Exploring nurse workforce flexibility as an solution towards higher patient throughput and resilience

A project created in cooperation with Aalborg University Hospital

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Exploring nurse workforce flexibility as an solution towards higher patient throughput and resilience

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Abstract:

Purpose: The report seeks to explore if flexibility in operation theater nurses can create higher patient throughput and resilience
Method: This is done qualitatively by interviewing both perioperative nurses and certified registered nurse anesthetists from four surgical specialisms to estimate procedures considered capable of using cross-trained nurses and which factors prohibit this
Results: Factors such as procedure frequency, knowing the team, experience, and undefined skills impact which procedures can use cross-trained nurses. On average could, 48% of surgeries historically have used a cross-trained certified registered nurse anesthetist and 36% of surgeries with the cross-trained preoperative nurse, though the number varies significantly between surgical specialism
Proposal: Considering the identified cross-training factors, a road map is proposed. The road map contains four steps towards a more flexible workforce. These steps are 1) data foundation, 2) visualization of competencies and availability, 3) quality assurance on team composition, and 4) balancing competencies with procedural demands.
Discussion: It is projected that the proposal can improve patient throughput and resilience, but this is only considered feasible if ICT can be integrated due to an increase in organizational complexity.

Preface

This report is a 4^{th} semester thesis completed in the period from the 7^{th} of February to 30^{th} of June 2022 by Julie Thuri Thrane. The thesis is the last educational element in the Operations and Innovation Management track within the master's program in Management Engineering at Aalborg University, Denmark.

Acknowledgments

I want to thank my supervisors, Professor John Johansen and Associate Professor Rikke Vestergaard Matthiessen, for all the constructive feedback and discussions on the project and for helping me establish contact with the hospital. I would also like to show my appreciation to Professor Nicolas Dellaert from Eindhoven Technical University for introducing me to the field of healthcare operation management and providing me with the confidence to pursue a thesis in healthcare. I thank Mikkel Lyngholm Olesen and Beth Marckmann Iversen from Aalborg University Hospital tremendously for staying extraordinarily positive and supportive throughout the project and helping me find the right people. Thank you to all the nurses and administrative staff who showed me around and answered my many questions, emails, and phone calls. Lastly, I would like to thank my family and friends for being engaged throughout the project and being incredibly helpful when it was needed the most.

Reader's guide

This thesis is structured in five parts; Introduction, Method, Analysis, Proposal, and Discussion. The references in the report are made according to the Harvard Referencing method, where references in-text contain author(s), publication year, e.g., [Tsai et al., 2017]. All the references are in the bibliography containing how it was cited in-text, author(s), year of publication, the title of the reference, place of publication, and publisher, e.g., Tsai, M., Sanford, J., Black, I., Boggs, S. and Urman, R. [2017]: 'Operating Room Management at the Edge of Order and Chaos, The Journal of medical practice management: MPM, 32, pp. 250–255.

Signature

Julie Thuri Thrane
30-06-2022

Abbreviations

Aalborg UH:	Aalborg University Hospital
A-kir:	Abdominal and gastric surgery
CAS	Complex Adaptive Systems
CRNA nurse:	Certified Registered Nurse Anesthetists
Gyn/Obs:	Gynaecology and obstetric surgery
ICT:	Information and coordination technology
NAU:	New Aalborg Univerity Hospital
OP area:	Perioperative Area
OP nurse:	Perioperative Nurse
OR:	Operating Room
OT:	Operating Theatre
OT nurse:	Operating Theatre nurses (Both OP and CRNA nurses)
TV-kir:	Thorax and vascular surgery

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1 | Introduction

Every day organizations around the globe have to deal with more uncertainty. Take for instance COVID-19 and international conflicts such as sanctions against Russia due to the Ukrainian war. These have both created more uncertainty by disrupting supply chains around the globe and forced people to change their habits. The article *"Managing supply chains in an era of turbulence"*, illustrate this phenomenon quite well [Christopher and Holweg, 2011]. This change in the world means organizations need to incorporate become more resilient, to stay in the game. But, resilience is not just bouncing back from sudden shocks, it can also be about incorporating everyday resilience, which many healthcare providers experience [Barasa et al., 2017] Danish healthcare is affected by the demographic challenge of an aging population, as the workforce is expected to decrease by 1800 citizens between 2016 and 2036, where the number of retired citizens will increase by 394,000 citizens [Højgaard and Kjellberg, 2017]. The increase in life expectancy [Roser et al., 2013] also results in more citizens living with chronic diseases and multi-morbidity[1] [Højgaard and Kjellberg, 2017]. These changes in patient care create uncertainty about future staffing levels, patient mix, and volume.

