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THE ARCTIC UNIVERSITY OF NORWAY

Department of Clinical Medicine

The Faculty of Health Sciences

The Use of Context Data in Elective Surgery Scheduling and Planning

- *A literature review*

Marie Knutsen

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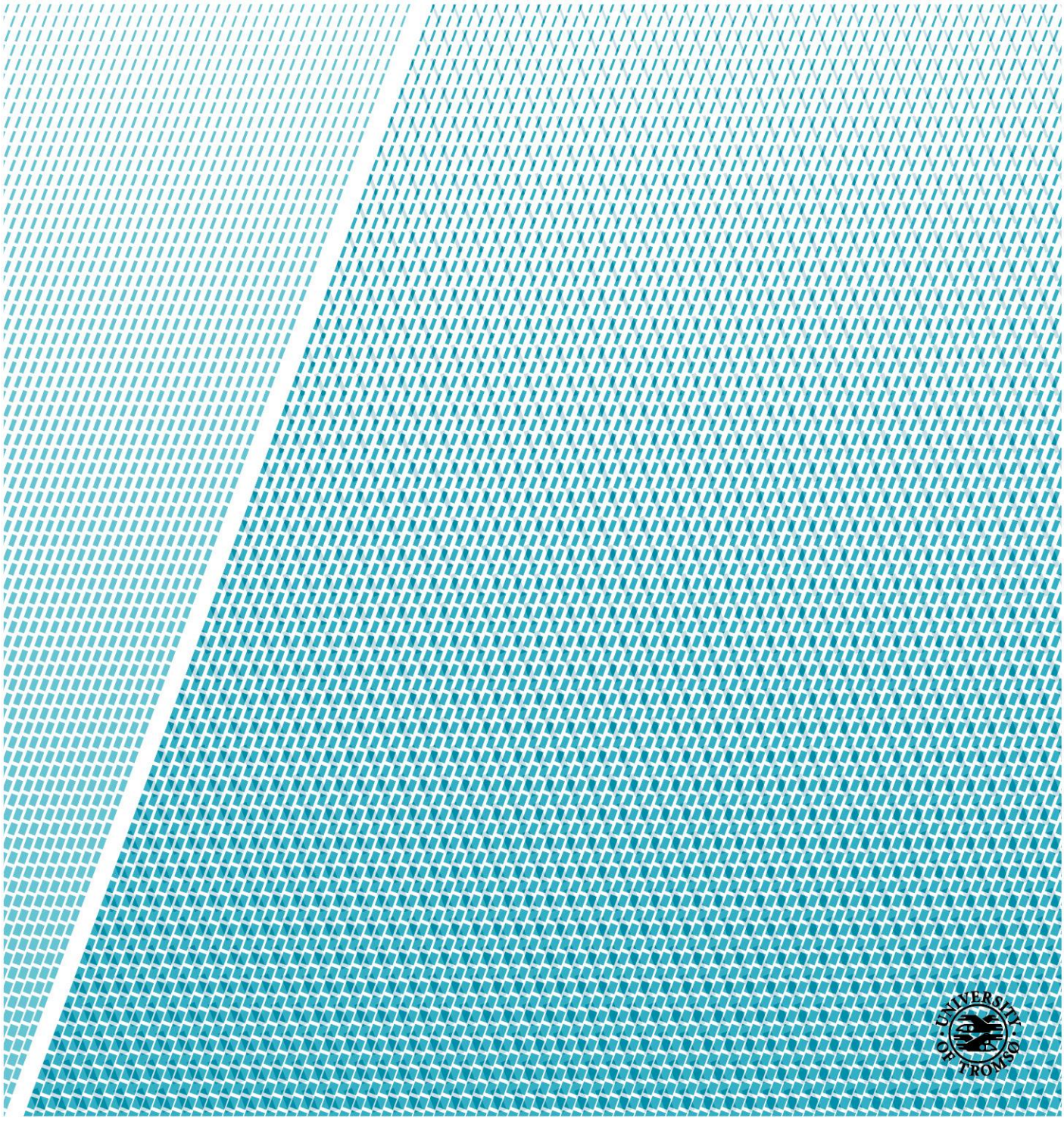

In loving memory of Niklas Owen Vik.

Thank you for teaching me what truly matters.

Abstract

The aim of this thesis is to examine how the use of context data in scheduling tools can contribute to the reduction of elective surgery cancellations. A literature review, following the recommendations to systematic reviews, was conducted in order to gather information on what context data could be used to improve elective surgery scheduling, and how the use of these data could affect elective surgery cancellations. The results indicated that the context data most mentioned concerning the improvement of the elective surgery scheduling was historical data, and information on decision-making and staff experiences. The effect most reported in the articles selected for full-text review was increased efficiency and improved utilization of resources. In addition to this, many of these articles also focused on patient satisfaction. This is in alignment with national and global recommendations for future healthcare. However, more research is needed concerning the use of context data and context-awareness in hospital settings.

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List of abbreviations

ACO	Ant Colony Optimization
ASRP	Advance scheduling and rescheduling problem
DEMO	Design and Engineering Methodology for Organization
DoD	Department of Defence
LUO	Long-term Development and Conversion
MeSH	Medical Subject Headings
MSS	Master Surgery Schedules
NCBI	National Center for Biotechnology Information
NOK	Norwegian kroner
NSE	Norwegian Centre for E-health Research
NUI	Natural user interface
NST	Norwegian Centre for Integrated Care and Telemedicine
OECD	Organisation for Economic Co-operation and Development
OR	Operating room
ORIS	Operating room information system
PRISMA	Preferred Reporting for Systematic reviews and Meta-Analyses
RFID	Radio frequency identification devices
SAA	Sample average approximation
SIS	Surgical information system
SPC	Statistical process control
TPOT	The Productive Operating Theatre
UiT	The Arctic University of Norway
UNN	University Hospital of Northern-Norway
VSS	Value of stochastic solution
WHO	The World Health Organization

1 Introduction

Operating rooms (ORs) and surgery departments are often a major source of investment and one of the greatest sources of income in hospitals, and it is estimated that ORs contribute to more than 40 % of the total revenue in hospitals [1]. This also implies that if ORs are not utilized adequately they can contribute to loss in income and become a very costly resource [2, 3]. Depending on the surgical case and what surgical need the patient has, surgeries can be divided into two main groups:

Emergency surgeries, are acute procedures, which if delayed could lead to severe impairment or death, therefore, these surgeries cannot be postponed [4].

Elective surgeries, are pre-planned surgical procedures scheduled ahead of time. These surgeries are often beneficial and/or necessary for patients but does not demand immediate attention. Examples are elective surgeries conducted as a measure to improve life quality or surgeries to treat a non-life-threatening condition. The surgeries are planned in advance, and does not require instant treatment as opposed to acute surgeries [5].

Even though elective surgeries are planned ahead of time and both patients and surgical teams are aware of the scheduled surgery, elective surgeries are often cancelled or postponed on the day of surgery, leading to lost income for the hospital and inconvenience for patients [2, 3]. Research reveals that between 10 and 40 % of elective surgeries are not conducted at the scheduled time [3, 6-8]. Many of these cancellations happen on the intended day of surgery, and several published articles state that as many as 20 % of elective surgeries are cancelled on the day of surgery in western countries [9-11]. In addition to this, it is stated that up to 50 % of these cancellations could have been avoided [3, 12, 13]. The cancellation rates of elective surgeries are especially high in the public sector [12, 14].

Surgeries are a vital part of everyday work at the hospital both to fulfil the need of the patient, and as a source of revenue. This is also why surgery cancellations are undesirable [3]. The elective surgical problem has multiple consequences: Cancellations lead to loss of income to the hospital, increase the time for patients on surgical waiting lists, lead to work redundancy and unswervingly affect the patient [2, 15]. Hospitals use a lot of resources during the planning and scheduling process of elective surgeries. This includes maintaining and booking operation rooms, making sure surgeons and other healthcare professionals are available to

operate on the given date and time, and assembling the needed surgical equipment. In addition, the patient needs to be informed, and the hospital needs to make sure the patient is able to be present on the given time and date of the surgical appointment [3, 16]. When surgeries are cancelled the staff scheduled to operate will likely be superfluous, the OR might become a unused resources, and the hospital will experience loss of income [3, 16]. In addition to this, patients will be affected due to physical and mental preparation, taking time off work, and traveling to the hospital site [16, 17].

The decision to cancel a surgery can be made by the hospital or the patient [2]. The reasons why elective surgeries are cancelled vary. Cancellations due to hospital decision can be divided into two categories: surgical planning and medical causes [18]. When the decision to cancel surgery is taken by the patient, the reasons for cancellations are mainly due to patients not wanting to undergo surgery, refusing treatment, or that the patient is a "no-show" on the agreed day or time [3, 9, 11, 19].

In order to get a better understanding of the cancellation problem in this thesis, the *University Hospital of Northern-Norway (UNN)* is used to characterize the elective surgical problem. In 2018, 1847 surgeries were cancelled at UNN the same day that the procedures were scheduled to be conducted. The cancellations in 2018 is believed to have resulted in between 5,6 to 7,8 million Norwegian kroner (NOK) lost income for the hospital, keeping in mind that these numbers only represent the cancellations on the day of surgery, and does not include cancellations one, or several days ahead of surgery [20]. 9,3 % of all surgeries are cancelled on the day of surgery, this is approximately one out of ten surgeries a day [20]. These cancellations lead to considerable cost for the hospital and affect the patient greatly. This is information that has been acknowledged for a long time, and is now getting attention from the media and the public [20].

The reasons for cancellations of elective surgeries at UNN are multifactorial. About 88 % of the elective surgery cancellations were due to hospital related reasons, the other 12 % were patient related cancellations [18].

Hospital related reasons for cancellations on the day of surgery includes several different circumstances, such as staff members being sick, acute surgery cases with higher priority, or for instance, that essential equipment or operating room facilities are not available after all [2]. Cancellations due to hospital related reasons can be divided into two groups; planning and medical causes [18]. At UNN, medical causes represent 10 % of the cancellations, while

cancellations due to inadequate planning represent 67 % of the hospital related cancellations. The remaining 11 % were other hospital related reasons [18].

As previously mentioned, most of the elective surgery cancellations that occurs at UNN, are hospital related. Studies have shown that 67 % of elective surgery cancellations at UNN are due to bad planning [18]. Surgeries cancelled because of bad planning often includes problems concerning resource utilization; meaning requiring, for instance, enough human resources, staff and department beds, unpredicted emergency surgeries, overbooking or unavailable operating theatres due to surgeries with higher duration than initially planned [2, 18]. Other reasons for cancelling elective surgeries could be efficiency problems such as unfinished pre-operative preparation [9, 19] or unavailable operating rooms due to surgery overtime [9], or it could be due to unavailability of the surgical staff [2, 6, 11, 12]. These problems all challenge the quality care in health settings.

As a measure to decrease the cancellation rates at UNN, a Lean project was conducted with the hopes of improving elective surgical patient pathways, and in this way reducing cancellations due to bad planning and cancellations concerning efficiency problems [21, 22]. These types of projects are often used in order to increase OR productivity and cut cost [21]. The Lean project was meant to provide the needed action at the needed time to avoid underutilization and avoid overbooking [2, 22]. However, a report published in 2012 revealed that Lean was not implemented as a management model [22]. The report does state that the Lean project gave some positive outcomes, but neither the method nor thinking have been implemented at the surgical level, and is poorly implemented in the clinics [22].

The main focus in this thesis will be on hospital related reasons for cancellations. This was a conscious decision due to the high percentage of hospital related reasons for cancellations at UNN [22]. In addition, patient related reasons for cancellations are often highly difficult to foresee and control, hospital related reasons for cancellations on the other hand, are more controllable and the possibility of hindering a cancellation of an elective surgery is better from a hospital perspective as opposed to patient perspective [18].

The increasing need for improved resource utilization, increased efficiency and improved quality care in the modern society of healthcare is also acknowledged on a global level by The World Health Organization (WHO), Organisation for Economic Co-operation and Development (OECD), and The World Bank [23]. Providing the needed care or treatment, for instance surgery, at the right time and avoiding resource waste is an important part of

providing the users of healthcare with the high-quality healthcare they need [23]. Therefore, it is important to have a high functioning and well-developed health information technology platform as a tool to increase the productivity in healthcare settings. Achieving proper exploitation and predictability in patient care and treatments, and having an efficient and safe use of resources, should be a priority in healthcare politics [23]. Telemedicine and electronic healthcare systems are meant to support this work.

Improving efficiency and increased quality care in healthcare can benefit the society as a whole [23]. Creating better infrastructural pathways between different information systems in healthcare is an important part of this development, and will possibly have a multitude of benefits [24]. Such benefits include reducing cost, for instance, due to cancellations, creating a more economically sustainable healthcare system. Healthcare providers can get a more structured and updated information platform, which could possibly make decision-making easier in some cases. Furthermore, patients may even receive a higher quality treatment and the risk of error could be reduced [23, 24]. In correlation to the above-mentioned aspects from WHO, OECD, and The World Bank, the Norwegian Ministry of Health and Care Services', that states that health IT is a corner stone in the improvement of healthcare quality [25]. ICT and ICT-solutions should be a focus area in order to increase patients' participation concerning their own health according to The Norwegian Ministry of Health and Care Services' Coordination Reform [26].

The use of context data in surgery scheduling could possibly contribute in solving or decreasing the problems related to surgery cancellations. "*Context is any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant for the interaction between a user and an application, including the user and applications themselves" [27]*. Context data involves gathering information about the context in which an IT system operates. In an IT setting, context-awareness can be described as the IT systems and hardware components ability to react or use relevant information provided by the environment or the context of surgeries, and provide a response [27, 28]. In this thesis, the goal is to gather knowledge about what, and how, context data could be used as a resource when creating a elective surgery scheduling system for hospital [27].

1.1 Background

In order to solve a practical scheduling problem by mathematical means it is necessary to create a model. Information on this topic is complex and complicated, and the information on this topic originate from reference [29]. The model must capture the crucial elements of the practical problem in the sense that it should be possible to convert a solution obtained from the model into a solution of comparable quality for the practical problem. It is also important that the solutions provided for the model must be found within a moderate amount of computation time. A major problem concerning the relation between the theory and practice of scheduling, is that most models considered in the literature, up until now, are either too simple or too complex. If a system is too simple the system is not able to reflect reality. If the system is too complex it will not be quickly solvable and, therefore, not usable. The elective surgical problem could be improved by using a context-aware model [29]. Creating a model that is closer to practice by including awareness could possibly lead to a more well developed system [29]. The system should be an aware-system in the sense that it should be able to automatically sense the context data from different sensors, including calendar information, work schedule, speciality, role, etc. and use the gathered data to suggest patient appointment schedules and resource staffing that are adjusted to the hospitals reality of operations. The model would become a context-aware system by using context data to identify the surgical patterns at the specific hospital. Furthermore, the system would use the gathered data to improve the precision of the generated schedules, adjust the generated schedules in real time, and create adaptive workflows [29].

This thesis investigates the published work in research on this field, examines what context data is needed in a context-aware model, and how context data can be applied to elective surgery scheduling in hospitals, according to published studies. To the best of my knowledge, context-based data has never previously been used for patient appointment scheduling and resource staffing [29].

In order to enable a in depth understanding of the problem and theme of this thesis, some of the most important topics of this thesis will be presented hereafter.

Scheduling: Hospitals often use a so-called “block-booking system” to plan surgeries. A block-booking system is designed to assign a medical specialty to a specific place and/or time. For instance, the system “blocks out” an operating room during a specific time frame, and during this block the surgery will be carried out [29, 30]. The block-booking system

makes it possible to repeat blocks in a fixed cycle; this is conducted by combining blocks into cyclical Master Surgery Schedules (MSS) [29]. This scheduling system has both tactical and strategic advantages. *"At the strategic level of block-booking system, the number of blocks assigned to the specialties and emergencies during a MSS cycle is determined. At the tactical level, OR-days are allocated to specialties in an MSS, such that the strategic allocation is met" [29]*.

As health IT evolves and the need for efficiency increases, the need to have a more complex and reliable MSS module grows. When attempting to develop a new MSS module three main challenges are important to consider according to [29]:

First, "*Enlarging the scope of the MSS: MSS approaches embedded in commercial software consider only the impact of the MSS on operating theatre and operating staff; the goal here is to enlarge the scope to down-stream resources, such as the intensive care unit ICU and the general departments required by the patients. The solution module should be flexible enough to cope with different features that appear in different hospitals that interfere with the planning activities" [29]*.

Second, *"Planning with uncertainty: Surgical management processes are subject to high variability resulting in significant deviations between intended and actual performance of surgical plans. For instance, when surgeries take longer than predicted or emergency patients arrive, it often results in overtime and possible cancellation of surgeries. When planning at an aggregate level, uncertainties are usually neglected. The challenge is to anticipate the uncertainties and incorporate them during the MSS decision-making" [29]*.

Third, "*Solution approaches: The problem cannot be totally described in mathematical programming terms. The volatility of information (see previous point) makes it difficult to incorporate all uncertainty in a single solid deterministic model" [29]*.

The use of context data in systems can be a favourable in order to approach these challenges [29].

The Long-term Development and Conversion (LUO) – from the Norwegian name "Langsiktig Utvikling og Omstilling" project: In June 2007, The University Hospital of Northern-Norway (UNN) established a project that aimed to create an optimal utilization of the operating capacity at UNN Tromsø. The project was named "Langsiktig Utvikling og Omstilling" (LUO), in English this translates to "Long-term Development and Conversion"

[31]. This project was created as a response to the UNN Board of Directors decision concerning saving requirements for the hospital. The Board wanted to save 175 million NOK from March 2007 to the end of 2007. As a result, all departments received an unavoidable requirement for implementation of measures to achieve economic balance in line with the saving requirements [31]. In the Operations and Anaesthesiology department one of the suggested measures to reduce cost was to decrease the number of working positions at the department. This proposal was turned down by the management at the hospital because it was considered that job cuts at these departments would have unacceptable consequences for parts of the hospitals core business, the surgical business. Instead it was decided to investigate measures to optimize the utilization of the surgical capacity, which became the main focus of the LUO project [31].

