	
2								
3								
4								
5								
6							13	
7					8 (?)			
8				4, 9				
9								
13								
14								
15				5	2	3	3	4, 10
W4	4	4	5			7	2	3, 8
10								9
11						8		
12	5	5	6					
16								
TOV1								
TOV2								

Appendix F

FROM/TO TABLE: ONLY OPD1 (Sub-category AB1)

	Entrance/Exit	Self check-in	Counter	W1	Rheuma/Physio	Other areas	Waiting Bl.S.	Blood sampling	W2	WC	X-ray	W3	5	6	7	8	9	13	14	15	W4	10	11	12	16	TOV1	TOV2	
Entrance/Exit	0	25	40	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	67
Self check-in	0	0	7	16	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25
Counter	63	0	0	38	1	5	1	0	2	4	0	3	0	0	0	0	2	0	1	0	2	0	0	0	1	0	0	123
W1	3	0	6	0	0	5	1	0	2	0	0	19	0	1	1	2	3	1	5	1	11	0	1	1	5	2	0	70
Rheuma/Physio	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Other areas	0	0	0	10	0	0	0	0	0	1	0	1	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	14
Waiting Bl.S.	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Blood sampling	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
W2	0	0	2	0	0	1	0	0	0	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	6
WC	0	0	1	3	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
X-ray	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
W3	0	0	0	0	0	1	0	0	1	0	0	0	1	10	4	5	5	0	0	0	0	0	0	0	0	0	0	27
5	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
6	0	0	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11
7	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
8	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7
9	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10
13	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
14	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7
15	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
W4	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	5	4	1	2	0	13
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	6
12	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
16	0	0	7	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8
TOV1	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
TOV2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SUM	67	25	123	70	2	14	2	1	6	6	0	27	1	11	6	7	10	1	7	1	13	0	6	5	8	5	0	424

FROM/TO TABLE: ONLY X-RAY (Sub-category AB2)

	Entrance/Exit	Self check-in	Counter	W1	Rheuma/Physio	Other areas	Waiting Bl.S.	Blood sampling	W2	WC	X-ray	W3	5	6	7	8	9	13	14	15	W4	10	11	12	16	TOV1	TOV2	
Entrance/Exit	0	5	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	26
Self check-in	0	0	4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
Counter	2	0	0	0	0	0	1	0	29	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	33
W1	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Rheuma/Physio	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other areas	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Waiting Bl.S.	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Blood sampling	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
W2	8	0	3	1	0	2	0	0	0	6	26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	46
WC	1	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7
X-ray	15	0	2	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	27
W3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
W4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOV1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOV2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SUM	26	5	33	2	0	2	1	0	46	7	27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	149

FROM/TO TABLE: BOTH X-RAY AND OPD1 (Sub-category AB3)

	Entrance/Exit	Self check-in	Counter	W1	Rheuma/Physio	Other areas	Waiting Bl.S.	Blood sampling	W2	WC	X-ray	W3	5	6	7	8	9	13	14	15	W4	10	11	12	16	TOV1	TOV2	
Entrance/Exit	0	9	13	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24
Self check-in	0	0	8	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10
Counter	22	0	0	6	0	1	0	0	20	0	0	1	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	54
W1	2	1	3	0	0	0	0	0	1	0	1	7	0	0	4	1	0	0	0	0	4	1	0	0	0	0	0	25
Rheuma/Physio	0	0	2	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Other areas	0	0	0	3	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Waiting Bl.S.	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Blood sampling	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
W2	0	0	2	3	2	2	1	0	0	1	23	1	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	37
WC	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
X-ray	0	0	5	8	0	0	0	0	7	0	0	3	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	24
W3	0	0	0	0	0	0	0	0	1	0	0	0	1	1	4	3	2	0	0	0	0	0	0	0	0	0	0	12
5	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
6	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
7	0	0	6	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8
8	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	4
9	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	3	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
W4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2	2	3	0	0	0	9
10	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	3
11	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
12	0	0	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOV1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOV2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SUM	24	10	54	25	4	4	1	0	37	1	24	12	1	1	8	4	2	0	0	6	9	3	2	3	0	0	0	235