Other trends also affect the future operating theater. In the future, the operating room (OR) is expected to have an increase in minor to non-invasive surgeries, which leads to less pain, shorter stays, and less anesthesia as new clinical technologies and robot surgery are used more [Kopelman et al., 2013]. The operating theatre nurses have to gain and maintain skills in both clinical and information and coordination technologies (ICT) [Smedley, 2005] [Konttila et al., 2018]. This need is further supported by clinical nursing personnel who manage OR complexity on an operational level. They conclude that coordination and reaffirming information are crucial, and the resilience of the professional staff is expressed as the capacity to prepare, respond, and adapt to expected and unexpected situations [Göras et al., 2020] [Bogdanovic et al., 2015]. The nurses' adaption of these skills are affected by their attitude, professional knowledge, and skills, as well as organizational factors [Kaye, 2016]. Tsai et al. argues that ORs can be considered as complex adaptive systems (CAS), as they fit the description of *"a group of individual agents, each communicating, competing, and having conditional interaction with each other to help lead an emergent behavior which is more than the by-product of simply adding individual actions"* [Tsai et al., 2017].

This report will focus on the potential of using operating theatre nurses (OT nurses) to create a more flexible workforce, which should enable higher patient throughput by increased resilience in the everyday planning. In the following sections, will the essential information on the case hospital be explained, hereafter will a problem identification be provided, as well as a literature search in the context of flexible work-forces.

[1] The term "multi-morbidity" is used throughout the report in connection with people with multiple health conditions. These are often long-term health conditions that require complex and ongoing care [?]

1.1 | Case Settings

The report takes place at Aalborg University Hospital (Aalborg UH). Aalborg UH dates back to 1787, when it was an infirmary with beds for fifteen soldiers. Over the years, the hospital has expanded and changed with the times. In its more modern history, it became a part of Aarhus University Hospital from 2003 to 2012, resulting in new collaborations, teaching, and more specialized labor. In 2013, Aalborg UH became a University Hospital in its own right, as a collaboration between Aalborg University and the North region of Denmark took place. Today, Aalborg UH has locations both in Aalborg, Farsø, Hobro, and Thisted, which collectively cover the public health care services of the North region of Denmark. Aalborg UH states its mission as three key points [Aalborg Universitetshospital, 2022]:

- Together, we create a more safe and effective patient course for the individual patient
- Together, we develop the treatment of tomorrow
- Together, we develop the employees of tomorrow

This report will aim to support this forward thinking missing of theirs by creating a workforce which is able to respond to changing treatments and patient demands. This will be done by investigating the potential in increasing its nurses' flexible capacities.

The next couple of years will bring considerable changes to Aalborg UH, as they will push their two facilities, in Aalborg North and South respectively, into one new building in the southeastern part of Aalborg, which will become the New Aalborg University Hospital (NAU). NAU is a strategic decision that should allow them to fulfill its mission. The vision for NAU is to improve the overall health care quality in Region North as functions across specialism, cadastral, sectors, and general practice will collaborate closely to make more coherent and safe patient courses possible. The goal of NAU is to create the highest quality of care, research, and development. This project will analyze Aalborg UH, but it is important to mention that the proposed flexible workforce is considered for NAU, which is expected to open in 2024. The new building will support many initiatives, such as:

- *Centralized service building* connected with NAU through an underground tunnel of 300 meters. The Service building will handle non-clinical services, such as kitchen, linen, apparatus and medicine inventory, sterilization, and workshops. Big items will be transported using AVG, and smaller items, such as tests, will be transported as pipe posts.
- *Digital location tracker* is proposed to assist clinical personnel in locating items, a general issue many health care facilities experiences because of the number of shared resources.
- *Research center and the faculty of health* will have locations at NAU. This will include access to research laboratories, microbiology, simulation training, and a shared library.
- *Centralized surgical clinics* of 32 OR, where four are hybrid ORs, with room for 96 perioperative patients at a time.

These initiatives means that many processes will change when moving Aalborg UH to NAU, especially the centralized clinics are in this reports interest, as the number of OR will be reduced.