After the establishment of the LUO project, the Steering Committee found it natural to focus on the workflow at the hospital to promote interaction between different disciplines and professions within the hospital. This was done in order to ensure a more comprehensive patient care pathway. The goal was to create a better and more comprehensive patient care pathway by improving the interactions between the different professional groups at the hospital that are involved in the surgery and anaesthesiologic work [31]. A part of this work is to improve the resource utilization and to create a more efficient infrastructural pathway, and design better communication tools within the hospital and the surgical department. It has been recognized that the resource utilization in the operational and anaesthesiologic department is only sub-optimal, and that there is a need for further optimization [31]. This belief is confirmed by, among others, the fact that most operation and anaesthesiologic departments experience insufficient capacity relative to the patient groups in need of treatment [31]. This recognition is also based on comparisons with corresponding hospitals that can document significantly better capacity utilization, as well as previous investigations at UNN [31].

The LUO project revealed several weaknesses, shortcomings and inadequate organization structure in the implementation of planned surgical programs. These weaknesses were among others a poor overall system for allocation of surgical capacity, a deficient preoperative planning and coordination, and poor utilization of the operating rooms during the daytime; primarily due to late start-up in the morning and long waiting time in between surgeries [31].

Digitalization of the healthcare system: Ever since the technology was introduced in the Norwegian healthcare it has been a partial part of creating a high functioning and economic

efficient healthcare system. Health technology is recognized as a tool in the process of achieving health policy goals from national authorities. Examples of this is the national strategy plan from the Ministry of Social Affairs and Health in Norway published in 1996: *"Mer helse for hver bIT"*, which translates to *"More healthcare for each bIT"* [32]. Today a new strategy plan is in use: "Nasjonal e-helsestrategi 2017-2022", in English: "National E-health Strategy 2017-2022" [33]. This strategy plan was created by the Norwegian Directorate for E-health on behalf of the Ministry of Health and Care Services. The plan was created in order to make a detailed and strategic proposal on how E-health can contribute to the Norwegian health sector. Corresponding plans in areas of national importance will also be prioritized [33]. The plans are created as part of the process of digitalization of the healthcare system. The focus is to have a cost productive and safe healthcare system with a shared and unified infrastructure and data foundation. This will contribute in creating an integrated and process-oriented care system in Norway [32, 33].

The process of expanding the infrastructural pathways and creating a functioning process-oriented healthcare system takes time, and there have been many projects leading up to where we are today. In 1999, the Norwegian Centre for Integrated Care and Telemedicine (NST) lead an initial assessment of the possibilities of developing and implementing a system for online access to patient information called the "Elvira" project [34]. The visons of the "Elvira" project is similar to "Kjernejournalen", in English: "National core health record", which is in use in Norway today [35]. Other examples of projects that have impacted the development of process-oriented systems and integrated care in Norway are: Initiative 48 from National ICT [36], this initiative is part of creating standards and clinical guidelines for process- and decision support [36], and Stortingsmelding nr 9 [37], which included important information on previous goals concerning health technology, in addition to current projects and achievements, and future ambitions in Norwegian healthcare. Because of the governmental focus on integrated care systems this has also become a priority for National ICT, the Norwegian Directory of Health, and Norwegian Centre for E-health Research (NSE) [34, 35, 37].

This thesis investigates how the use of context data in scheduling systems could contribute to a high functioning and economic efficient surgery planning system that the hospitals, the patients, and the healthcare system in general, would benefit from. The benefits are believed to decrease cost by reducing the numbers of elective surgery cancellations, and to improve

efficiency by avoiding underutilization of resources [3, 16]. This is in correlation to the "National E-health Strategy 2017-2022" that encourages a further development and modernization of healthcare technology in order to increase the quality of patient care [33].

1.2 Motivation

My personal interest in telemedicine and E-health helped me find a suitable theme by contacting one of my lecturers, Terje Solvoll, during the second semester of the study. Solvoll had an ongoing research project with Conceição Granja, concerning context-aware scheduling and allocation systems [38]. The purpose of this study is among others to investigate how the use of context-based data can affect the patient pathways and workflow in hospital settings, and to integrate process support within electronic health records [38]. I found it very motivating that the thesis could be part of a larger research project that could possibly contribute to science and make a difference in how context-based data is used in healthcare. In addition, I wanted to learn more about how systems are functioning today, and how they could be changed in order to meet the increasing need for improved resource utilization, increased efficiency and enhanced quality care like WHO, OECD, and The World Bank, the Norwegian Ministry of Health and Care Services' all acknowledge as a need in the future [23, 26]. Furthermore, the numbers provided from UNN concerning cancellations in 2018 and the amount of lost income [20], is a problem that motivates me. The results from UNN [20], makes me want to investigate how to reduce the cancellation numbers, providing the needed treatment for patients, and avoiding loss of income for the hospital.

1.3 Research questions

This thesis examines how elective surgery cancellations could be avoided and/or reduced using context data. A literature review to gather information was conducted following the recommendations to systematic reviews. The overall aim of this thesis was to acquire knowledge concerning elective surgery scheduling and planning, in correlation to context data.

Sub-questions/secondary objectives investigated were:

- What context data can be used to improve the elective surgery scheduling?
- How can context data contribute to improve elective surgery scheduling?

1.4 Master thesis structure

This thesis is structured in four chapters. Chapter 1 presents some background information, the problem of interest in this thesis, and purpose of the research. Chapter 2 contains a thorough explanation of the research methods and how material was gathered throughout the research process. Chapter 3 presents the gathered data and the obtained results. In Chapter 4, the results presented in Chapter 3 are summaries and interpreted in order to investigate and discuss the gathered data, and to examine the data in correlation to the research questions in this thesis. Limitations and future work will also be presented.

2 Materials and methods

The study presented in this thesis consist of a literature review. In the following section the methods and materials used to answer the research question, will be presented. There will be a description of the method of choice, the search strategy, and how the information to answer the research question was gathered.

2.1 Research approach – Literature review

The aims of this thesis were to investigate literature on how context data could be applied to elective surgery scheduling in hospital settings, and if the use of this data can contribute to increased efficiency and the reduction of the number of elective surgery cancellations. A literature review was selected as the method of choice, because it contributes in examining the existing knowledge on context data in scheduling, but also, explore possibilities and contradictions for the future. In addition to this, a literature search could reveal gaps in the existing knowledge concerning the use of context data in elective surgery scheduling and reducing elective surgery cancellations [39, 40].

According to Jesson et al. *"A literature review is a re-view of something that has already been written"* [39]. A literature review is created in order to investigate published work. The reasons behind those investigations varies greatly, but it could be because researchers want to investigate the published work in a specific field, or as part of a larger research project [39].

Literature reviews can be further divided into two different approaches: the traditional review and the systematic review. The *traditional literature review* is an appraisal of the information and data that has already been identified. Traditional literature reviews can provide insight in specific views of the information of interest, this could be positive in many cases, but in some scenarios the traditional literature review could contain arguments that might be considered as biased. The *systematic literature review* is a review created to gather information on a topic and identify what works and what does not work by reviewing the research already published on the topic of interest. This type of research demands a clearly specified research question and purpose of the review. In addition, a systematic literature review needs to have a precise search approach and inclusion/exclusion criteria. Because of clearer standards in method and structure, the systematic literature review is viewed as more neutral and objective compared to a traditional literature review [39]. The systematic review collect and summarize all empirical evidence that fits into a pre-specified eligibility criteria in order to answer a defined

research question [40]. The search to identify relevant information is extensive and conducted in a systematic manner using specific methods. Therefore, systematic reviews are acknowledged as representing a high quality of evidence [39-41]. Systematic methods are used in order to select and provide information that can contribute to minimize bias, draw a conclusion, and help decision making [40].

There are, however, some study limitations concerning the choice of conducting a literature review in this thesis, these limitations are stated in chapter *2.5 Study limitations and ethical considerations*. In an attempt to minimize bias and limitations, the literature review was conducted following the recommendations to systematic reviews.

2.2 Search strategy

In order to fulfil the requirements of a literature review researchers need to follow a certain methodology strategy. This includes stating a research question, creating a plan for the literature search, and creating inclusion/exclusion criteria [39]. In the beginning of this project a research protocol was created, including research questions and requirements clarifying the inclusion/exclusion criteria. In addition to this there was a need to decide the framework, create a suitable search string, and investigate the possible databases suitable for this study [39]. The methods for reviewing articles were established before conducting the review, and the reports did not justify any deviations from the research protocol.

2.2.1 Keywords and framework

Keywords: The goal of this thesis was to create a literature review concerning the use of context data in elective surgeries. In order to gather information, and proper literature, regarding the research question, a search to find suitable keywords for the query was conducted. The keywords were tested in different combinations in databases as a strategy to investigate the articles it provided. This tactic is useful to narrow the search and identify the most current literature, but it is time-consuming and requires a lot of trial and error in order to create a suitable search string that provides the desired information. The literature retrieved from the initial searches was used in order to find suitable keywords and terms that were later used in the final query, this query and the search terms applied are depicted in *Table 1*.

Framework: The acronym PICO is short for: Population, Intervention, Comparator, and Outcome, and is a requirement for systematic reviews [40]. The PICO search strategy was used as a framework in this thesis, in order to create a high-quality search string, retrieving

the desired information to answer the research question. Keywords were applied to the given groups and combined with the Boolean Operator OR. The accumulated results of the groups were combined with the Boolean Operator AND. Comparator (C), was not applicable to this study and, therefore, not included. As a result of this work, three groups (Population, Intervention, and Outcomes), consisting of 22 terms were chosen and used as keywords in the search, these terms are depicted below.

Table 1- Keywords used in the literature search presented in a PICO framework

P (population)	Surgical ward Surgical theatre Surgical department Operating theater Operating room Planned surgery Planned surgeries Surgical planning Surgical team "Elective Surgical Procedures"[MeSH]
I (intervention)	Scheduling Planning Management Staffing Appointment “Appointments and Schedules”[MeSH] “Personnel Staffing and Scheduling Information Systems”[MeSH]
C (no comparison)	
O (outcome)	Perspectives

	Narrative Narratives Attitude Attitudes

In the population (P) section of the framework, the search string states that the desired information should include words concerning surgery, therefore, the section includes several different synonyms and discretional words concerning this theme. By stating this in the population part of the framework there is no need to re-state it in other parts of the framework. There is, for instance, no need to include “surgery scheduling” or “surgical team management” in the intervention (I) part of the framework, because the PICO structure already stated that the desired theme has to do with surgery and management. The comparator (C) was not applied in this research because the articles were not required to have a comparison in order to be included in the study, and the outcome (O) section of the framework includes desirable words to describe the outcome of interest. The terms in the outcome-section were selected because the desired articles aimed for in this thesis should include experiences gathered from staff and/or users of surgical healthcare.

2.2.2 Scientific databases

In addition to deciding suitable keywords, a decision on what databases to search within was also needed. In systematic literature reviews there is a requirement of using at least two databases [39]. Several different databases were checked for adequacy on this topic to get an overview over the provided search results. The databases PubMed, Scopus and IEEE Xplore were chosen for possible extraction of data. These databases were considered in order to retrieve information from both the medical, sociological, and technical point of view. When the final search string was finished, the query was tested in the three selected databases.

After searching the databases with the finished query, IEEE Xplore was excluded. This decision was made mainly because of two reasons. First, IEEE Xplore provided a result of 34,120 items; this workload was not feasible with the given time of the thesis. It should be noted that there is a possibility that the huge number of items in this result was due to an error in the search within IEEE Xplore. However, the search was conducted with the help of an academic and research librarian, and tested in numerous ways without succeeding in

retrieving a result with a lower number of items. Second, IEEE Xplore is indexed in Scopus, meaning that the results in Scopus would include searches from IEEE Xplore [42]. This does not mean that including IEEE Xplore would not affect the search result given it is a large database, but because of the time constriction during this thesis, and the number of items provided in IEEE Xplore, the database was excluded. This left the databases PubMed and Scopus that were used for extraction of data.

2.2.2.1 Selected databases

In this section the selected databases will be presented shortly. Following this the searches within the two databases will be explained. There will also be an in-depth description of the searches within PubMed and Scopus describing the search and filters used.

PubMed: PubMed is produced by the National Library of Medicine, and the National Center for Biotechnology Information (NCBI) runs the database. PubMed provides access to MEDLINE, life science journals, and online books [43]. It is the biggest medical database, containing over 27 million references, and individuals can use it without cost [44].

The National Library of Medicine also allows you to use Medical Subject Headings (MeSH) when searching within PubMed. MeSH terms can be used in order to index articles, this can help individuals to find relevant articles because by using MeSH terms the database is not only searching that specific term, but also, other subheadings linked to the MeSH term, creating a broader search [45].

In some cases, the number of search results might be so large that it is not possible to go through all articles. In these cases, PubMed gives the user the opportunity to narrow the search by search restrictions. This could be done in several different ways, for instance, the search can be restricted by choosing to only include articles with the desired keywords in the title and/or abstract of the article. If one for instance chose to only include articles with the desired keywords in title and abstract, it implies that all articles within the search result includes one or several of the keywords in the search string. If desirable the search could be further narrowed by applying filters such as publication date filters, language filters, or restricting the search to certain types of articles, for instance, only reviews, etc. [46].

Querying PubMed: When searching in PubMed all keywords were put into a given group following the PICO structure. Due to a large amount of hits on the search terms in the first

part of the investigation, the search was restricted to title and abstract. This was decided in order to narrow down the search and obtain the most relevant articles.

In addition to regular search terms, three Medical Subject Headings (MeSH) were also used. This was done in order to, not only search the given term, but also subheadings of the term to broaden the spectrum of the results [45]. Furthermore, filters were determined to specify the findings. Filters used in PubMed were language restrictions, only English language, and full text availability. In addition to this the publication date was restricted to custom date, making it possible to restrict the search to the date when the query was finished, and the final searches started. This date was set to 2018/11/30.

Scopus: Scopus is owned by Elsevier and it is the largest abstract and citation database of peer-reviewed literature in the world. Scopus provides access to scientific journals, books and conference proceedings, and it includes multiple research topics across all scientific and technical disciplines [47].

PubMed offered the possibility to use Medical Subject Headings (MeSH) in the search. This was not possible in Scopus because: *"In Scopus MeSH terms can be searched only as Keywords, so thesaurus searching of Medline records in Scopus is limited. Terms cannot be explored, nor can subheadings be applied, and this imposes limits which make Scopus alone inadequate for high level biomedical searching"* [48]. Therefore, these search terms were searched for within keywords, title and abstract.

Just like in PubMed, the number of hits could sometimes be so large that it was not possible to go through all articles. In these cases, Scopus gives the user the opportunity to narrow the search by restricting it, but with some variation to PubMed. For instance, the search can be restricted by choosing to only include articles with the desired search terms in the title *or* abstract. It is not possible to search for desired terms in *both* title and abstract. It is, however, possible to search for the desired terms in title, abstract and keywords [49]. Scopus also allows the user to narrow the search even more by applying filters such as language filters or publication year filters [50].

Querying Scopus: When searching in Scopus all keywords were put into a given group, following the PICO structure described above. Due to a large amount of hits on the search terms in the first part of the investigation the search was restricted to title, abstract, and keywords to narrow down the search and obtain the most relevant articles. This is somewhat

different from the search in PubMed because of the additional search within the keyword section of articles.

Like explained above, MeSH terms do not have the same function in Scopus as in PubMed. Therefore, it was not searched directly for MeSH terms in Scopus, but the terms were set in punctuation marks, in this way the words would not be searched for separately, only as a sentence, and searched for within title, abstract and keywords. This is depicted in *Table 2.*

Furthermore, filters in Scopus were determined to specify the findings. PubMed and Scopus have some differences. The filter for only including articles in English language was applied. There was not an option for choosing a full-text availability filter in Scopus. As opposed to PubMed, Scopus does not allow date restriction, only years. Therefore, the year 2019 was excluded. This means that there is a one-month difference in the two databases. This inequality was not discovered in the beginning, because it was assumed that Scopus also would allow date restriction. Although the query would be more optimal if it was the same date in the searches in both databases, it was decided to keep the first date restriction in PubMed, because the work of reading through titles had already started at that point. This will be further discussed in *Chapter 4 Discussion and conclusion.*

2.2.3 The search string

The keywords were applied within PubMed and Scopus search request following the PICO structure. The terms within every group were combined with the Boolean Operator OR and the accumulated results of the groups were combined with the Boolean Operator AND. It was restricted to title and abstract, or, title, abstract and keywords, to narrow down the search and obtain the most relevant articles. As explained above the MeSH headings were not applied in the same way in PubMed and Scopus.

Table 2 - How the search was conducted within PubMed and Scopus

		Database	
ID	**Keyword**	**PubMed**	**Scopus**
#1	Surgical ward	[Title/Abstract]	TITLE-ABS-KEY
#2	Surgical theatre	[Title/Abstract]	TITLE-ABS-KEY
#3	Surgical department	[Title/Abstract]	TITLE-ABS-KEY

#4	Operating theater	[Title/Abstract]	TITLE-ABS-KEY
#5	Operating room	[Title/Abstract]	TITLE-ABS-KEY
#6	Planned surgery	[Title/Abstract]	TITLE-ABS-KEY
#7	Planned surgeries	[Title/Abstract]	TITLE-ABS-KEY
#8	Surgical planning	[Title/Abstract]	TITLE-ABS-KEY
#9	Surgical team	[Title/Abstract]	TITLE-ABS-KEY
#10	"Elective Surgical Procedures"	[MeSH]	TITLE-ABS-KEY
#11	#1 OR #2 OR #3 #5 OR #6 OR #7 OR #8 OR #9 OR 10		
#12	Scheduling	[Title/Abstract]	TITLE-ABS-KEY
#13	Planning	[Title/Abstract]	TITLE-ABS-KEY
#14	Management	[Title/Abstract]	TITLE-ABS-KEY
#15	Staffing	[Title/Abstract]	TITLE-ABS-KEY
#16	Appointment	[Title/Abstract]	TITLE-ABS-KEY
#17	“Appointments and Schedules”	[MeSH]	TITLE-ABS-KEY
#18	“Personnel Staffing and Scheduling Information Systems”	[MeSH]	TITLE-ABS-KEY
#19	#12 OR #13 OR #14 OR #15 OR #16 OR #17 OR #18		
#20	Perspectives	[Title/Abstract]	TITLE-ABS-KEY
#21	Narrative	[Title/Abstract]	TITLE-ABS-KEY
#22	Narratives	[Title/Abstract]	TITLE-ABS-KEY
#23	Attitude	[Title/Abstract]	TITLE-ABS-KEY
#24	Attitudes	[Title/Abstract]	TITLE-ABS-KEY
#25	#20 OR #21 OR #22 OR #23 OR #24		
#26	#11 AND #19 AND #25		

2.2.4 Inclusion/exclusion criteria

A list of inclusion/exclusion criteria was determined, in order to retrieve useful information that enables answering the research question, and to limit the amount of results. The inclusion/exclusion criteria list is depicted in *Table 3*.