Appendix G

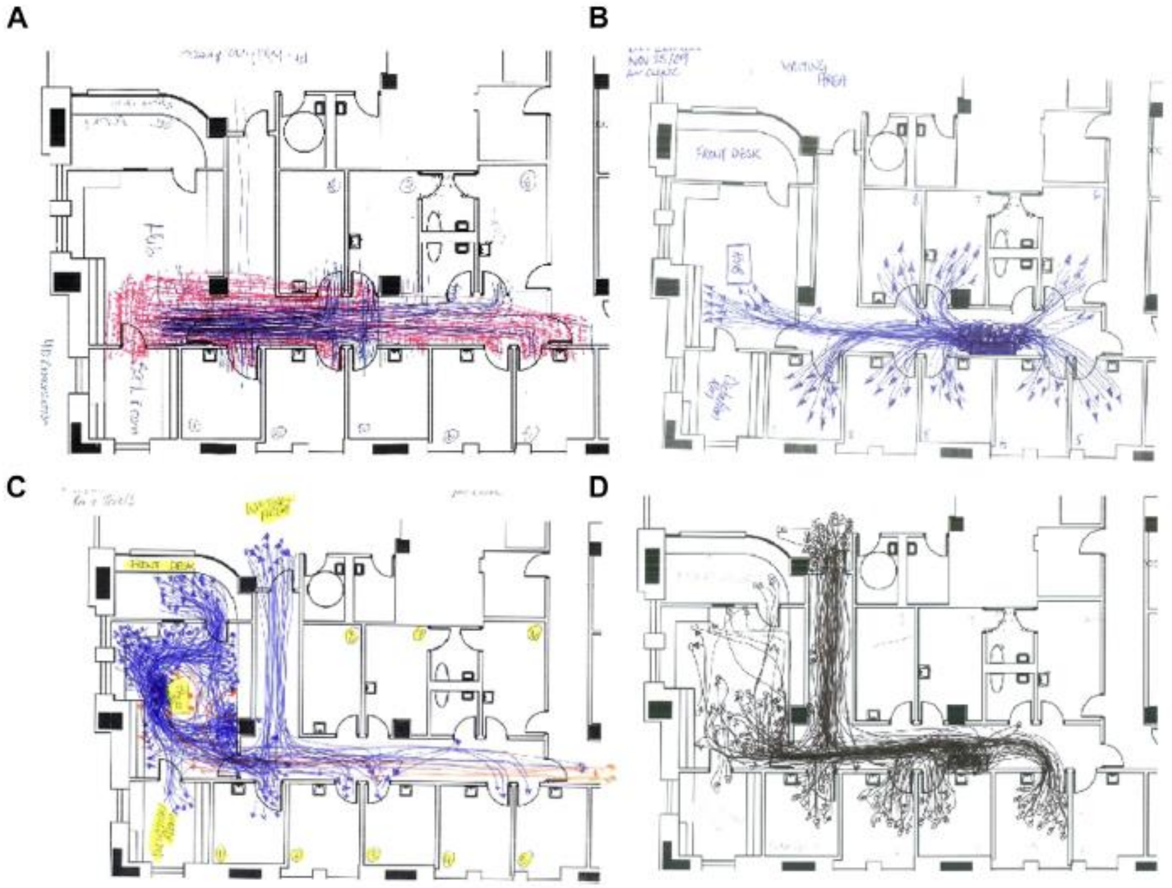