Operation Theater

To understand how the ORs and the OT as a whole functions, it must be known that a standard operating team comprises one surgeon, two perioperative nurses (OP nurses), one monitoring certified registered nurse anesthetist (CRNA nurse), and one circulating CRNA nurse. The OP nurses also take on distinct roles; one will work in the sterile operating area and hand over apparatus to the surgeon, this nurse is called a scrub nurse, and the other will be on the floor free to perform non-sterile tasks, such as moving and controlling larger equipment, finding additional apparatus and coordinating with the outside of the OR. This role is called the scout nurse. The CRNA nurses also have distinct functions; one will be in the room throughout the operation to monitor the patient's values and react, in this report referred to as the monitoring nurse, whereas the other will enter the room upon being called, most often to assist with the initial anesthesia and again when the patient has to awaken from the anesthesia. This function is called the circulating nurse. The circulating nurse is assigned two ORs at once and goes back and forth as assistance is needed. Most surgeries only require the presence of CRNA nurses, but some will require an anesthesiologist. Therefore, there is always an anesthesiologist on shift if needed. These roles can be seen in figure 1.1.

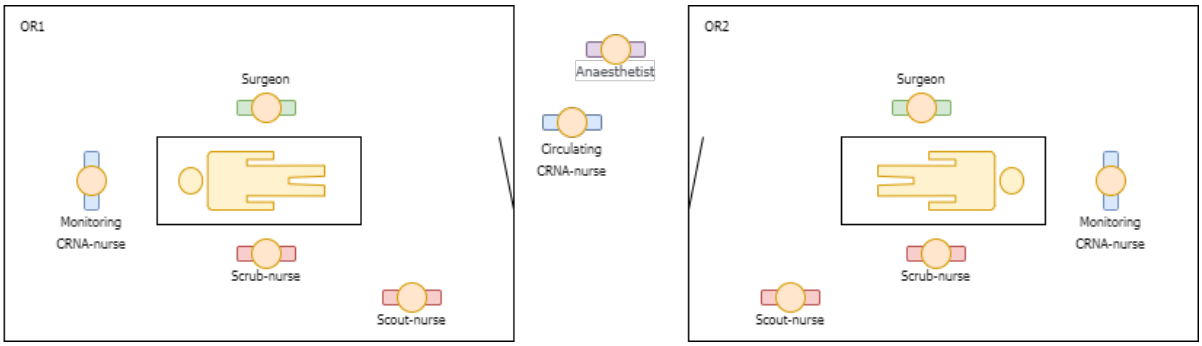

Figure 1.1. The roles within the OR

The OR tasks depend on the procedure type, the patient, and the surgery progression. There are however, still some tasks that commonly take place. Some of these are performed by cleaning staff and porters, who serve as key personnel for the OR efficiency. Cleaners and porters are not designated to any hospital area but take jobs based on the task priority and closeness to the location. This also means that a lack of porters and cleaners can lead to increased waiting time across the hospital. Below is the list of the main actors in the OR and their essential tasks concerning the OR:

- *Surgeon:* Sterile hand-wash, dress sterile, confirm patient, and perform surgery
- *Monitoring nurse:* Call the circulating nurse, perform anesthesia, prepare anesthesia, wake up the patient, and hand over the patient to the ward.
- *Circulating nurse:* Assist monitoring nurse when called and assist in tasks outside the OR.
- *Scrub nurse:* Sterile hand-wash, sterile dress, assist surgery, handled removed patient matter, and clean up.

- *Scout nurse:* Log surgery timestamps, scan used equipment, handle machines, find equipment, send jobs to cleaning and porter, coordinate with outside actors, and collect new equipment packages.
- *Cleaning:* Clean OR between patients.
- *Porter:* Transport patient to and from the OR.

In reality, the number of people in surgery is often higher, as Aalborg UH is a learning university; therefore, nursing and medical students also tend to be present. Some procedures also require an anesthesiologist presence, as mentioned earlier, or an extra assisting OP nurse. At NAU the OT process explained above expected to change, as there will be a preparation room outside the OR, which is expected to reduce the shift time between patients.

Planning elements

Due to the timing needed to assure the right resources, at the right place with the right patients, some key planning elements will be explained. An overview of key planning can be found in figure 1.2. Here there is a clear distinction between the offline planning, which involve both strategic, tactical and some operational planning and the online-planning, which is not so much planning, as it is coordination and re-planning based on whatever new information have occurred on the day of surgery.