2.2.4.1 Inclusion and exclusion criteria

Table 3 – List of inclusion criteria.

Inclusion Criteria
Research had to be published in English language
Full-text must be available.
The study had to deal with elective surgery appointment scheduling and/or cancellations of elective surgery appointments.
The study had to include at least one of the following items: 1. Mention at least one factor that can be considered as relevant when it comes to context-aware methods in surgery planning, and/or managing elective surgery cancellations. 2. Mention methods that have an impact in surgical planning or impact of elective surgery cancellation. 3. Include a technological aspect in the work of planning and/or avoiding cancellations of elective surgeries. 4. Factors that were considered relevant to description of user pathways

In addition to the list of inclusion criteria presented in *Table 3*, some other factor should be mentioned: Because the research question deals with a rather new topic in E-health, both peer reviewed articles and grey literature, such as reports, can be included if viewed as relevant. The peer-reviewed articles are written by experts in the field, and the text is reviewed by other experts before it is published in a journal [51]. The research has been approved by experts in addition to being read and assessed during the work with this thesis to determine if it could be included to answer the research question. This is a good way to insure high quality data, and it also works as a measure to insure quality control [51]. The grey literature has not been peer reviewed but was read and assessed according to this thesis and its inclusion criteria. Grey

literature was only included if it met the inclusion criteria and was viewed as highly relevant and credible.

For this thesis it was chosen to include original studies, conference proceedings, reviews and editorials if viewed as relevant to the research question and the thesis. There is a possibility that some relevant reviews will include studies that might not have been found applicable due to the keywords and search string used for this thesis. These studies might use different terms and keywords but could still be highly relevant to investigate how context-aware methods affect surgery planning in hospitals and if using these methods can contribute to avoid pre-elective surgery cancellations.

Articles that did not meet the inclusion criteria, seemed to lack information or had no relevance were excluded. This could for instance be during the screening of titles. Titles that did not provide any information about the content of the article was excluded. An example of this was an article with the title *"A little imagination"* [52]. This article could possibly have contained valuable information, but the title did not meet the inclusion criteria and gave little information about what material the article contains, and therefore, it was excluded.

2.3 Selecting the articles

The finished search string was searched for within both databases, following this all titles were read through and screened for relevance. After reading through the titles, abstracts of relevant articles were read and screened for relevance following the inclusion/exclusion criteria. While reading the abstracts each article was moved into one of three possible groups: "include", "in-doubt", or "exclude". The articles were read in alphabetical order, and notes were made for every article explaining why it was placed in its given group. Some articles were placed in the "in-doubt" group in the screening of abstracts if it was believed that the article might contain valuable information. Therefore, a second reading was performed, where the abstracts of the articles in the "in-doubt" groups were read through once more in order to decide if the articles were relevant. The second reading was done in high focus settings where more thorough notes were taken in order to decide if the abstract gave enough information, and if the article met the inclusion/exclusion criteria. The articles left were articles selected for full-text review. These articles were read through and if they still fulfilled the inclusion criteria and had relevance to the thesis and the research question the article was included in the result of this literature review.

2.4 Data-extractions form

The data-extraction sheet was created in the beginning of the project and included in the project description of this thesis. This data-extraction sheet was designed in order to extract data from the articles selected for full-text review in an appropriate manner. Four categorized tables were created, within each table, groups were created in columns, in order to retrieve the desired data, and are explained hereafter. The first column in every group was always the reference citation in order to keep track of the origin of the data.

The first table, shown in *Table 4*, was titled "Categorization of article". Six columns were included in this table. The first column included Reference citation; this column is the same in all four categories and will not be shown in the tables. The second column included Authors, this was in order to know who wrote the paper. The third column included Year, this was in order to know when the study was published. The fourth column included Title, this was needed to know the name of the paper and to give some insight to the theme of the article. The fifth column included Country, this was helpful to understand culture, possible economic variables considering if it was a developing country or a industrialized country. In addition, information about the country provides an opportunity to gather knowledge about health problems in the relevant country if needed. The sixth column included information on Type of hospital, for instance private or public, this was helpful in order to have an understanding of the economic aspects and founding. If the department was stated this was also noted to better understand the study of interest.

Table 4 - Categorization of article

Categorization of article				
Author	**Year**	**Title**	**Country**	**Type of hospital (private/public etc.) & department**

The second table, *Table 5*, was titled "Categorization of study", including seven groups: Reference, Description of intervention/phenomena of interest, System in use, Phase of study, Focus, Purpose/aim/goal, and Economic variables. Column two included the description of the intervention, or the phenomena of interest, this was important information in order to

understand what the study concerned. Column three described the system in use, including the name of the system and other important information. Column four included information concerning if the article was published pre-implementation, during implementation or post-implementation. Column five included information on the focus of the article. Column six was important in order to know the purpose/aim/goal of the study. Last, in column seven, economic variables were noted if this was mentioned in the article. This was helpful to investigate if the study had investigated the economical aspect.

Table 5- Categorization of study

Categorization of study					
Description of intervention/phenomena of interest	**System in use**	**Phase of study**	**Focus**	**Purpose/aim/goal**	**Economic variables**

The third table, *Table 6*, was titled "Methodology", including eight groups: Reference, Method (type of study), Data collection method, Data analysis approach, Sample size, Method for recruitment of participants, Duration of participating, and Profession(s) in focus. Column two included information on type of study and method. Column three included data collection method, this was important to understand how the data presented in the papers was collected. Column four included information on the approach concerning data analysis, this was important in order to know how the data was examined. Column five included the sample size, this is important to get an understanding over the study participants and the size of the subject pool. Column six includes information on how participants were recruited. Column seven includes information on the duration of study participation, this is important in order to know how long the study of participants lasted and to give an estimate on whether it was a long-term, medium-term or short-term study. The last column, column eight, included information on profession/professions in focus if this was stated. This was helpful in order to know if the gathered data concerned one specific profession or point of view.

Table 6 - Methodology

Methodology						
Method (type of study)	**Data collection method**	**Data analysis approach**	**Sample size**	**Method for recruitment of participants**	**Duration of participating**	**Profession(s) in focus**

In the fourth table, *Table 7*, the table was divided into two data-extractions parts gathering data concerning the *outcomes* and *results* of the study and, therefore, titled "Outcome and Results", this table included seven columns.

In the *Outcome* section of the table, four columns were created: conclusion, response rate, limitations and ethical considerations. Column two included information on the conclusion the authors stated in the article. The third column included response rate, so if studies included a questionnaire the response rate could be documented in order to know how many answered the questionnaire. Column four included limitations in order to note if the authors addressed limitations to the study. Column five included limitations in order to note if the authors declared any ethical issues or mentioned ethical perspectives. In the *Result* section two columns were created: Data item (data collection), this was the sixth column, and Effect, which was the seventh column. Column six included the collected data in the study presented in the article, this was the knowledge retrieved from the study the authors used to draw conclusions from, and was, therefore, important. Column seven included the effect of the intervention if there was an intervention in the study, or the effect of different measures taken in the study.

Table 7 - Outcome and Results

Outcome				Results	
Conclusion stated in the article	**Response rate**	**Limitations**	**Ethical considerations**	**Data item (data collection)**	**Effect**

2.5 Study limitations and ethical considerations

The Cochrane Handbook for Systematic Reviews of Interventions [40] state that two researchers should review the literature, select the relevant articles and present the result [40]. This thesis is an individual paper making the approach difficult to complete in full as a systematic literature review. The abstraction of data and decision-making of which studies to include and exclude was conducted by one person; meaning that the decision on what articles to include or exclude in this thesis was not controlled by another investigator. This may lead to bias or errors, but the systematic nature of the study, the data-extractions, and the inclusion and exclusion criteria was investigated and approved by two supervisors, both before and after the search was conducted. This, alongside with following the Cochrane Handbook's guide [40] and the PICO framework [40], could make this thesis more objective than a traditional literature review.

Studies should in some cases conduct a bias-analysis in order to assess the validity of the study. A bias-analysis measure the risk that the study over- or underestimated the effect of the intervention, and in this way represent a deviation from the truth concerning the study results [40]. There was, however, no need for a bias-analysis in this thesis because the desired information in the literature review concerned the experiences with context data and context-awareness, and one cannot measure bias in experience and opinions.

3 Results

The search string identified 1810 articles from the two databases, Scopus and PubMed. The search in PubMed provided 199 articles without filters. When filters were applied 166 articles remained. The search in Scopus provided 1803 articles without filters. When filters were applied 1644 articles remained. These articles were imported to the citation manager EndNote X9, and sorted into a group set consisting of two groups, one group including articles from PubMed, the other including articles from Scopus. Following this, an automatic search for duplicates was conducted in EndNote X9, to find duplicated in the group set. Duplicates are articles that were both found in the PubMed database, and Scopus database. The automatic search for duplicates removed 123 retrieved articles. Following this, all articles with incomplete citations were removed; meaning removing articles missing information on e.g. author and/or journal name. This removed an additional 56 articles. 25 articles were removed because they stated that the reference type was serial, books or book chapters, which was viewed as not relevant for this thesis. When these search results were removed, a manual search to find duplicates that were not found in the automatic duplicate search was conducted. The manual duplicate search removed another 32 articles. The articles removed in the manual duplicate search usually had some inconsistency in the way the title was written, or it was published in two different journals and, therefore, not picked up by the automatic search within EndNote X9. A total of 236 articles were excluded due to duplicates or incomplete citations. The remaining 1574 article titles were read through and included or excluded by evaluating the information provided by the title of the article. Some articles were given the benefit of the doubt because titles are somewhat restricted in what they can contain, so if there was a doubt whether the article could be relevant it usually was included in order to avoid losing applicable articles in the screening of the titles. After title screening, 185 articles were chosen for abstract review. The abstracts of the given articles were read for compliance with inclusion/exclusion criteria described in *Table 3*. The articles with abstracts providing relevant information to meet the inclusion/exclusion criteria were chosen for full-text review. While reading the abstracts each article was moved into one of three possible groups. The first groups, the inclusion group, were articles that included information viewed as valuable. The second group, the exclusion group, were articles that did not meet the inclusion criteria. The third group, the in-doubt group, included articles that the researcher had trouble excluding because they could include valuable information, but the abstracts did not clearly meet the

inclusion criteria. The abstracts of these articles were, as mentioned in *Chapter 2.3 Selecting the articles*, read through a second time in high focus settings. Thorough notes were taken as a measure in order to decide if the abstract met the inclusion/exclusion criteria. After reading all abstracts, 30 articles were chosen for full-text review. In the full-text review 13 articles were excluded due to new information that was not presented in the title or abstract leading the article to not meet the inclusion criteria. The reasons for excluding the articles were: One of the articles had an English title and abstract, but the full-text was in Italian [53]. Three articles were not available for full-text review after all, the articles were requested to the library at the The Arctic University of Norway (UiT), but did not arrive on time [54-56]. Two articles concerned acute hospitals and trauma facilities [57, 58]. Five articles were excluded because they were considered not relevant, these articles had promising titles and abstracts, but the full-text review revealed that the article somehow did not fulfil the inclusion criteria [59-63]. These articles often lacked a technical intervention [63], missed crucial information on the result of the study [62], did not mention any changes in order to improve the situation [61], or in other ways lacked information making it unfit or unable to contribute to the thesis [59, 60]. In addition, two of the articles seemed to have potential but missed important information on method description and/or clearly stated results. These two articles seemed promising, but had a very theoretical and technical approach and did not provide the desired information for this thesis and were, therefore, not included in the study [64, 65]. After the full-text review, a selection of 17 articles containing helpful information were used to answer the research question. A short summary of the data extracted from these 17 articles are presented in *Table 8.* The full data- extraction sheet, including all the collected data, can be viewed in appendix A.

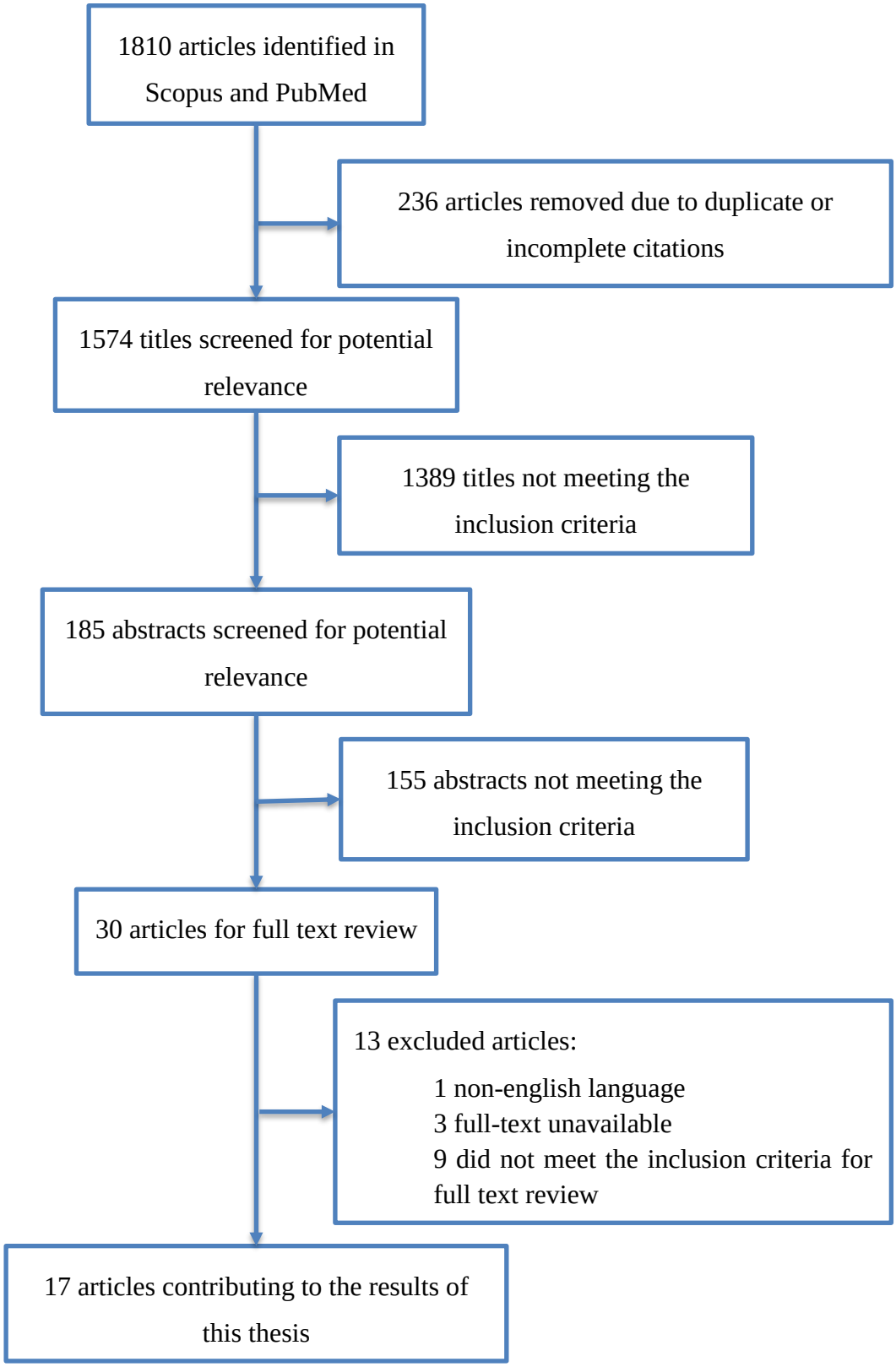

Figure 1 – Preferred Reporting for Systematic reviews and Meta-Analyses (PRISMA) flowchart of the literature search and article selection.

Table 8 - Summary of information retrieved from the 17 articles selected for full-text review. The articles are presented in alphabetical order after the title of the article.

Summary					
Ref	**Author**	**Country**	**Purpose/aim/goal**	**Method (type of study)**	**Conclusion stated in the article**
[66]	Gillespie, B. M. Gwinner, K. Fairweather, N. Chaboyer, W.	Australia	*"The aim of this observational study was to describe the strategies used to communicate decisions during surgery and the ways in which this dialog creates or compromises shared situational awareness" [66].*	Post observational study	*"Strategies used to convey decisions that enhanced shared situational awareness included the use of "self-talk", closed-loop communications, and "overhearing" conversations that occurred at the operating table. Behaviours that compromised a team's shared situational awareness included tunnelling and fixating on one aspect of the situation" [66].*

[67]	Ahmed, T. Khan, M. Khan, F. A.	Pakistan	The purpose of the paper was to investigate the reason for surgery cancellations for patients attending preoperative anaesthesia Clinic [67]**.**	Prospective audit	The authors found that patient related reasons for cancellations were the most frequent cause for cancellations, these cancellations were viewed as uncontrollable. Anaesthetic reasons for cancellations could possibly be reduced by improving communication between anaesthesiologists and surgeons. Improving the organizational strategies might contribute to reduce cancellations related to overbooking and administrative matters [67]**.**
[68]	Nouei, M. T. Kamyad, A. V. Soroush, A. R. Ghazalbash, S.	Iran	The purpose of this study was to develop and test a new operation room information system. The article presents the prototype "MediNav" [68].	Case study – developing a new information system (prototype)	The article states: *"The results reveal that integration of these systems into a complete solution is the key to not only stream up data and workflow but maximize surgical team usefulness as well. It is now possible to comprehensively collect and visualize*

					medical information, and access a management tool with a touch-less NUI in a rather quick, practical, and harmless manner"[68].
[69]	Yahia, Z. Iijima, J. Harraz, N. A. Eltawil, A. B.	Egypt	The main goal of this paper is to: 1. *"Evaluate the operational performance of the case mix and master surgery plans that are obtained at the higher decision levels" [69].* 2. "*Model not only the implementation part of the OR scheduling, but also to represent the ontological part" [69].*	Case study – presentation of simulation model	*"The initial results show the simulation potential in the performance improvement of the operating room system. Furthermore, it makes understanding and exploring the system easier" [69].* The authors state that there is a possibility to increase the number of surgeries with around 180 more cases per year, and to reduce the overall waiting list with approximately 45 %, which among others are believed to improve patient satisfaction [69].