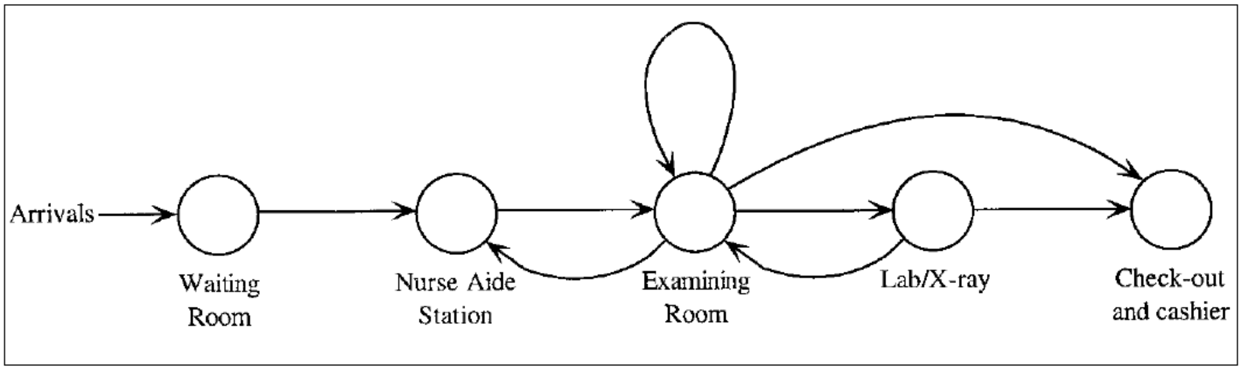
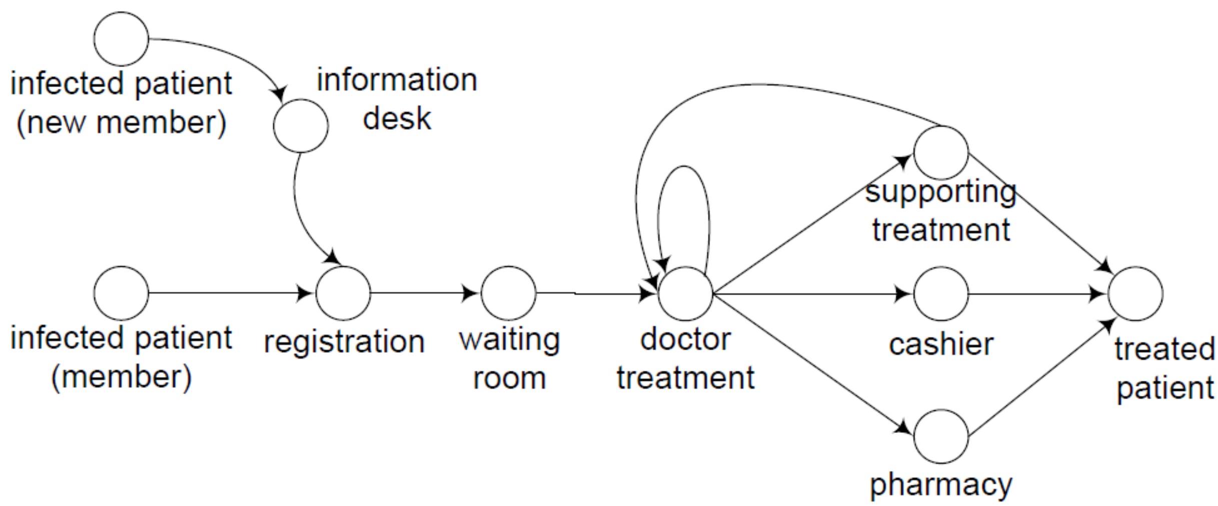