[70]	Westbrook, M. L. Dinn, S. E. Wilcox-Riggs, S.	USA	Summarization and presentation of the development efforts when developing a comprehensive surgical information system (SIS) [70].	Case study – presentation of the development of a new information system	The authors conclude that the comprehensive SIS developed by Madigan Army Medical Center is equal, and in some ways better than commercial products. The SIS filled a void in data collection required by the Department of Defence (DoD). The system also had less costs than buying an off-the-shelf system [70].
[71]	Fayed, A. Elkouny, A. Zoughaibi, N. Wahabi, H.	Not stated	The purpose of the paper was to investigate the rates and reasons for surgery cancellation, in addition the authors investigated the how installing new operating rooms affected the cancellation rate using statistical process control (SPC) analysis [71].	Retrospective review (detailed review of reasons for cancellations using statistical analysis)	The authors conclude that the reasons for cancelling surgeries varied greatly among the different institutes. The article states that installing extra ORs and extending the infrastructure is not the only solution to the problem of cancellations [71].

[72]	Doll, D. Kauf, P. Wieferich, K. Schiffer, R. Luedi, M. M.	Germany	*"To understand the impact and managerial implications of the interplay between anesthesiologists and surgeons on OR efficiency" [72].*	Retrospective study	*"A surgeon is usually predefined for scheduled surgeries (surgical list). Allocation of the right anesthesiologist to a list and to a surgeon can affect the team performance; thus, this assignment has managerial implications regarding the operating room efficiency affecting turnaround times and thus potentially overutilized time of a list at our hospital" [72].*
[73]	Caesar, U. Karlsson, J. Olsson, L. E. Samuelsson, K. Hansson-Olofsson, E.	Sweden	The goal of the study was *"to evaluate and describe the number and reasons for cancellations in elective orthopaedic surgery" [73].*	Retrospective observational single center study	The study concluded that the cancellation rate at the center of interest is high; 39% of all surgeries were cancelled at least once. In addition to this the study showed that many of the cancellations are avoidable. *"By clarifying the reasons for the cancellations, everyone involved has*

					better knowledge to improve and develop better routines to reduce the number of cancelled patients. (…) The high number of cancellations in this study is a major quality problem affecting the individual patient *and the actual healthcare organisation" [73].*
[74]	Lehtonen, J. Torkki, P. Peltokorpi, A. Moilanen, T.	Finland	*"The aim of this study is to develop a practical scheduling system that considers the advantages of both surgery categorization and newsvendor model to surgery scheduling" [74].*	Case study	The study results showed a significant increase in cases per day, and the research revealed that a way to increase operating room efficiency was by *"planning to have one OR team to work longer" [74]*. In addition, the authors state that in surgical services *"productivity and cost-efficiency can be improved by utilizing historical data in case scheduling and by increasing*

					flexibility in personnel management" [74].
[75]	Ahmed, K. Khan, N. Anderson, D. Watkiss, J. Challacombe, B. Khan, M. S. Dasgupta, P. Cahill, D.	England	*"The aim of this study was to evaluate the implementation of TPOT in urology operating theatres and identify obstacles to running an ideal operating list" [75].*	Report on introduction of The Productive Operating Theatre (TPOT) programme in urology operating theatres.	The authors concluded that TPOT has contributed in revealing important obstacles concerning creating functioning operating lists. In addition, TPOT improved the cumulative cost, and the efficiency in the operating theatres by reducing overrun times and increasing the number of surgeries starting on time. According to the authors patients' satisfaction also increased due to a more efficient communication [75].

[76]	Xiang, W.	Not stated	The purpose of this study was to investigate how a meta-heuristic approach integrating Pareto sets and Ant Colony Optimization (ACO) could solve problems in optimization of multi-objective OR scheduling [76].	Computational study	*"It can be concluded that the algorithm can solve the multiple objective surgery scheduling problem effectively, while at the same time provide a shortening makespan and a relative balanced resource allocations" [76].*
[77]	Zhu, S. Fan, W. Yang, S. Pei, J. Pardalos, P. M.	Not stated	The overall aim of this paper was to provide a comprehensive classification on operating room planning and scheduling problems. The authors conducted a literature review, and reviewed the literature *"from the perspectives of decision level, scheduling strategy, patient characteristics, problem setting, uncertainty, mathematical models, and solutions and methods" [77].*	Literature review	The literature review concludes that *"studies reviewed in this paper clearly indicate that different decisions in different levels have a significant effect on the performance of the surgical center" [77].* The authors underline that most of *"most of the research is directed towards the scheduling problem within everyday horizon, which is very close to the actual situation" [77].* The

					literature review states that the articles included in the study showed that none of the theoretical work published seems to have profound effect in real-life practise or the management of ORs [77].
[30]	Addis, B. Carello, G. Grosso, A. Tànfani, E.	Not stated	Investigating how to select patients from a waiting list of elective patients and how the use of a block scheduling strategy using a rolling horizon approach could contribute to minimize the overall waiting time and the tardiness of patients [30].	Case study	The authors used a block scheduling strategy in order to solve the advance scheduling and rescheduling problem (ASRP). The article concludes that the computational results are promising. According to the authors the solution provides a better resource utilization and reduce the number of cancelled surgeries [30].

[78]	Liu, H. Zhang, T. Luo, S. Xu, D.	China	The purpose of this study: *"(...) solving a surgery scheduling problem with multiple ORs and multiple surgeons to minimize cost and improve utilization of operating theatre" [78].*	Case study	The authors concluded that the model and methods used provided good solutions in diverse sample sizes. In addition, they state that: *"Real-life constraints and duration uncertainty were considered in the study, and the model was also very applicable in practice. Average overtime of each OR was reducing and tending to be stable with the number of surgeons increasing, which is a discipline for OR management" [78].*
[79]	Kumar, R. Gandhi, R.	Not stated	*The aim was: "To investigate and evaluate the reasons for cancellations of operations on day of surgeries" [79].*	Audit of reasons for cancellations.	The authors wanted to investigate why surgeries were cancelled on the day of surgery, and if the cancellations could have been avoided. They conclude that most causes of cancellations of operations are avoidable [79].

[80]	Pang, B. Xie, X. Song, Y. Luo, L.	China	According to the authors the purpose is to: *"(...) develop an optimization model to address inefficient scheduling. The goal is that this will contribute in minimizing the costs from the perspectives of both healthcare providers and patients" [80].*	Case study	*"The case study revealed that the total cost can be reduced by approximately 27 %. Investigation of the value of stochastic solution (VSS) revealed the necessity of considering a stochastic programming* *formulation. The authors state that the developed solutions provided by the models are better than ones obtained from the current practice at the hospital" [80].*
[81]	Damani, Z. Conner-Spady, B. Nash, T. Stelfox, H. T. Noseworthy, T. W. Marshall, D. A.	Not stated	The goal of the review was: *"(1) summarise existing research on the scope, use and Implementation of SEMs for elective surgical services; (2) to report on the evidence about the influence of SEMs on timeliness and access;*	Systematic literature review	*"The review demonstrates a potential ability for SEMs to improve timeliness and patient-centredness of elective services; however, the small number of low-quality studies available makes it challenging to draw firm conclusions about the effectiveness of SEMs in*

			and (3) patient-centredness (patient and provider acceptability) of SEMs." [81].		*improving timeliness of access to elective procedures. Our findings show a consistently positive impact by SEMs on the access-related variables. While promising, they also prompt the need for ongoing study in critical areas, but with higher quality designs, more comprehensive scope and greater methodological rigour" [81].* The majority of the studies included in this review had a weak observational design according to the authors [81].

4 Discussion and conclusion

The articles included in this thesis can be categorized in three groups, depending on the content. The *first group* included articles containing reports concerning information on a system or, in other ways included information and/or data concerning context-aware systems, to a total of nine articles [30, 66, 68-70, 74, 75, 77, 81]. The *second group* comprises four articles that mainly investigated reasons for cancellations, but included some kind of information concerning how these cancellations could have been avoided [67, 71, 73, 79]. This information was viewed as valuable to this thesis considering creating context-aware programs and solutions and were, therefore, included in the study. The *third group* contained the articles that presented a mathematical approach to the problem. These studies viewed how the scheduling problem could be solved using different programming models as a suggested solution [72, 76, 78, 80]. This was also the case for the two of the articles excluded from the full-text review, that did seem promising, but had a very theoretical and technical approach and did not provide the desired information for this thesis and were, therefore, not included in the study [64, 65]. Hereafter, the three groups will be introduced and the information and findings within each articles in the given group will be presented and discussed in relation to the research question.

4.1 First group

The Madigan Army Medical Center developed their own comprehensive Surgical Information System (SIS) [70]. The system included four important aspects that were viewed as very valuable in the process. The first aspect mentioned was, that the system was created with the involvement of hospital staff and the end-users that wanted the system to succeed. The second aspect mentioned was that organizational staff and "command staff" were included in the development. The third aspect emphasizes that the developers had continuous meetings with end-users, creating the system with user classifications, so that surgeons, nurses and other surgical staff had their personalized display providing the needed information for the different roles. Lastly, the fourth aspect in the development process describes how when the system was launched as a small pilot, during which problems and errors were fixed before gradually expanding the system to the hospital [70]. These aspects contributed to the system functionality, and the authors stated that all surgical services used the SIS after implementation. The time spent on surgical scheduling was drastically reduced, in other

words, the efficiency increased. Nevertheless, a problem with the system was that the staff did not receive enough training in using the system and, therefore, many staff members continued using the previous system [70]. According to this, article the SIS implementation was a success, and it contributed to increase the efficiency at the Center. However, the authors fail to mention how they plan to train the staff in the future in order to get the system to be used at all levels. This paper is more than 20 years old (1996), and it is likely that the system might be outdated, or has drastically changed since the article was published [70].

Another study presenting development of a new system, suggests creating a comprehensive operating room information system (ORIS) [68]. The ORIS presented in the article is a prototype called "MediNav", that was deployed in 2013 [68]. The purpose of creating a comprehensive ORIS was to create a system that could maximize workflow, and gather medical information in a safe, fast and practical manner, which is similar to the wished of development aims of the SIS in 1996, [68, 70], and can be linked to context awareness. The article, [68], addresses how it is important to plan the different surgical stages in the surgical pathway, being able to access important data and vital information quickly, but avoiding contamination; meaning transferring contaminated substances between the sterile and non-sterile zones. In addition, there might be a need to document surgical steps, for instance, by using video or audio recordings. The authors state that using Kinect sensors (motion sensing input devices), and radio frequency identification devices (RFID) in the comprehensive ORIS would be the key to offer a complete solution to comprehensively collect and visualize medical information [68]. The authors concluded that using touch-less natural user interface (NUI) could possibly contribute to the management tool, in addition to collect and visualize medical information [68]. The article states that at the time of publishing the article, the system has not been integrated. The authors also note that there is a need for further testing and comparison of system to against solutions, such as, other human-machine interfaces in order to evaluate what solution would be optimal. This is in accordance to the articles that will be presented in group three [72, 76, 78, 80], but these articles has a very mathematical approach as opposed to [68]. In [68] the authors are using context awareness when collecting data from interviews and watching and listening to the users, without referring to it as context aware data collection.

Two urology operating theatres in London introduced a programme called The Productive Operating Theatre (TPOT) [75]. The programme was developed by the NHS Institute for

Innovation and Improvement with the hopes of improving the surgery outcomes and enhance patient safety and satisfaction. The aims of this article are aligned with the two abovementioned articles [68, 70]. After the introduction of the TPOT programme the overrun times were reduced and the number of surgeries starting on time was increased. These results are believed to be consequence of the introduction of a briefing and debriefing system. The briefing system lead to staff members addressing potential issues ahead of time, and lead to a better structured operating plan leading to increased efficiency. The authors concluded that TPOT has contributed in revealing important obstacles concerning creating functioning surgery lists. In addition, TPOT improved the cumulative cost, and the efficiency in the operating theatres by reducing overrun times and increasing the number of surgeries starting on time. According to the authors patients' satisfaction also increased due to a more efficient communication [75]. It is also worth mentioning that by avoiding overrun times, one could also possibly avoid cancellations because the scheduling and OR block times are correct, leading to surgeries finishing within the planned timeframe and, therefore, avoiding cancellations due to unavailable ORs. The results presented in [75] are of great importance because they are in alignment with the needs stated in the introduction section of this thesis by WHO, OECD, The World Bank and the Norwegian Ministry of Health and Care Services' [23, 25], concerning the need for improved utilization, increased efficiency and improved quality care in the modern society of healthcare.

Another article presenting results that could improve utilization, increase efficiency and improve quality care is [69]. Here, the authors attempt to create a simulation model with focus on the essence of the system in use at the hospital of interest. A simulation model was developed using Design and Engineering Methodology for Organization (DEMO)-based simulations, and the goal was to create a more holistic view of the enterprise [69]. According to the article *"The initial results show the simulation potential in the performance improvement of the operating room system. Furthermore, it makes understanding and exploring the system easier"* [69]. The authors state that there is a possibility to increase the number of surgeries with around 180 more cases per year, and to reduce the overall waiting list with approximately 45 %, which among others are believed to improve patient satisfaction [69]. In difference to the other studies in this group, the researchers are approaching the problem by going from a detailed view to a holistic view of the information needed in surgical cases.

Another way of creating a better scheduling system, is the use of single-entry models (SEMs). In 2016 the first systematic review on SEMs for adult elective surgeries was published [81]. SEMs are suggested as a solution to decrease waiting lists and increase patient flow using a single point-of-entry, and a first-come first-serve approach. The results from the review revealed SEMs could decrease time on waiting lists and increase patient satisfaction. However, there were only a small number of studies available and these studies often had low-quality, such as case studies. Because of these findings the authors were reluctant to draw any firm conclusions about whether the SEMs do improve timeliness of access to elective surgery procedures or not. The authors do, however, stress that SEMs are promising, but there is a need for more in-dept high quality studies on the matter [81]. The first-come first-serve approach should be mentioned as a potential problem, because it is not clearly stated how many cases assessed urgency and priority. If this is not taken into consideration the model will most likely have huge problems in practice. It is, however, worth mentioning that the results from this article is in alignment with the literature review conducted in this thesis. Most of the articles used in this review are small case studies, and the quality of the studies vary, revealing that there is a gap in knowledge. Another model [30], focuses on how to reduce the overall waiting time and the avoidance of tardiness by using a rolling horizon approach. The purpose of the study was to investigate how to select patients from a waiting list of elective patients and how the use of a block scheduling strategy, that included a rolling horizon approach could contribute to minimize the overall waiting time and the tardiness of patients [30]. As opposed to several of the articles mentioned in the literature review [81], this study did provide priority to urgency cases [30]. The authors used a block scheduling strategy in order to solve the advance scheduling and rescheduling problem (ASRP). The article concludes that the computational results are promising, and according to the authors the solution provides a better resource utilization, and reduce the number cancelled surgeries[30]. It should be mentioned that the authors state that future work should involve combining surgery scheduling and bed management. The reason why this is suggested as future work is because bed availability is a significant resource that needs to be functioning in order to avoid problems in scheduling and surgery planning, and execution [30]. This information is important to keep in mind because it could be linked to the context data needed in order to have highly functioning scheduling system.

Gillespie et al. [66], focused on situational awareness and how important communication is to avoid misunderstandings and create a safe surgical environment [66]. This article mostly

focused on the communicational aspect in order to create situational awareness without clearly stating if communicational tools such as pagers, smartphones or tablets, were considered. Being able to communicate with staff members that are not in the same room but involved in the surgical process could also contribute to increased situational awareness. The authors state that by improving communicational strategies, one can improve the situational awareness within the teams, leading to a better overview, which could lead to discovering possible obstacles ahead of time and avoiding unnecessary cancellations [66].

A Finnish study published in 2013 aimed to *"develop a practical scheduling system that considers the advantages of both surgery categorization and newsvendor model to surgery scheduling"* [74]. The authors state that many of the former studies focus on mathematical modelling, this is often hard to apply in real-life environment, therefore, the researchers wanted to investigate the problem from a practical view [74]. This will be discussed later on in this thesis. The researchers applied the newsvendor model in the OR environment, including planning and scheduling. The study results showed a significant increase in cases per day, and the research revealed that a way to increase operating room efficiency was by *"planning to have one OR team to work longer"* [74]. However, this suggestion was, not described further, and it could be argued that this is not a solution but rather "planning to be delayed", therefore, one could claim that instead of planning to work longer one needs to investigate if the timeframe is too narrow, causing delays. In addition, the authors state that in surgical services *"productivity and cost-efficiency can be improved by utilizing historical data in case scheduling and by increasing flexibility in personnel management."* [74]. Limitations mentioned by the researches was, among others, that the study was conducted in a very specific setting and, therefore, the applicability to other disciplines and situations cannot be confirmed [74]. Another important point the authors make is that scheduling of surgeries are often complicated and staff working with scheduling on an everyday basis often acquire important information and experience concerning how planning and scheduling should be conducted [74], and, therefore, these experiences are important knowledge to obtain in order to create a high-functioning scheduling system.

Zhu et al. [77] published a comprehensive survey concerning problems related to operating room planning and scheduling. The review attained 315 articles, and concludes that the studies *"clearly indicate that different decisions in different levels have a significant effect on the performance of the surgical center"* [77]. In addition to this the authors underline that

"*most of the research is directed towards the scheduling problem within everyday horizon, which is very close to the actual situation"* [77]. It is usually beneficial to plan ahead of time, using long-term scheduling, in order to have work schedules for the surgical teams, and because the patients need time to prepare, and often needs to take time off from their own work. Therefore, a everyday horizon could be viewed as a disadvantage for both hospital staff and patients. One should note that according to the authors the review attained 315 articles, but it is not clearly stated if these were all included in the final result. The literature review states that the articles included in the study showed that none of the theoretical work published seems to have profound effect in real-life practise, or the management of ORs, implying that there is still a lot of work to implement high-functional systems in practice [77]. This is consistent with this thesis and what the results from the literature review portrayed.

4.2 Second group

A study concerning surgery cancellations on the day of the intended surgery revealed that most of the cancellations at the hospital were avoidable [79]. Causes of cancellations varied but the most common causes were lack of availability of surgical time, hence, bad planning (63 %), and no-shows (19 %) [79]. These numbers are similar to the numbers from UNN [18], revealing that the surgical planning has a need for improvement in order to decrease the number of cancellations on the day of surgery. The study [79] suggest, among other things, making OR lists judiciously with better pre-surgical planning in order to achieve the best utilization of ORs [79]. Fayed et al.[71], also investigated cancellations on the day of intended surgery. The patient related reasons for cancellations were, however, higher, representing 27 % of the cancellations [71], compared to 19 % [79] and 12 % [18]. In this study [71], patient related reasons for cancellations represented the leading cause for cancellations. One possible explanation to this could be that the study only divided the cancellations in three categories: patient related factors, facility related factors, and preoperative preparation causes [71]. The authors noted that cancellations due to respiratory infections and febrile illnesses were more frequent during the wintertime, and that these reasons for cancellations were lower during the months May through July [71]. This could mean that the number of surgeries cancelled due to infections or fever will be lower during the summertime, however, this cannot be proven based on just one study, but is valuable knowledge as part of context awareness and understanding reasons for surgical cancellations. Some elective surgery patients attend a preoperative anaesthesia clinic before surgery [67].

According to [67], 58 % of the cancellations where patients attend a preoperative anaesthesia clinic were patient related [67]. This number is significantly higher compared to the three articles mentioned in this section [18, 71, 79]. The study was published as a prospective audit and the numbers presented only represents 55 cancellations within a two-month period. This could explain the high number of patient related reasons for cancellations. In addition the study was conducted in Pakistan, and patients have to finance the surgery themselves leading patients to investigate offers at other hospitals [67]. The article do, however, mention that over-booking and bad planning also was a problem representing 5,45 % of the cancellations, and suggest that a solution to this would be improving the scheduling system [67].

Article [73] concerned cancellations of orthopaedic surgeries, and the cancellation numbers due to acute cases were high. The number of cancellations due to acute cases with higher priority could be explained when considering that this study concerned elective orthopaedic surgeries. Orthopaedic surgeries often include trauma, so patients with higher priority, for instance, due to accidents, would be prioritized a head of an elective surgery. Therefore, it was suggested to have two waiting lists, one list for acute patients, and one for elective surgeries, in order to reduce cancellations [73].

In both [71, 73], the authors mentioned that providing the patient with a call or text message as a reminder of the surgical appointment ahead of time could reduce the number of no-shows and cancellation last-minute. Also, several of the articles included information on how improving communication between doctors, nurses and patents can be used as a way of preventing problems and avoiding surgical cancellations [67, 73, 79]. In other words the articles state that patient related causes for cancellations are hard to avoid, article [79] even classify it as “nonavoidable”. However, several articles do suggest increasing communication with patients, providing information of sending reminders as a way to avoid patient related cancellations [67, 73, 79]. This thesis focuses on the hospital related reasons for cancellations, and, therefore, patient related reasons for cancellations has not been the main focus. Patient related reasons for cancellations represented 12 % of elective surgery cancellations at UNN [18]. It could, therefore, be a suggestion to implement text reminders to patients in a context-aware scheduling system, as a measure to reduce the patient related reasons for cancellations.

4.3 Third group

In 2018, an article concerning a stochastic integer programming model developed by researchers at a West China Hospital, was published [80]. In the article the authors present a

case study where they integrated a stochastic programming model at two departments, with the hopes of reducing cost for the hospital and provide better care for the patients. The article presents three decision-making problems that affect cancellation rates at the hospital [80]. First, the problems concerning patient admission. This is among other problems concerning capacity, admission and assigning surgeons to patients. Second, the problems concerning block scheduling. This problem concerns how to make choices when assigning time blocks to departments and recipients of surgery. Third, the problems concerning surgery sequencing. This problem concerns the sequencing of the surgery within the block time [80]. The case study had promising results and was viewed as a better solution compared to the current system in use at the hospital. According to the researchers, and reduced the costs by roughly 27 % [80]. However, the study also had several limitations that are mentioned and should be changed in the future. This was among other that the system was not a dynamic scheduling system, and that the research did not include emergency surgeries, which is highly necessary. The authors did address this and stated that emergency surgeries would have to be implemented in the model in the future [80].

An article published in 2017 [76], investigate how a meta-heuristic approach integrating Pareto sets and Ant Colony Optimization (ACO) could solve problems in optimization of multi-objective OR scheduling [76]**.** In the article the evaluation of the OR scheduling system are controlled by performance criteria such as *"waiting time, throughput, utilization, leveling, makespan, patient deferrals, cost measures and preferences, etc." [76]*. The author divided these performance criteria into different categories. These categories were: *"patient-related measures, staff-related measures, and OR management-related measures" [76]*. The algorithm created was tested in two different test settings and the article concludes that "*that the algorithm can solve the multiple objective surgery scheduling problem effectively, while at the same time provide a shortening makespan and a relative balanced resource allocations" [76]*. However, the article states in the very end of the "Conclusion and ongoing work" section that the algorithm needs to be improved in order to solve the scheduling problems with "more realistic constraints" in order to function in an real-life surgical setting [76], meaning that as of now the system would not be a successfully implemented in hospital settings. Other articles investigated how team setups could improve efficiency using mathematic and algorithmic decisions [72]. The results showed that stable surgical teams increased operating room efficiency which improved the turnaround times and, in this manner, contributing to avoiding operating room delays [72]. One could argue that surgical

teams usually will vary due to different circumstances making it difficult to always have stable surgical teams, this includes turn-around schemes at the hospital and the hiring of additional staff.

Chinese researchers developed a stochastic model as a tool for operating room scheduling and surgeon assignment [78]. The authors used what they describe as “a two-step mixed integer programming model”. A sample average approximation method was used in order to solve the model [78]. The programming model was a two-step model: The aim for the first step was to lower the opening costs and overtime cost for the ORs. The aim for the second step was to reduce overtime in the ORs by increasing utilization. The study results displayed that the model and method provided a satisfying solution in different sample sizes. The average of overtime in the ORs was reduced and the availability of surgeons who could perform the surgery on the given day increased [78]. There are some uncertainties concerning this article, for instance, the inclusion of real-life constraints included in the model is not clearly stated, but it is noted that “more real-life constraints” are needed in the future. Additionally, the article states that emergency cases and surgery cancellations need to be introduced in the modelling process [78], meaning that these factors have not been considered in the model as of now. The article could be criticised for not clarifying these statements.

All of the above-mentioned articles included in group three presented a mathematical approach, only considering how programming models could change the planning and/or scheduling system at the hospital [72, 76, 78, 80]. Like the article by Lehtonen et. al. [74] stated in their article, included in group one, the problem with this is that this approach, is that it often fails in an actual hospital setting [74]. This can also be seen in the article concerning development of a comprehensive surgical information system (SIS) [70], where the authors stated that the use of the application encountered major difficulties in an actual hospital setting [70]. It is also worth noticing that none of the programming models had actually been implemented in a hospital setting and did require changes according to the articles’ future work section [64, 65, 76, 78, 80]. The changes included improving efficiency [64], considering dynamic scheduling systems [80], and implementing more real-life constraints, such as nurse and surgeons preference in medical teams [76, 78]. This supports the statement from Lehtonen et al. [74] concerning that studies only focusing on mathematical modelling, are often proved hard to apply in real-life environment, therefore, the problem might be more approachable from a practical view, or in a combination, in order to succeed [74].

The articles in all three groups have common traits concerning the content of the desired outcome of the studies. Therefore, the groups can be summarized as articles that in some way investigates elective surgery scheduling. The articles often aimed to investigate how to improve efficiency, enhance patient satisfaction, improve patient safety, or decrease cost/increase income [30, 66-81]. This is in alignment with the needs stated by WHO, OECD, The World Bank and the Norwegian Ministry of Health and Care Services' [23, 25] and is, therefore, a natural focus area because research on these topics could possibly get founding from, for instance, health departments in the country of interest.

The articles included in this thesis have been categorized and presented according to three different groups, depending on the content of the articles. It could, however, be worth noticing that articles excluded from the full-text review had similarities, but this concerned lack of content. For example, several articles focused on increasing resources without focusing on optimizing the systems in use. Meaning that the hospital increased the capacity of ORs or increased operating teams and resources without considering if there should have been other changes, like optimization of the scheduling system or the planning of the surgeries or surgical teams [61, 62]. For instance, Lloyd [62], suggested to have a multi-skilled staff team available to reduce the number of cancellations in standalone surgeries at hospitals, but does not mention planning and scheduling strategies in order to in cooperate this team and how to avoid having superfluous staff members and redundancy in practise, therefore, risking economic loss [62]. Another example of increasing capacity without optimizing the systems used is a study at a 600-bed university hospital with ten operating rooms [61]. Here two additional operating rooms where built with the hope of reducing cancellation rates on day of surgery. The hospital did, however, not hire more staff members, nor does the article mention that any planning features or technological aspects were changes or optimized. The article concluded that the cancellation rates actually increased due to the instalment of an additional two operating rooms, and that the most common reason for cancellations after the installations of two new ORs were departmental issues [61]. This could possibly have been avoided if the hospital in addition to the new ORs also optimized the planning and scheduling systems.

The author of this thesis acknowledges that the root causes of suboptimal resource utilization are multifactorial and include all phases in patient-flow from: referenced to surgery, pre-elective surgery planning, hospitalization of patient, conducting surgery, and post-surgery. In

this work the area of focus is the technological aspect and investigating workflow and context-awareness concerning elective surgeries.

4.4 Research questions

In this section, the most relevant information gathered during the literature review, and its discussion, will be summarized and presented in correlation to the research questions in *Table 9.*

The first column in *Table 9,* identifies the group in which the article was classified, and the citation number of the article. The second column presents the most relevant data and information gathered from the retrieved articles. The third column includes information from the articles that contributes to answering the research question concerning *what* context data can be used to improve the elective surgery scheduling. The fourth column denotes the information gathered that contributes to answering the research question concerning *how* context data can contribute to improve elective surgery scheduling, including the effects it provided or hoped to achieve.

From the information in *Table 9,* it is concluded that the use of context data in scheduling tools positively affects the number of elective surgery cancellations, by reducing cancellations. The context data most mentioned concerning *what* data could be used to improve elective surgery scheduling was historical data and information on decision-making and staff experiences. The effect most articles reported, concerning *how* context data could improve elective surgery scheduling, was increased efficiency and improved utilization of resources. In addition to this, many articles also focused on patient satisfaction. This is in alignment with national and global recommendations for future healthcare [23, 25].

Table 9 - Data gathering in correlation to the research question

Group & Ref.	Data (information from the retrieved articles)	What (is needed)	How (the effects - what is the improvements mentioned/hoped for in the articles)
1 **[70]**	- Surgeons, nurses and other surgical staff had their personalized display providing the needed information for the different roles - Context-awareness	- Information on how the users use the system and what information they need in surgical context	- Increased efficiency (The time spent on surgical scheduling was drastically reduced) - Right information, to the right person, in the right moment
1 **[68]**	- Addresses how it is important to plan the different surgical stages in the surgical pathway - The importance of accessing important data and vital information quickly, but avoiding contamination - Physical contamination – context awareness is needed for location of the needed information	- For example: they collect interviews and watching and listening to the users while they work and also questionnaires for usability satisfaction - They are using context-awareness without referring to it	- Using Kinect sensors (motion sensing input devices), and radio frequency identification devices (RFID) in the comprehensive ORIS would be the key to offer a complete solution to comprehensively collect and visualize medical information - Using touch-less natural user interface (NUI) could possibly contribute to the management

	- Creating historical data that we can use to know what the task implies in terms of medical equipment - Tracking people by RIFD (location and context awareness)		tool, in addition to collect and visualize medical information
1 **[75]**	- The context data used here: improved block times for OR scheduling	- Introduction of a briefing and debriefing system - Data relevant for the system	- Leading to staff members addressing potential issues ahead of time, and leading to a better structured operating plan leading to increased efficiency - The overrun times were reduced and the number of surgeries starting on time was increased - TPOT has contributed in revealing important obstacles concerning creating functioning surgery lists - TPOT improved the cumulative cost, and the efficiency in the operating theatres by reducing

			overrun times and increasing the number of surgeries starting on time - Patients' satisfaction also increased
1 **[69]**	- In difference to the other studies in this group, the researchers are approaching the problem by going from a detailed view to a holistic view of the information needed in surgical cases - Approaching the problem with standardized data to create more efficient scheduling systems	- Using Design and Engineering Methodology for Organization (DEMO)-based simulations. Focusing on the essence of the system used at the hospital	- Theoretical paper, the authors state that there is a possibility to increase the number of surgeries with around 180 more cases per year, and to reduce the overall waiting list with approximately 45 %, which among others are believed to improve patient satisfaction
1 **[81]**	- Systematic review on scheduling system using single-entry models. Acquired 11 articles presented in the article - SEMs can be interpreted as context data in this setting	- Gathering data concerning the use of single point-of-entry, and a first-come first-serve approach	- Systematic review, the authors does not want to draw any firm conclusions about whether the SEMs does improve timeliness of access to elective surgery procedures or not

			- The authors do, however, state that SEMs can increase access related variables
1 **[30]**	- Block data regarding surgery time	- The system gathers all block data regarding surgery that could affect operational time - Use of a block scheduling strategy, that included a rolling horizon approach	- According to the authors the solution provides a better resource utilization, and reduce the number of cancelled surgeries - Contribute to minimize the overall waiting time and the tardiness of patients
1 **[66]**	- Focused on the communicational aspect in order to create situational awareness by using situational data, overhearing, and communication data, such as communicational patterns	- Closed loop communication. Being able to communicate with staff members that are not in the same room but involved in the surgical process could also contribute to increased situational awareness	- Creating a better situational awareness in order to avoid misunderstandings and create a safe surgical environment

1 **[74]**	- The use of historical data in case management and increasing fixability in personnel management	- Utilizing historical data in case scheduling to create a improved scheduling system	- Increased efficiency in cases per day
1 **[77]**	- The problem is on the operational and strategic levels – patient pathway data or patient related data that could change the pathway	- Literature review - Use the lack of context-awareness to make the operating rooms more general (They are lowering the speciality level in order to increase efficiency in each operation room)	- None of the theoretical work published seems to have profound effect in real-life practise, or the management of ORs - Planning on a strategic, tactical and operational level
2 **[79]**	- Gathering data regarding surgical cancellation on the day of surgery - Common causes were lack of availability of surgical time, hence, bad planning (63 %), and no-shows (19 %)	- There is a need for increased knowledge about the systems in use at the hospital, and the patient flow - Better pre-surgical planning means more information on the patient, pathway and	- Making OR lists judiciously with better pre-surgical planning in order to achieve the best utilization of ORs - Suggests call/text reminders to patients to avoid no-shows

		resources selected to be used by the patient prior to surgery. For example, be aware of the patient health status, possible vacations of resources (keep track if the resources remain available), further examinations required (changes in the pathway)	
2 **[71]**	- Gathering data regarding surgical cancellation on the day of surgery. E.g. statistical data and seasonal changes do affect the cancellation rate, with less febrile illnesses during summertime vs. winter	- Gathering context data by investigating why cancellations of surgery occurred to provide a possible solution - Again, be aware of the patient health status (other pathologies that might have appeared that hinder surgery	- The article suggests installing additional operating rooms - Suggests call/text reminders to patients to avoid no-shows

2 **[67]**	- Gathering data concerning surgery cancellations of patients attending a preoperative anaesthesia clinic	- Improving information flow with the hospital staff and to patients - Better management of uncertainty (for example emergency). Improve the management of uncertainty by analysing historical data and describing it in the scheduling module using context data	- Suggest that a solution to this would be improving the scheduling system and communicational tools at the hospital and in consideration to patient communication
2 **[73]**	- Gathering data on cancellations of orthopaedic surgeries	- Collecting context data about the severity of the surgical need and placing it into a given group, selecting placement on waiting time list	- It was suggested to have two waiting lists, one list for acute patients, and one for elective surgeries, in order to reduce cancellations - Suggests call/text reminders to patients to avoid no-shows

3 **[80]**	- Developing a stochastic integer programming model and integrating the model into hospital settings	- Gathering context data concerning decision-making problems and what data is needed in order to solve the problems, this includes data concerning allocation, sequencing, and surgery duration - Improve the stochasticity of the system through the use of context awareness. Include department level variables that allow a better adjustment to the individual reality of each department	- The model has not been implemented and there is a need for future work, but the hope is that the model could reduce cost for the hospital and provide better care for the patients
3 **[76]**	- Using a meta-heuristic approach integrating Pareto sets and Ant Colony Optimization (ACO) to improve resource allocations	- Using algorithms to solve the scheduling problems	- The model has not been implemented and there is a need for future work, but the algorithm can solve the multiple objective

		- Collecting data to pinpoint the needed resources to increase efficiency	surgery scheduling problem effectively according to the authors, in this way optimizing scheduling and increasing efficiency
3 **[72]**	- Creating a perioperative team setup in the management of operational teams and management decisions	- Using mathematic decisions to assess turnaround times, analysing what personnel is most compatible in order to avoid overtime	- The thought is that stable surgical teams increased operating room efficiency which improved the turnaround times and, in this manner, contributing to avoiding operating room delays
3 **[78]**	- Developing a stochastic model as a tool for operating room scheduling and surgeon assignment. Used what they describe as “a two-step mixed integer programming model”, using a sample average approximation (SAA) method to solve the model	- Collecting context data on OR block scheduling times, staff availability and surgical planning	- The model has not been implemented, but the idea is that the effect will be lowering costs, increasing utilization and reducing overtime

4.5 Limitations

The literature review presented in this thesis was conducted in a systematic way, but was only reviewed by one author, therefore, it cannot be classified as a systematic review. However, attempts were made in order to minimize bias and limitations by conducting the review following the recommendations to systematic reviews [40]. The decision concerning inclusion and exclusion of articles was not controlled by another investigator. In addition, the investigator did not have previous experience regarding conducting this type of research on a master thesis level. This may lead to bias or errors. Nevertheless, the systematic nature of the study, the data extractions, and the inclusion and exclusion criteria were investigated and approved by two supervisors, both before and after the search was conducted. This, alongside with following the Cochrane Handbook's guide [40] and the PICO framework [40], could possibly make this master thesis more objective than a traditional literature review.