Figure 1. Spaghetti diagrams depicting physician and nurse flow during the clinic. **A** and **B** represent physician flow before and after a rapid improvement event (RIE), respectively. **C** and **D** represent registered nurse flow before and after a RIE, respectively. (Color version available online.)

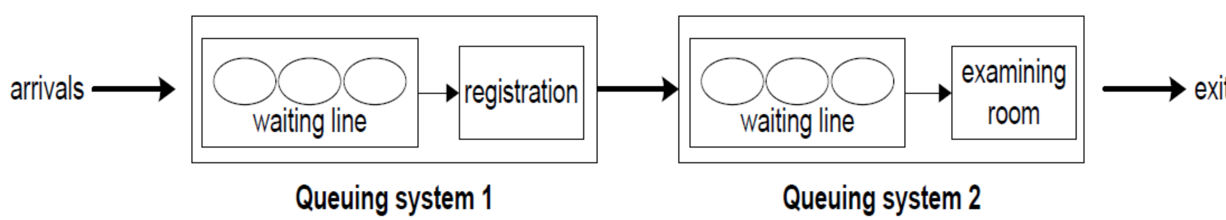
Appendix H



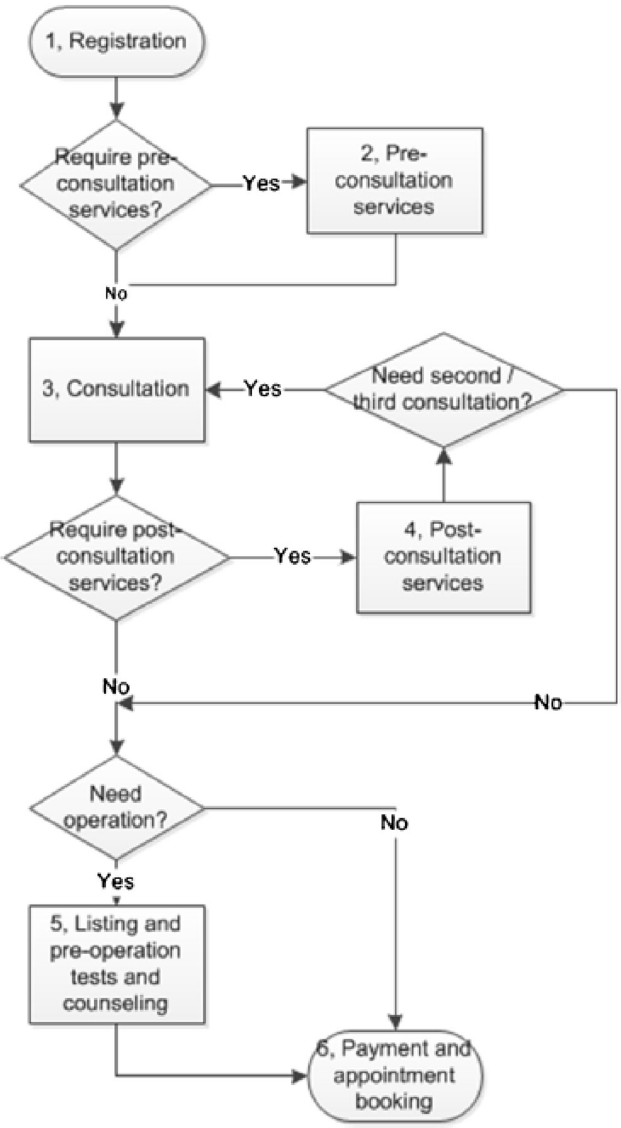
From (Côté, 2000): *Figure 2: Patient flow for patients at a family practice clinic*



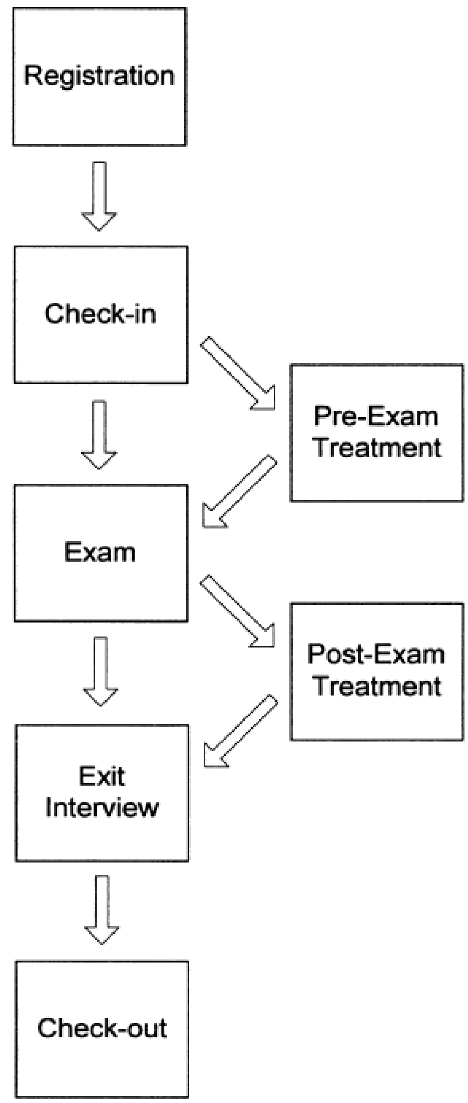
From *(Mardiah and Basri, 2013):* Figure *6: Patient Flows for Specialist outpatient Clinic*