The method used in order to answer the research question could also be criticised because, like mentioned, in *2.2.2.1 Selected databases*, there were some inconsistencies between the searches in Scopus and PubMed. Scopus did not allow date restricted searches, while PubMed did, this resulted in a one-month gap between the two searches. Like previously mentioned, this inequality was not discovered before the reading of titles had started. However, it was decided to investigate if there were any relevant articles among the 31 missing days in PubMed. Therefore, the same search string was investigated with the time constriction from 2018/12/01 to 2018/12/31. This search provided three articles. These articles did not include titles that seemed to be of relevance to this thesis, meaning that they would have been excluded from the research. In retrospect this was a lesson for the future, and in upcoming work, one should keep in mind that Scopus only allow year restrictions and adapt to this when conducting searches that includes the Scopus database.

Another problem encountered during the search process was a discrepancy within PubMed concerning the number of hits. This discrepancy was discovered when the investigator redid the search in PubMed to double check the results. The search in PubMed used in this thesis provided 199 articles without filters. When filters were applied 166 articles remained. The exact same search, with the same filters applied could also provide 167 articles. The explanation to this discrepancy this was unclear for some time, but after some investigations, it was discovered that there is an inconsistency in the number of search results considering if one chooses to sort the results in relation to "Best match" or "Most recent". By conducting the

exact same search, with the same filters, but selecting to sort the results in order of "Best match", 167 articles are retrieved. While, if you chose to sort the results in order of "Most recent", 166 articles are retrieved. There is no clear reason as to why this inconsistency occurred, and nor the investigator, nor supervisors or other staff members at NSE are able to describe why this problem occurred. In practise, it should not matter whether one chooses to sort the search result in order of "best match" or "most recent". Given all titles would be read no matter how recent they were, or if they were considered "best match" in accordance to the query, this was not taken into account, and the discrepancy was not discovered before after the searches was retrieved. The "Sort by" selection on the computer used for conducting the search within PubMed was set to "Sort by: Most recent": Thus, by chance, 166 articles were retrieved from PubMed. If desirable the search string for both databases can be found in Appendix B.

This thesis has no clear ethical considerations that needs to be mentioned.

4.6 Future work

In this thesis, the goal was to gather knowledge about what information would be relevant when creating a elective surgery context-aware scheduling system for hospitals. The literature review in this thesis reviled that there is a gap in research concerning the use of context data in scheduling. Most of the articles used in this review are, like in article [81], small case studies, and the quality of the studies vary greatly. In other words, there is a need for more high-quality, in-depth studies concerning this theme. This thesis is a predecessor to an upcoming systematic review on this topic. The systematic literature review will be conducted by two authors. The author declares no conflict of interest.

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Appendices

Appendix A – Full data extraction sheet

Ref	Categorization of article				
	Author	**Year**	**Title**	**Country**	**Type of hospital (private/public etc.) & ward**
[60]	Saberi, N. Mahvash, M. Zenati, M.	2015	An artificial system for selecting the optimal surgical team	Unclear	Not stated
[66]	Gillespie, B. M. Gwinner, K. Fairweather, N. Chaboyer, W.	2013	Building shared situational awareness in surgery through distributed dialog	Australia (Queensland)	Large metropolitan teaching hospital

[67]	Ahmed, T. Khan, M. Khan, F. A.	2009	Cancellation of surgery in patients attending the preoperative anaesthesia assessment clinic: A prospective audit	Pakistan	Unclear, only states: five hundred bed tertiary care referral centre. Ward: preoperative anesthesia clinics
[68]	Nouei, M. T. Kamyad, A. V. Soroush, A. R. Ghazalbash, S.	2015	A comprehensive operating room information system using the Kinect sensors and RFID	Iran	Teaching hospital
[69]	Yahia, Z. Iijima, J. Harraz, N. A. Eltawil, A. B.	2017	A Design and Engineering Methodology for Organization-based simulation model for operating room scheduling problems	Egypt	Karmoze hospital (a nonprofit hospital)
[55]	Ramacciotti, M. Leoni, F. Persichetti, A.	2014	A design paradigm for the development of advanced operating rooms		

	Roccella, S. Rugnone, A. Ferrari, V.				
[70]	Westbrook, M. L. Dinn, S. E. Wilcox-Riggs, S.	1996	Development of a comprehensive surgical information system at Madigan Army Medical Center	Usa	Army Medical Center
[59]	Dyb, K. Bolle, S. R. Granja, C. Hartvingsen, G.	2016	Digital users in pre-digital hospital organisations?: An analysis on the readiness for electronic communication between a hospital and surgical patients	Norway	University Hospital of North Norway (UNN)
[61]	Yoon, S. Z. Lee, S. I. Lee, H. W. Lim, H. J.	2009	The effect of increasing operating room capacity on day-of-surgery cancellation	Korea	600-bed university hospital with ten operating rooms

	Yoon, S. M. Chang, S. H.				
[71]	Fayed, A. Elkouny, A. Zoughaibi, N. Wahabi, H.	2016	Elective surgery cancelation on day of surgery: An endless dilemma	Unclear	Tertiary Hospital
[54]	Schmid, V. Doerner, K. F.	2014	Examination and operating room scheduling including optimization of intrahospital routing		
[64]	Landa, P. Aringhieri, R. Soriano, P. Tànfani, E.	2016	A hybrid optimization algorithm for surgeries scheduling	Not stated	Not stated

	Testi, A.				
[62]	Lloyd, H.	2008	The impact of multi-skilled staff availability on day surgery cancellations	England and Wales	Not stated, but focusing on stand alone surgery units
[72]	Doll, D. Kauf, P. Wieferich, K. Schiffer, R. Luedi, M. M.	2017	Implications of Perioperative Team Setups for Operating Room Management Decisions	Germany	St. Marienhospital in Vechta, a 321-bed teaching hospital of the Medical School of the University of Hannover
[73]	Caesar, U. Karlsson, J. Olsson, L. E. Samuelsson, K.	2014	Incidence and root causes of cancellations for elective orthopaedic procedures: A single center experience of 17,625 consecutive cases .	Sweden	University hospital clinic

	Hansson-Olofsson, E.				
[74]	Lehtonen, J. Torkki, P. Peltokorpi, A. Moilanen, T.	2013	Increasing operating room productivity by duration categories and a newsvendor model	Finland	Finnish orthopaedic specialist centre t
[75]	Ahmed, K. Khan, N. Anderson, D. Watkiss, J. Challacombe, B. Khan, M. S. Dasgupta, P. Cahill, D.	2013	Introducing the productive operating theatre programme in urology theatre suites	England (London)	Guy's Hospital

[76]	Xiang, W.	2017	A multi-objective ACO for operating room scheduling optimization	Not stated	Not stated
[77]	Zhu, S. Fan, W. Yang, S. Pei, J. Pardalos, P. M.	2018	Operating room planning and surgical case scheduling: a review of literature	Not clearly stated (but the authors are Chinese, and they received founding from China, so one could assume that the country is China)	Not stated
[30]	Addis, B. Carello, G.	2016	Operating room scheduling and rescheduling: a rolling horizon approach	Not stated	Not stated

	Grosso, A. Tànfani, E.				
[78]	Liu, H. Zhang, T. Luo, S. Xu, D.	2018	Operating room scheduling and surgeon assignment problem under surgery durations uncertainty	China	Tianjin Third Central Hospital (TTCH)
[53]	Agnetis, A. Coppi, A. Corsini, M. Dellino, G. Meloni, C. Pranzo, M.	2014	Operations management and health: A decision support system for elective surgery planning		

[79]	Kumar, R. Gandhi, R.	2012	Reasons for cancellation of operation on the day of intended surgery in a multidisciplinary 500 bedded hospital	Unclear (possibly India?)	Government hospital
[57]	Buchanan, D. Wilson, B.	1996	Re-engineering operating theatres: the perspective assessed		Leicester General Hospital
[63]	van Brenk, C. M.	2009	Setting Up a Robotic Surgery Program: A Nurse's Perspective	Unclear/not stated	Unclear/not stated
[65]	Erdem, E. Qu, X. Shi, J. Li, G.	2012	A stochastic mathematical programming model for elective patient scheduling		
[80]	Pang, B. Xie, X. Song, Y.	2019 *(NB: articles*	Surgery Scheduling under Case Cancellation and Surgery Duration Uncertainty	China	West China Hospital

	Luo, L.	*from 2019 was excluded, butthis article was re-published in 2019, maybe just make a footnote and state that?)*			
[58]	Beach, M. J. Sions, J. A.	2011	Surviving OR Computerization	USA, Morgantown	West Virginia University Hospitals
[56]	Tsai, M. H.	2008	Ten Tips in Providing Value in Operating Room Management		

[81]	Damani, Z. Conner-Spady, B. Nash, T. Stelfox, H. T. Noseworthy, T. W. Marshall, D. A.	2017	What is the influence of single-entry models on access to elective surgical procedures? A systematic review	Unclear	Not stated (literature review)

	Categorization of study					
	Description of intervention/phenomena of interest	**System in use**	**Phase of study**	**Focus**	**Purpose/aim/goal**	**Economic variables**
[60]	Excluded – full text review did not meet inclusion criteria An intelligent system to optimize a team composition based on the team's historical outcomes and apply this system to compose a surgical team	(not named) An intelligent system developed based on the theory of probability and the inclusion exclusion principle to compose an optimal team	The system has been tested in what seems to be a simulated environment. It is unclear if it is in use	The article explains how a system to create team compositions in order to have high functioning surgical teams with high success rates.	Unclear (not stated?) – just a presentation of the data system	Not mentioned

[66]	Research concerning the dialog around clinical decisions made by team members in surgery and the impact of communications on shared situational awareness.	No system, insvestigating situational awareness and communicatio n	Post observational study	Communication for situation awarweess	*"The aim of this observational study was to describe the strategies used to communicate decisions during surgery and the ways in which this dialog creates or compromises shared situational awareness" [66].*	Not mentioned
[67]	Why cancellations of surgery in patients attending preoperative anesthesia clinics occur	Unclear if they use a special system. Most likely no system in use, just data gathering.	Post prospective audit (not mentioned how long after)	In order to define the processes that can be improved, we conducted an audit to identify the factors that	The purpose of the paper was to investigate the reason for surgery cancellations for patients attending preoperative	Not mentioned (only mentioning finicial constraints when it comes to patient

		Investigating reasons for cancellations.		could be responsible for the cancellation of elective surgeries in patients attending preoperative anaesthesia assessment clinic.	anaesthesia Clinic [67].	related reasons for cancellation)
[68]	The article describes an attempt to develop a comprehensive operating room information system called ‘‘Medinav’’ to tackle the			A prototype operating room information system called ‘‘Medinav’’. The system is to	The purpose of this study was to develop and test a new operation room information system. The article presents the prototype “MediNav” [68].	Not relevant

	needs of surgeons in operating rooms settings.			be compatible with Health Level 7 (HL7) and digital imaging and communications in medicine (DICOM).		
[69]	The authors develop a Design and Engineering Methodology for Organization (DEMO)-based simulation model that combines simulation and the enterprise engineering approach in order to achieve a more	Not named	This paper is a presentation of the developed system. According to the article the researchers will discuss the system with staff members and assess the effectiveness of the simulation model.	This study focuses on the Surgery Scheduling Problem (SSP) and considers the hierarchal relationship with the other two	The main goal of this paper is to: 1. *"Evaluate the operational performance of the case mix and master surgery plans that are obtained at the higher*	Not stated

	holistic view of the enterprise.			problems, the CMP and the Master Surgery Scheduling Problem (MSSP).	*decision levels" [69].* 2. "*Model not only the implementation part of the OR scheduling, but also to represent the ontological part" [69].*	
[55]	Excluded – full text not available					
[70]	Explaining how the hospital chose to develop their own surgical information system (SIS)	SIS developed by the Madigan Army medical Center	Post implementation/development	Why they chose to develop their own system and how they did it	Summarization and presentation of the development efforts when developing a comprehensive	Not mentioned (other than that they would rather develop their own

	instead of buying a commercialized product.				surgical information system (SIS) [70].	system, than pay for a commercialized system that they still needed to fix in order to fit their needs).
[59]	Excluded – full text review did not meet inclusion criteria The paper discusses the readiness for electronic communication between surgical patients and a university hospital in Norway	Not relevant			Investigate e-readiness	to discuss the readiness for electronic communication between surgical patients and a university hospital in Norway.

[61]	Excluded – full text review did not meet inclusion criteria *In this study, we surveyed* *the causes and overall rates of elective surgery cancellation and then compared the number of cancellations that* *occurred before and after the installation of additional operating rooms.*	Not relevant	Post implementation of additional ORs	investigated the causes and overall rates of elective surgery cancellation before and after the installation of additional ORs and evaluated the data that was generated to determine if increased operative capacity can	The cancelation ratio was higher after the installations of two new ORs. (20,5% cancellation ratio before installation vs. 23,8% post installation).	Not main focus, but the article states that due to higher cancellation rates the economic loss was also greater with two additional ORs.

				prevent day-of-surgery cancellation.		
[71]	Investigating cancellation rates, why the cancellations on day of surgery occurred and if the installation of new ORs would reduce cancellations.	Not relevant	Post study. Summary of findings after investigating the cancellation rates. (A detailed review of a total of 1813 cases canceled on the day of surgery from January to December 2012, to examine the various reasons of cancelation among surgical specialties.)	Cancellation rates on day of surgery cancellations and reasons for cancellations To investigate the cancellations at the hospital from Jan. 2009 to dec 2012, and assess the implementation of new operating rooms	The purpose of the paper was to investigate the rates and reasons for surgery cancellation, in addition the authors investigated the how installing new operating rooms affected the cancellation rate using statistical process control (SPC) analysis [71].	Not stated

[54]	Excluded – full text not available					
[64]	Excluded – missing key information on method/result The problem addressed consists of two interrelated sub-problems: 1. “advance scheduling’’ - The decisions considered are the assignment of a surgery date and an OR block to a set of patients to be operated on over a given planning horizon	Mathematical algorithm - A hybrid two-phase optimization algorithm which exploits the potentiality of neighborhood search techniques combined with Monte Carlo simulation is developed	Post study, the system has not been implemented at the hospital (main reasons are linked to difficulties in introducing and interfacing stand alone resolution methods into the hospital information systems)	This paper deals with the Operating Room (OR) planning problem at an operational planning level.	There are two purposes of this paper: 1. to provide an efficient algorithmic framework to solve the joint advance and allocation scheduling problem taking into account the inherent uncertainty of surgery durations. 2. to provide a tool to develop robust	Not stated

	2. “allocation scheduling’’ - determining the sequence of selected patients in each OR and day.	to solve the overall problem.			offline OR schedules which consider the trade-off between reducing surgery cancellations and postponements while maximizing the operating theater utilization.	
[62]	Excluded – full text review did not meet inclusion criteria Investigating how the availability of a multi-skilled staff could impact the cancellation rates on	Not relevant	Post study	The author presents findings from a questionnaire containing both quantitative and qualitative methods, in addition the article includes a	To assess the impact of the availability of qualified and competent multi-skilled nursing and technical staff in the workplace on reducing the number of operating sessions cancelled in stand	Not stated

	day of surgery cancellations			literature review.	alone day surgery facilities.	
[72]	Investigating if stable surgical and teams that worked together over time would become more efficient than random teams.	Not relevant	Post study	The authors hypothesized that the interplay between anesthesiologists and surgeons would affect operating room turnaround times, and teams that worked together over time would become more efficient.	*"To understand the impact and managerial implications of the interplay between anesthesiologists and surgeons on OR efficiency" [72].*	Not stated
[73]	Investigating the reasons for cancellation of	Not relevant	Post study	Cancellations of elective	The goal of the study was *"to evaluate and*	Not stated

	elective orthopedic procedures			orthopedic procedures	*describe the number and reasons for cancellations in elective orthopaedic surgery" [73].*	
[74]	presents the development of a scheduling system that takes into account the advantages of both practical case categorization and computer approaches to surgery scheduling	Unclear "Model description: The discrete-event simulation model"	Post study	The focus of the study is to increase the understanding of practical scheduling methods used to improve efficiency in surgical services The research objective of this paper is to	*"The aim of this study is to develop a practical scheduling system that considers the advantages of both surgery categorization and newsvendor model to surgery scheduling" [74].*	Not stated

				evaluate how scheduling systems based on time categories can be improved to increase productivity.		
[75]	The Productive Operating Theatre (TPOT) is a module-based theatre improvement programme designed by the NHS Institute for Innovation and Improvement. Its	The Productive Operating Theatre (TPOT)	Post implementation at two urology operating theatres. "The TPOT programme at Guy's Hospital urology operating theatres has progressed through the foundation module and is currently advancing through the enabler modules»	The focus of the article is to describe and evaluate the TPOT	*"The aim of this study was to evaluate the implementation of TPOT in urology operating theatres and identify obstacles to running an ideal operating list" [75].*	The authors state that a comprehensive cost analysis is needed to evaluate whether or not the resources can be directed to another area.