From (Mardiah and Basri, 2013): Figure 5: Queuing Model for Specialist Outpatient Clinic



From (Pan et al., 2015): Figure 1: Patient flow in the Specialist Outpatient Clinic



From (Swisher et al., 2001): Figure 6: Diagram of patient service flow

Appendix I

In addition to the descriptions found about patient flow in outpatient departments in the literature, some illustrations found in the literature were also used in the development of the illustration of patient flow in outpatient departments (Figure 3). The arguments for choosing the different elements of the illustrations found in the literature, for the development of the illustration in Figure 3, are given below. The illustrations by the respective authors referred to, can be found in Appendix H.

Côté's (2000) illustration of patient flow for patients at a family practice clinic starts with the arrival of the patient (Côté, 2000), while Swisher et al. (2001), Pan et al. (2015) and Mardiah and Basri (2013) mentions registration as the first activity for patient service flow/patient flow in specialist outpatient department (Swisher et al., 2001, Pan et al., 2015, Mardiah and Basri, 2013). The above illustrations referred to only mention either arrival or registration. However, Mardiah and Basri (2013) shows arrival and registration as two separate activities. The developed illustration does therefore contain both arrival and registration as separate activities.

Some illustrations include waiting areas in their model (Côté, 2000, Mardiah and Basri, 2013), while other illustrations do not include waiting areas (Swisher et al., 2001, Pan et al., 2015). However, as it is difficult to compile a full overview, it can be assumed that there is a possibility of waiting for each activity. E.g. a patient waits for both registration and entering the examination room (Mardiah and Basri, 2013).

The patient flow in outpatient departments can include one or multiple steps, depending on what the patients' needs are. Swisher et al. (2001) illustrates a sequenced process with an examination, and a possible pre-examination and post-examination if required (Swisher et al., 2001). Côté (2000), Pan et al. (2015) and Mardiah and Basri (2013) illustrates a process with a loops, such that patients can move from a sequential step to a previous step (Côté, 2000, Pan et al., 2015, Mardiah and Basri, 2013). In addition, Côté (2000) and Pan et al. (2015) also illustrates that a patient can move out of one room, for so return to the same room as the next stage in the patient flow (Côté, 2000, Pan et al., 2015). Thus, the developed illustration does include possibility of multiple stages, flows between them (forward and backward), as well as a loop from one and to the same stage.

Appendix J

Layout Objectives from Stevenson (2014):

1. To facilitate attainment of product or service quality.
2. To use workers and space efficiently.
3. To avoid bottlenecks.
4. To minimize material handling costs.
5. To eliminate unnecessary movements of workers or materials.
6. To minimize production time or customer service time.
7. To design for safety.

Layout Objectives from Slack et al. (2010):

To a large extent the objectives of any layout will depend on the strategic objectives of the operation, but there are some general objectives which are relevant to all operations:

- *Inherent safety*. All processes which might constitute a danger to either staff or customers should not be accessible to the unauthorized.
- *Length of flow*. The flow of materials, information or customers should be appropriate for the operation. This usually means minimizing the distance travelled by transformed resources. However, this is not always the case (in a supermarket, for example).
- *Clarity of flow*. All flow of materials and customers should be well signposted, clear and evident to staff and customers alike.
- *Staff conditions*. Staff should be located away from noisy or unpleasant parts of the operation.
- *Management coordination*. Supervision and communication should be assisted by the location of staff and communication devices.
- *Accessibility*. All machines and facilities should be accessible for proper cleaning and maintenance.
- *Use of space*. All layouts should use space appropriately. This usually means minimizing the space used, but sometimes can mean achieving an impression of spacious luxury, as in the entrance lobby of a high-class hotel.
- *Long-term flexibility*. Layouts need to be changed periodically. A good layout will have been devised with the possible future needs of the operation in mind.