	main agenda is to 'improve patient experience and outcome					
[76]	A meta-heuristic approach integrating Pareto sets and Ant Colony Optimization (ACO) is proposed to solve such multi-objective OR scheduling optimization problem.	Pareto Sets (PS) and Ant Colony Optimization (ACO) - with multi-objectives (PSACO-MO)	Post testing, Future research will be in the direction of extending our ACO algorithm to solving the OR scheduling problems with more realistic constraints arise in actual OR management in hospital, like nurse rostering constraints and surgeons/nurses reference constraints in medical team etc.	The focus of this article is to investigate how one could find an efficient approach for OR management to solve such multi-objective optimization (MO) problem.	The purpose of this study was to investigate how a meta-heuristic approach integrating Pareto sets and Ant Colony Optimization (ACO) could solve problems in optimization of multi-objective OR scheduling [76].	Not stated
[77]	This paper provides a comprehensive survey of	Unclear	Post study (literature review)	Focusing on literature	The overall aim of this paper was to	Not stated

	research on operating room planning and scheduling problems.			relating operating room planning and surgical case scheduling	provide a comprehensive classification on operating room planning and scheduling problems. The authors conducted a literature review, and reviewed the literature *"from the perspectives of decision level, scheduling strategy, patient characteristics, problem setting, uncertainty, mathematical models, and*	

					solutions and methods" [77].	
[30]	How to assign patients for elective surgery among a given waiting list and assigning them to a set of available operating room blocks using a block scheduling strategy.	a block scheduling strategy in which the number and the length of available blocks are given, in addition using a rolling horizon approach for the patient selection and assignment.	Post study	The authors have chosen to focus on the patient point of view: the goal of the model is to minimize the overall waiting time and the tardiness of patients.	Investigating how to select patients from a waiting list of elective patients and how the use of a block scheduling strategy using a rolling horizon approach could contribute to minimize the overall waiting time and the tardiness of patients [30].	Not stated
[78]	the objective	A two-step stochastic	Post study	Surgery scheduling and	The purpose of this study: *"(...) solving*	Not stated (does focus on

	of this paper is solving a surgery scheduling problem with multiple ORs and multiple surgeons to minimize cost and improve utilization of operating theatre.	model which considers The uncertainty of surgery durations was proposed, and SAA method was applied to solve the problem.		hospital management	*a surgery scheduling problem with multiple ORs and multiple surgeons to minimize cost and improve utilization of operating theatre" [78].*	reducing costs, but not what the system development would cost).
[53]	Excluded – full text in Italian					
[79]	Cancellations on day of intended surgery.	Not relevant	Post study	Cancellations on day of elective surgery, and why the cancellations occur.	*The aim was: "To investigate and evaluate the reasons for cancellations of operations on day of surgeries" [79].*	Cost of study, not stated. No implementation therefore no cost (for implementatio). The study does

						mention that there would be lost income when surgeries are cancelled.
[57]	Excluded – not elective surgery (acute settings)					
[63]	Excluded – full text review did not meet inclusion criteria Hiring OR robotic coordinators	Not relevant - no system in use	Only opinion of one nurse	How an robotic OR coordinator could help with scheduling and planning of roboticsurgery	Unclear/not stated (only presentation of view on robot coordinator?)	Unclear/not stated
[65]	Excluded – missing key information on method/result	A stochastic programming model		The focus of the study is to investigate how the authors developed a stochastic	to develop a stochastic programming mathematical model for scheduling the elective	

	The research employs a stochastic programming model to study the scheduling of elective patients with respect to several constraints on operating rooms and downstream clinic units such as post anesthesia care (PACU) units.			programming model that considers the variation of durations among the different type of surgeries. A commercial optimization solver is employed to solve a small-scale case with four operating rooms.	patients with respect to various constraints related with the availability of surgical teams, operating room time slots, the number of PACU beds/equipment/supporting clinic staff members.	
[80]	The authors developed a stochastic integer programming model for multiple ORs that	a three-stage stochastic programming	Post case study	Many factors contribute to the inefficiency of OR scheduling,		Not stated concerning the development of the system, but

	simultaneously considers the uncertainties of case cancellation and surgery duration.	model in the surgery scheduling problem		which eventually results in high cost and poor care delivery quality. This paper presents a case study.		the article does focus on how the system could contribute to cost reduction.
[58]	Excluded – not elective surgery (acute settings)					
[56]	Excluded – full text not available					
[81]	A systematic literature review of the Single-entry models (SEMs) for the management of patients awaiting elective surgical	Single-entry models (SEMs)	Post literature review	Single-entry models (SEMs) for the management of patients awaiting elective surgical	According to the authors the purpose is to: *"(…) develop an optimization model to address inefficient scheduling. The goal*	Not stated

	services			services are designed to increase access and flow through the system of care. We assessed scope of use and influence of SEMs on access (waiting times/ throughput) and patient-centredness (patient/provider acceptability).	*is that this will contribute in minimizing the costs from the perspectives of both healthcare providers and patients" [80].*	

	Methodology						
	Method (type of study)	**Data collection method**	**Data analysis approach**	**Sample size**	**Method for recruitment of participants**	**Duration of participating**	**Profession(s) in focus**
[60]	Excluded – full text review did not meet inclusion criteria The theory of probability and the inclusion exclusion principle to model the probability of team outcome for a given composition.	Unclear	Unclear	No participants	No participants	No participants	The surgical teams at hospitals. (mentioning nurses, surgeons and assistants) BUT – the main focus is on the data system.

[66]	Post observational study Observational study - Qualitative study design: *Fieldwork methods were used to capture the dynamic integration of individual and situational elements in surgery that provided the backdrop for clinical decisions [66].*	Semistructured interviews and participant observations	Thematic analysis was used	24 participants	participants were drawn from interdisciplinary groups who worked across 10 surgical specialties	Fieldwork progressed over 6 months and data were collected during 2009–2010.	Focusing on the surgical team as a collective: nurses, surgeons... (page 2)
[67]	Prospective audit	Information regarding the	Cancelled cases	A total of 1258 patients		The duration of the audit	No profession (just

		cancellation of surgeries were collected from various sources including; the operating room daily surgical schedule, patients vital signs recording charts, preoperative assessment form, primary physicians, the anaesthetist responsible for the preoperative	were identified from the operating room lists and the reasons for cancellations were categorized into four factors.	were evaluated in OPPAC in the study duration of two months, out of these 810 patients were scheduled to have surgeries in the main operating rooms. In these 810 patients 55 cancellations During the period of the	Data was collected from the OPPAC system, number of cancellations and why.	was two months.	cancellations and why)

		assessment, the anaesthetist responsible for conducting the case and by contacting patients if required. Data of patients who presented to the pre anaesthesia clinic with their surgeries planned in the main operating rooms of our hospital		study 55 cancellations where identified. Extra info: Approximately six to seven hundred patients are seen each month. The study lasted two months so about 1200-1400 patients should have been in the clinic.			

[68]	Case study – developing a new information system (prototype) Presentation of a prototype of a operation room information system	Unclear	Unclear	Not relevant	Not relevant	Not relevant	The system is in focus, but the article focuses on *surgeons* needs in the system.
[69]	Case study – presentation of simulation model	Not sure. Difficult to find a good answer.	Not sure. Difficult to find a good answer.	Not relevant	Not relevant	Not relevant	No specific profession in focus, the article focuses on the simulation model
[55]	Excluded – full text not available						

[70]	Case study – presentation of the development of a new information system. Summarization of the development efforts when developing a new SIS (surgical information system) for the medical center	Data to develop the new SIS was gathered in numerous ways: interviews with hospital staff, consultations with end-users, comparing commercialized options, surveys, one-on-one interviews	Unclear	Unclear/not stated No sample size	Unclear/not stated No participants	Not stated	No specific profession in focus, but information system in focus.
[59]	Excluded – full text review did not meet inclusion criteria						

	The study approach consists of the following: (1) a study of the most recent health reforms in Norway, focusing on e-readiness from political and policy perspectives; (2) an in-depth empirical observation and interview study of the pre-operative planning process at a university hospital, focusing on the readiness						

	for two-way electronic communication prior to surgery; (3) a qualitative interview study of patients' experiences with surgical cancellations, focusing on the patients' readiness for electronic communication; (4) an inquiry into the readiness of the hospitals' electronic health record to						

	integrate two-way communication and (5) a study of the readiness for electronic patient– hospital communication from the perspective of the regional health authority's ICT operational unit.						
[61]	Excluded – full text review did not meet inclusion criteria Survey of the causes and overall rates of elective surgery	surveyed all patients scheduled to undergo elective surgery requiring general	*The causes for cancellations were divided into six categories: departmental issues, abnormal*	Before installations: 2494 patients for elective surgery 512 cancelled	*all patients undergoing elective surgery for 100 days prior to and after the installation of additional*	(length of study not participation). 100 days beginning on July 1, 2003. Then a pause,	Not relevant, surgery in focus

	cancellations, and after this a comparison of cacellations that occurred before and after installations of additional operating rooms.	anaesthesia for 100 days beginning on July 1, 2003 prior to the installation of the additional operating rooms. To avoid seasonal or monthly variations, as well as other factors that may affect cancellation rates and settling-in period of new ORs, the aftersurvey	*laboratory results, patient denial, inadequate preparation, over-booking and other issues.* *departmental causes* *were further divided into four categories: ward overflow, scheduling date errors, unavailable surgeons and other*	After installations: 2886 patients for elective surgery 688 cancelled	*operating rooms*	when installing new ORs and testing them, then another 100 days beginning July 1, 2004.	

		was conducted for 100 days beginning July 1, 2004.	*issues.*				
[71]	Retrospective review (detailed review of reasons for cancellations using statistical analysis)	The numbers of scheduled and canceled surgeries were obtained from the OR registries from January 2009 to December 2012. We defined the canceled cases as the booked case (already documented on the OR list), which is canceled	detailed review of a total of 1813 cases canceled on the day of surgery from January 2012 to December 31, 2012 was conducted to examine the various reasons of cancelation and	Not relevant	Not relevant	Not relevant	Not relevant, surgery cancellations in focus

		on the same day of surgery.	surgical specialty of canceled cases.				
[54]	Excluded – full text not available						
[64]	Excluded – missing key information on method/result Not clearly stated (might be obvipus to researchers?) It is a paper presenting mathematical	The approach developed searches for a feasible and robust solution designed to balance the trade-off arising between the hospital and patient perspectives, i.e. maximizing the OR	The proposed algorithm has been tested on a set of instances based on real data. A series of computational experiments was carried out to evaluate the impact of the	Not relevant	Not relevant	Not relevant	Not relevant

	algorithms for surgery scheduling.	utilization and minimizing the number of patient cancellations.	main parameters and components of the algorithm.				
[62]	Excluded – full text review did not meet inclusion criteria The author conducted a literature review which is presented in full. In addition a questionnaire was distributed nationally in 244 day surgery facilities in England and Wales.	Littarature review and postal questionnaire with both quantitative and qualitative research methods.	The data from the questionnaire was analysed and coded, the author does not state how.	244 questionnaire was distributed nationally.	Not stated	Not relevant	Not stated

	The questionarrie used both quantitative and qualitative research methods to gather data.						
[72]	retrospective study	Staff and patient data pertaining to a total of 36,834 cases over a 71-month period were taken from the ORBISTM database and anonymized for analysis To ensure comparable	The authors analyzed 13,632 surgical cases at the hospital that involved 64 surgeons and 48 anesthesiologists. We detrended and adjusted the data for potential confounders including	In total there were 36834 cases during the study period, but of various reasons some cases where excluded, leading to the final number of 13632 surgical cases. The authors	Participants were chosen by gathering data from the ORBISTM database.	May 30, 2007, to April 29, 2013	anesthesiologists and surgeons

		conditions (all cases studied follow a preceding case), first cases of the day and cases after a switch of the surgical list in the room were excluded, leaving 14,712 cases. Cases in which the turnaround time exceeded 90 minutes (implying "hard stop events," in which	age, American Society of Anesthesiologists physical status, and surgical list (scheduled cases of specific surgical specialties). The surgical lists were categorized as ear, nose, and throat surgery; trauma surgery; general surgery; and gynecology. We assessed the elationship between turnaround times	analysed the chosen 13632 surgical cases involving 64 surgeons and 48 anaesthesiologists			

		anesthesiologists had to stop the OR list, eg, for out-of-OR emergencies) were also excluded, yielding 13,632 cases for final analysis.	and assignment of different anesthesiologists to specific surgeons using a Monte Carlo simulation.				
[73]	retrospective observational single center study	Studied were all the elective patients scheduled for joint replacement, arthroscopy and foot & ankle surgery, January 1, 2007 to December 31, 2011,	The study was a descriptive single center study with retrospective observational data collection through the hospital's records and registers.	He sample size were 17,625 patients scheduled for elective surgery	The study population comprised all the patients scheduled for orthopaedic surgery between, January 1, 2007 to December 31, 2011	January 1, 2007 to December 31, 2011	Not relevant

		whose procedure was cancelled at least once.					
[74]	Case study	The single-period order quantity model, also known as the newsvendor model, was applied in the OR environment, and planning and scheduling procedures in the surgical process at a Finnish orthopedic specialist center were developed.	The care paths of patients in the hospital were examined by collecting existing process charts and interviewing the personnel. Based on the case analysis, a discrete-event simulation model of the care paths was built to address the	Unclear	Not relevant	Not relevant	Not relevant

			research objectives.				
[75]	Report on introduction of The Productive Operating Theatre (TPOT) programme in urology operating theatres. It is a paper presenting the TPOT	A multidisciplinary team identified and audited obstacles to the running of an ideal operating list. A brief/debrief system was introduced and patient satisfaction was recorded via a structured questionnaire	The primary outcome measure was the effect of TPOT on start and overrun times.	1365 patients underwent surgery during the monitored period.	Monitored from September 2010 to June 2011 during which 1,365 patients underwent surgery.	Not relevant	Not stated
[76]	Computational study	Two kinds of test cases are used to evaluate the	Test cases from both simulation and literature are used	Not relevant	Not relevant	Not relevant	Not relevant

		proposed algorithm. One kind of test cases is the same test cases from our previous research. Another is the test case used in literature from MD Anderson Cancer Center	to evaluate the proposed approach. The scheduling result of the proposed PSACO-MO algorithm is compared with the simulation scheduling result, the ACO with single objective of makespan, and the ACO with multi-objective by weighted sum method.				

[77]	Literature review	Not stated	Not stated	Not relevant	Not relevant	Not relevant	Not relevant
[30]	Case study	Each block is related to a specific day, by assigning a patient to a block his/her surgery date is fixed, as well. Each patient is characterized by a recommended maximum waiting time and an uncertain surgery duration. N ew patients enter the waiting list continuously. Patient selection	The authors consider two sources of uncertainty that complicate the problem: (1) new patients arrivals that occur within the planning horizon and (2) surgery times, that are only roughly predictable.	Not stated	Not relevant	Not relevant	Not relevant (focusing on patients point of view)

		and assignment is performed by surgery departments on a short-term, usually a week, regular base.					
[78]	Case study	Surgery durations were predicted by fitting the distributions. A two-step mixed integer programming model considering surgery duration uncertainty was proposed, and sample average	In this paper, we constructed the surgery schedule in two steps. The first step was OR scheduling and the second step was surgery sequencing and surgeon assignment.	The authors state that they tested the system with different sample sizes, but these are not clearly stated.	Not relevant (no participants)	Not relevant (no participants)	Not clearly stated

		approximation (SAA) method was applied to solve the model.	The objective of the first step is to minimize the regular opening costs for each OR and overtime costs. The second step seeks to minimize overtime of each OR. The objective is to increase the utilization of ORs, considering that surgeries have been determined in				

			each OR in the first step.				
[53]	Excluded – full text in Italian						
[79]	Audit of reasons for cancellations. Evaluation study of reasons for cancellations.	Data was gathered from all patients scheduled to undergo elective surgeries.	Analyzing the reasons for day of surgery cancellations using medical records and documenting reasons for cancellations.	The total number of scheduled surgeries during the study period was 7272.	All patients scheduled for elective surgeries were the surgery was cancelled on day of surgery.	Study period was December 2009 to November 2010.	Not relevant
[57]	Excluded – not elective surgery (acute settings)						
[63]	Excluded – full text review did not meet inclusion criteria	Unclear/not stated	Unclear/not stated	Unclear/not stated	Unclear/not stated	Unclear/not stated	Study from nurses perspective

	Unclear/not stated Opinion of a nurse			No sample size	No participants		
[65]	Excluded – missing key information on method/result Case study	In this research, we develop a stochastic mathematical programming model for day to day scheduling of the elective patients, and sequencing of those patients within a given day with regard to various constraints such as the					Not relevant

		availability of the surgical teams, operating room, and PACU units where the patients recover from the effects of the anesthesia, located downstream of the surgical operating room.					
[80]	Case study	The contribution of this paper includes the following two perspectives. 1) Compared with existing works, the main contribution of	The authors formulate the problem as a three-stage stochastic integer programming (SIP) model,	Not relevant	Not relevant	Not relevant	Not relevant

		this paper is that we are the first to jointly consider the uncertainty of case cancellation and surgery duration in scheduling multiple ORs with both the allocation and the sequencing decisions. Moreover, we apply the Benders decomposition approach and its enhancements to address	which integrates the decision of patient admission, block scheduling, and surgery sequencing problems. In addition they have also included a literature review on surgery scheduling.				

		the computational challenge and obtain a satisfactory performance. 2) The application of our model using real data from West China Hospital (WCH) shows that our model yields remarkable reduction of the total cost compared with common practice, which is					

		valuable to healthcare practitioners.					
[58]	Excluded – not elective surgery (acute settings)						
[56]	Excluded – full text not available						
[81]	Systematic literature review	Systematic review of articles published in 6 relevant electronic databases included studies from database inception to July 2016.	Included studies needed to (1) report on the nature of the SEM; (2) pecify elective service and (3) address at least 1 of 3 research questions related to (1) scope of use of	A total of 3672 citations were identified. Sixty-two full studies were reviewed, and 11 were selected for final analysis	Not relevant	Not relevant	Not relevant

		Eleven studies of various elective procedures were included from Canada, UK and Australia. Studies were of generally low rigour and weak observational design.	SEMs; (2) influence on timeliness and access; (3) patient-centredness and acceptability. Article quality was assessed using a modified Downs and Black checklist.				

	Outcome				Results	
	Conclusion stated in the article	**Response rate**	**Limitations**	**Ethical considerations**	**Data item (data collection)**	**Effect**
[60]	Excluded – full text review did not meet inclusion criteria *"We developed a system that can recommend the optimal* *team composition for a surgery only based on the recorded* *unfavorable outcome rates of surgical teams. This system*	Not relevant	Not stated	Not stated	unclear	Not stated/unclear. The system is only a model of how it could be done.

	does not require an expert to find which member of surgical team is responsible for most unfavorable outcomes and who causes the least complications.»					
[66]	*"Strategies used to convey decisions that enhanced shared situational awareness included the use of "self-talk", closed-loop communications, and "overhearing" conversations that occurred at the operating table.*	(not stated clearly). But it is assumed that none of the participants stated in the article withdrew	Limitations are addressed in the article. (the single locale of the study setting limits the extent to which its findings may be generalized because the staff working in this	Ethics approval was given and participants had the right to withdraw from the study at any time.	The domain "coordinating decisions in surgery" was generated from textual data. Within this domain, three themes illustrated the dialog of clinical decisions, ie, synchronizing and strategizing actions, sharing local	Effect of study not stated. Purley situational study investigating communication

	Behaviours that compromised a team's shared situational awareness included tunnelling and fixating on one aspect of the situation" [66].	from the study	hospital may be different in some way)		knowledge, and planning contingency decisions based on priority.	
[67]	The authors found that patient related reasons for cancellations were the most frequent cause for cancellations, these cancellations were viewed as uncontrollable. Anaesthetic reasons for cancellations could possibly be reduced by improving communication between	Not relevant (Prospective audit)	Not stated	Not stated	Fifty five (55) cancellations were identified; patient related factors (58%) were the most frequent cause followed by anaesthetic (22%), surgical (18.2%) and administrative (1.8%) factors. In patients related factors,	Not relevant (prospective audit)

	anaesthesiologists and surgeons. Improving the organizational strategies might contribute to reduce cancellations related to overbooking and administrative matters [67]**.**				most common causes appeared to be no-shows and patient's financial issues.	
[68]	The article states: *"The results reveal that integration of these systems into a complete solution is the key to not only stream up data and workflow but maximize surgical team usefulness as well. It is now possible to comprehensively collect and visualize medical*	Not relevant	Not stated	The authors received research grants from Green Cyber Inc., Ontario, Canada to finance the conduct the study, this is mentioned in conflict of interest.	The results the article presents are basically an explanation of how the first prototype of MediNav was deployed and further developed.	Not clearly stated how the system actually effected the workflow and the surgical teams. The athours do mention that surgeons were satisfied with the system, but there is no mentoning on how this was evealuated. The text also states that "the

	information, and access a management tool with a touch-less NUI in a rather quick, practical, and harmless manner"[68].					surgical manager was enormously pleased by the seamless approach for data gathering and displaying this data in an easily accessible format"
[69]	*"The initial results show the simulation potential in the performance improvement of the operating room system. Furthermore, it makes understanding and exploring the system easier" [69]*. The authors state that there is a possibility to increase the number of					

	surgeries with around 180 more cases per year, and to reduce the overall waiting list with approximately 45 %, which among others are believed to improve patient satisfaction [69].					
[55]	Excluded – full text not available					
[70]	The authors conclude that the comprehensive SIS developed by Madigan Army Medical Center is equal, and in some ways better than commercial products. The SIS filled a void in data collection required by the Department of	Not stated	Not stated	Not stated	All 12 surgical services are currently using SIS to schedule time in surgical suites. (Note: "currently" is when the article was published – 1996)	Enhances are still being made, but the system is successfully in use (1996)

	Defence (DoD). The system also had less costs than buying an off-the-shelf system [70].					
[59]	Excluded – full text review did not meet inclusion criteria The authors' conclusion is that Norwegian health policy strongly promotes electronic collaboration and that patients and healthcare workers are ready to use new electronic tools. However, the hospital					

	as an entity are currently not ready for electronic communication between patients and the hospital.					
[61]	Excluded – full text review did not meet inclusion criteria *The number of overall cancelled cases and scheduled cases increased following the increase in operating room capacity, although this increase was not statistically significant*	Not relevant (Operation numbers in focus) Before installations: 2494 patients for elective surgery 512 cancelled	Limited to one hospital only, in addition they mention that out-patient surgeries were excluded. The authors state: "Based on these limitations, our results should only be used as a reference for	A study protocol was reviewed by the Institutional Review Board and approved as a minimal risk study that did not require individual consent based on the institutional guidelines for waiving consent.	Results indicate that hospitals should optimise their OR schedules to ensure smooth patient flow prior to considering an increase in OR capacity. *The results of this study indicate that increased*	*the cancellation ratio rose significantly after the operating room capacity was increased.* Prior to the increase in OR capacity, the most common reason for cancellation was over-booking (157), followed by departmental issues (144) and

	In conclusion, increasing the operating room capacity is not an appropriate option for preventing the cancellation of operations.	After installations: 2886 patients for elective surgery 688 cancelled	institutions that do not have a formal OR director and in which out-patient anaesthesia is only performed on a limited basis".		*operating room capacity can prevent cancellation due to over-booking. However, the numbers of cancellations due to ward overflow exceeded the numbers of cancellations that occurred as a result of over-booking.*	patient medical problems (127). Following the increase in OR capacity, the most common reason for cancellation was departmental issues (365), followed by patient medical problems (174) and over-booking (54)
[71]	The authors conclude that the reasons for cancelling surgeries varied greatly among the different institutes. The article states that			The authors state that all patient records/information were anonymized and		

	installing extra ORs and extending the infrastructure is not the only solution to the problem of cancellations [71].			de-identified prior to analysis, and that there are no conflicts of interest.		
[54]	Excluded – full text not available					
[64]	Excluded – missing key information on method/result The problem is decomposed into two sub-problems which are solved in two sequential phases. Integer stochastic formulations	Not relevant	Not stated	Not stated	The proposed approach could represent a useful decision tool to be used by OR managers to determine reliable/robust OR schedules (i.e., planning and sequencing of patients). The approach has	Despite the efficiency demonstrated by the proposed approach, it has not yet been integrated in the hospital practice. The main reasons are linked to difficulties in introducing and interfacing stand alone

	are proposed for both sub-problems.				the advantage of exploiting the trade off between achieving an acceptable level of OR utilization rate while limiting the negative effects of surgery cancellations and postponements.	resolution methods into the hospital information systems.
[62]	Excluded – full text review did not meet inclusion criteria The author states that the availability of qualified multi-skilled nursing and technical staff in the workplace has a high impact on	27,4%	Not stated	Not stated	The author believes that the availability of a multiskilled team would reduce the number of cancellations in standalone day surgery in hospitals. This is because of her	not relevant(?)

	reducing numbers of cancelled operations.				literature review and her primary research.	
[72]	A surgeon is usually predefined for scheduled surgeries (surgical list). Allocation of the right anesthesiologist to a list and to a surgeon can affect the team performance; thus, this assignment has managerial implications regarding the operating room efficiency affecting turnaround times and thus potentially	Not relevant	Not stated	The authors declare no conflicts of interest.	The authors found significant differences in team performances among the different surgical lists but no team learning.	The authors stated that their analysis indicated that had the algorithm been used in staffing the operating room for the surgical cases represented in our data, median turnaround times would have a reduction potential of 6.8% (95% confidence interval 6.3% to 7.1%).

	overutilized time of a list at our hospital.					
[73]	The cancelation rate is high (39% of all surgeries), and many of the cancellations are avoidable. "By clarifying the reasons for the cancellations, everyone involved has better knowledge to improve and develop better routines to reduce the number of cancelled patients. (…) The high number of cancellations in this study is a	Not relevant	Limitations stated by the suthors: "Since there is both a continuous inflow and outflow from the waiting list, the numbers given can vary. This makes it difficult to provide the precise numbers from one moment to another. Another limitation could be that	Not stated	Of all 17,625 patients scheduled for elective surgery, 6,911 (39%) were cancelled at least once.	Not relevant (there was on intervention)

	major quality problem affecting the individual patient and the actual health care organisation»		different staff categories entered the data into the surgical planning system. They might have had different views of using terms and knowledge when handling the computer-based system. This in turn could have led to inconsistent grouping			

			and categorising of the reasons for cancellations. This study showed the cancellations at one specific clinic only, making the reproducibility unproven.»			
[74]	The article states that detailed analyses of surgery durations and the use of more accurate case categories and their combinations can	Not relevant	the study was conducted in a specific setting. Thus, despite the richness of the case-context information, the applicability of	Not stated	Detailed analyses of surgery durations and the use of more accurate case categories and their combinations in scheduling improved OR productivity 11.3	Planning to have one OR team to work longer led to remarkable decrease in scheduling inefficiency.

	improve OR productivity. case combinations that systematically lead to underutilized OR time should be replaced by better combinations that fulfil the reserved OR time. case categories and scheduling schemes should be kept simple enough for nurse schedulers to perform		the findings to other disciplines and circumstances could not be confirmed, as is typical for empirical normative quantitative research using modeling		percent when compared to the base case.	Utilizing half-hour categorization blocks instead of hourly-based categories had no effect on the required length of scheduling queue, but it increased productivity by 11.3 percent.

	their duties and for queues to be managed effectively. OR productivity can be improved markedly by increasing flexibility in the OR team's working hours. Planning to have one OR team work longer was shown to result in productivity improvement.					
[75]	The authors concluded that TPOT has helped identify key	Unclear	This study has a few limitations. First, some interventions	Not stated	The primary outcome measure was the effect of TPOT on start and	Start times: 39–41% increase in operating

	obstacles and shown improvements in efficiency measures such as start/overrun times. TPOT has helped identify key obstacles to running an ideal operating list though vision workshops. Improvements were seen in start times, theatre overrun times and cumulative cost. Effective communication through this TPOT		required time taken out of the theatre session, which was very restricted. For instance, members of staff were reluctant to remain for debriefing and, as a result, a few important issues may not have been discussed and evaluated. Second, the intervention was		overrun times.	lists starting on time from September 2010 to June 2011, involving 1,365 cases. Overrun times: Declined by 832 min between March 2010 and March 2011. The cost of monthly overrun decreased from September 2010 to June 2011 by GBP 510–3,030.

	programme also enhanced patient satisfaction. Future work entails implementation of the programme across other specialities.		only introduced in two operating theatres. Finally, a comprehensive cost analysis is needed to evaluate whether or not the resources can be directed to another area.			
[76]	It can be concluded that the algorithm can solve the multiple objective surgery scheduling problem effectively, while at the same time	Not relevant	Not stated	Not stated	The authors developed a hybrid Pareto set-ACO approach for solving multiple objective OR scheduling problem. The multiple objectives	The computational results show that the PSACO-MO achieves good results in shortening makespan, reducing nurses' overtime and balancing

	provide a shortening makespan and a relative balanced resource allocations.				are determined to minimize makespan, the total overtime and the leveling of resources utilization. Due to the combinatorial nature of the problem and the conflicting objectives considered, a hybrid ACO algorithm aiming at achieving sub-optimal solutions is proposed in this paper.	resources' utilization in general.
[77]	The studies reviewed in this paper clearly indicate that different	Not relevant	Not stated	Not stated	The analysis of the literature reveals that researchers are paying more attention	although a great deal of theoretical

	decisions in different levels have a significant effect on the performance of the surgical center. The author note that most of the research is directed towards the scheduling problem within everyday horizon, which is very close to the actual situation.				to the problems of combined resources with an increased complexity. Accordingly, it may be useful to find new and more comprehensive performance indicators that a manager should consider.	work has been published, none of them seems to have a profound effect on the real-word practice of OR management. With regard to the primary purpose of future research, there is still a lot to do to narrow the gap between theory and practice.
[30]	The computational results are promising, and the authors believe	Not relevant	Not stated	Not stated	The authors had two sources of	The models remain reasonably well solvable in all cases: meaning

	that the proposed model could be an effective decision-support tools in the mid-term operating room scheduling.				uncertainty that complicate the problem. They tackled issue (1) by adopting a rolling horizon approach with rescheduling. They tackled issue (2) by adopting a robust optimization model that allows to specify a robustness level *I'*.	that small optimality gaps are reached within the specified time limit for computations. Furthermore, starting from the deterministic model and moving towards more stringent robustness requirements the authors see a shift from solutions that show a better resource utilization, hence possibly appealing to the management of an hospital, to solutions that

						strongly limit the number of cancelled surgeries
[78]	Real-life constraints and duration uncertainty were considered in the study, and the model was also very applicable in practice. Average overtime of each OR was reducing and tending to be stable with the number of surgeons increasing, which is a discipline for OR management.	Not relevant	Not stated	Conflict of interest - None to report according to researchers.	Durations of various surgeries were log-normal distributed respectively. Numerical experiments showed the model and method could get good solutions with different sample sizes.	It was found that durations of various kinds of surgeries were fit log-normal distributions. It was an important prerequisite to an accurate prediction of surgery durations. Numerical experiments showed the relationship between the number of surgeons to perform and the average overtime of each OR.

						Hospital managers could determine the surgeons to perform in accordance with the discipline.
[53]	Excluded – full text in Italian					
[79]	Most causes of cancellations of operations are avoidable.	The total number of scheduled surgeries were 7272, 5986 surgeries were performed	Not clearly stated	Did not require approval of the hospital ethics committee because the study was considered as audit under a quality assurance project.	The Operation theatres was functional for 231 days during the study period, giving us an average of 25,9 cases per day. An average of 5,5 operations were cancelled every day.	Not relevant, there was no intervention, therefore no effect.
[57]	Excluded – not elective surgery (acute settings)					

[63]	Excluded – full text review did not meet inclusion criteria Robotic surgery is a growing field that has introduced a new range of instruments, procedures, and protocols into the standard OR suite. The safety and efficiency of robotic assistance in surgical practice depend significantly on the presence	Unclear/not stated	Unclear/not stated	Unclear/not stated	Unclear/not stated	Unclear/not stated

	of a consistent, trained, and experienced nursing staff and OR team. Establishing a robotic coordinator position goes a long way in optimal OR scheduling, timely procurement of instruments, training of nursing staff, and in collaborating between surgeons across multiple services.					
[65]	Excluded – missing key information on method/result					

	It is found that the commercial solver can generate the optimal solution in 30-60 minutes for the simple case using a personal computer. However, the approach is expected to encounter difficulties in providing efficient solutions for larger-scale cases. Future research on developing different solution methodologies for the					

	problem instances is called for.					
[80]	The case study revealed that the total cost can be reduced by approximately 27% Further analysis of the VSS showed the necessity of considering a stochastic programming formulation. The authors have also shown that the solutions given by the models are superior to the ones obtained	Not relevant	The authors state that there are several limitations to this paper. This is among others that they focused a static schedule containing both OR allocation and surgery sequencing, and they assumed that the uncertainty of case cancellation and surgery scheduling are independent. Also	Not stated	The article includes a literature review first, then goes on to present the models and solutions approach. The authors formulated a three-stage SIP model that integrates the operational decisions with tactical decisions as the uncertainties unfold in practical settings.	The total cost can be reduced by approximately 27%.

	from the current practice at WCH.		the authors noted that that the SP is difficult to solve in case studies even if they only considered a relatively small number of most probable scenarios. Therefore, better solution methods should be developed to solve the proposed models.			
[58]	Excluded – not elective surgery (acute settings)					

[56]	Excluded – full text not available					
[81]	11 studies from Canada, Australia and the UK were included with mostly weak observational design—2 simulations, 5 before–after, 2 descriptive and 2 cross-sectional studies. The review demonstrates a potential ability for	Not relevant	The article present a section describing limitations going into details and concerns around the articles in the review. The literature is of varying quality (mostly weak observational design) and small in overall quantity	Not stated for this article, but the authors have noted if the articles in the review have taken ethical considerations (page 9)	9 studies showed a decrease in patient waiting times; 6 showed that more patients were meeting benchmark waiting times; and 5 demonstrated that waiting lists decreased using an SEM as compared with controls. Patient acceptability was examined in 6 studies, with high levels of	Not relevant (review of literature, no intervention)

	SEMs to improve timeliness and patient-centredness of elective services; however, The small number of low-quality studies available makes it challenging to draw firm conclusions about the effectiveness of SEMs in improving timeliness of access to elective procedures. Our findings show a consistently positive impact by SEMs on the access-related variables.		and consequently, it is difficult to establish that using an SEM causes improvement in the quality of care—more rigourous studies are needed. Very few studies evaluated the influence of SEMs on timeliness and patient-centredness. Methods were		satisfaction reported. Acceptability among general practitioners/surgeons was mixed, as reported in 1 study. Research varied widely in design, scope, reported outcomes and overall quality.	

	While promising, they also prompt the need for ongoing study in critical areas, but with higher quality designs, more comprehensive scope and greater methodological rigour.		limited or poorly described in most studies; rigour was low.			

Appendix B – the search string

PubMed:

(Surgical ward[Title/Abstract] OR surgical theatre[Title/Abstract] OR surgical department[Title/Abstract] OR operating theater[Title/Abstract] OR operating room[Title/Abstract] OR planned surgery[Title/Abstract] OR planned surgeries[Title/Abstract] OR surgical planning[Title/Abstract] OR surgical team[Title/Abstract] OR "Elective Surgical Procedures"[MeSH]) AND (scheduling[Title/Abstract] OR planning[Title/Abstract] OR management[Title/Abstract] OR staffing[Title/Abstract] OR appointment[Title/Abstract] OR “Appointments and Schedules”[MeSH] OR “Personnel Staffing and Scheduling Information Systems”[MeSH]) AND (Perspectives[Title/Abstract] OR narrative[Title/Abstract] OR narratives[Title/Abstract] OR attitude[Title/Abstract] OR attitudes[Title/Abstract])

- **Filters:** Full text; Publication date to 2018/11/30; English
- The search should be possible to recreate by conducting a pure copy-paste in: https://www.ncbi.nlm.nih.gov/pubmed

Scopus:

(TITLE-ABS-KEY ("Surgical ward" OR "surgical theatre" OR "surgical department" OR "operating theater" OR "operating room" OR "planned surgery" OR "planned surgeries" OR "surgical planning" OR "surgical team" OR "Elective Surgical Procedures") AND TITLE-ABS-KEY (scheduling OR planning OR management OR staffing OR appointment OR "Ap pointments and Schedules" OR "Personnel Staffing and Scheduling Information Systems") AND TITLE-ABS-KEY (perspectives OR narrative OR narratives OR attitude OR attitudes)) AND (EX CLUDE (PUBYEAR , 2019)) AND (LIMIT-TO (LANGUAGE , "English"))

- **Filters are already applied within the search string.**
- The search should be possible to recreate by conducting a pure copy-paste by going to “Advanced” in the search section and entering the search string: https://www.scopus.com/search/form.uri?display=advanced