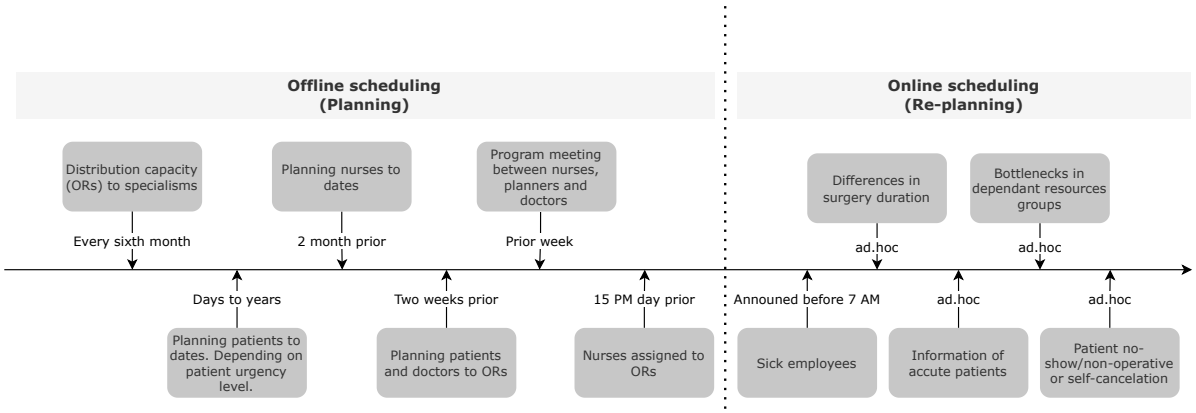

Figure 1.2. Planning decisions within the OT

The main elements in the planning phases are the division of OR capacity to each of the specialisms. The different specialisms have different planners, doctors, and nurses, so dividing the capacity makes it easier for the planners. In general, the number of ORs per specialism is relatively stable, so when discussing the capacity division every half year, is it mainly about borrowing an OR for a day per week for a limited amount of time. This decision is expected to be taken every quarter at NAU [Nyt Aalborg Univeristets hospital, 2021], to become more adaptable. With the available OR capacity establish, the planner can then use this information to schedule patient dates. If a patient has a higher urgency, the planner will move patients around, potentially cancelling other patients to find an earlier date. Nurse managers also use capacity information to identify how many nurses to schedule per day. The next step is to

schedule which patients and surgeons should be in which ORs. Most often, the surgeons are scheduled for the same OR the whole day, but this is not a hard constraint if a better solution can be found by shifting surgeons. The week before the next week's surgical program a meeting is arranged between the planners, surgeons, and nurse representatives. The goal is to identify any plan infeasibilities, such as moving a procedure date because of the surgeon's schedule or closing an OR due to short-term illnesses. The nurses are scheduled last to the ORs as they are scheduled the day before surgery at 1 PM. The reason for their late scheduling is that they mainly have the same skills, so as long as they are enough they should be able to cover all ORs, and secondly, the schedule is dynamic, so deciding which nurses is most qualified for which OR is postponed until the schedule is less likely to be disturbed. The schedule goes live on the day of the surgeries. Here, ill employees call in before 7 AM, and based on this information and the information on acute and no-show elective patients, a new plan is agreed upon at 7.15 AM. The OP and CRNA nurses then have a separate meeting in each of the specialisms, where they are finally assigned to ORs, where they will meet at 7.30 AM. Nurse coordinators handle any new disruptions throughout the shift, as a part of the online-planning phase. At NAU the coordinators are expected to be placed in the same room to better use each other.

From specialism to communities

The notion of specialisms deserves mentioning. Currently, the overall OT planning is performed on a higher aggregation level, than on specialism; instead, it is performed on perioperative areas (OP areas). The different OP areas on Aalborg UH are:

- Neurological surgery
- Orthopedic surgery
- Gynecology and Obstetric
- Urology
- Mamma and plastic
- Thorax and vascular surgery
- Ear, nose, and throat surgery
- Abdominal and gastric surgery
- Cardiology

The vision at NAU is to change these OP areas into larger communities to better utilize employee and OR resources between OP areas. The new communities are:

- *Community 1:* With Ear, nose, and throat surgery, Neurological surgery, and Orthopedic surgery,
- *Community 2:* With Urology, Gynecology and obstetric, Thorax and vascular surgery, Cardiology and Abdominal and gastric surgery and
- *Day surgery:* With Orthopedic surgery, Gynecology, Obstetrics, Mamma and plastic, Urology, and Children's surgery.

Day surgery will be an independent unit performing more elective, standardized surgeries. Here, the employees must become OP-flow experts and work toward being cross-trained within two specialisms. Community 1 and 2 will seek to standardize specialized surgeries over time to prime them for same-day surgery. However, Aalborg UH has not yet decided how to face this change.

To exemplify, the procedures for day surgery are not selected yet, which is a significant decision that impacts the capacity needed for each specialism and personnel.

OT Nurses

The report will focus on the nurses in the future community 2. Here, 15 OP nurses work in Gynecology and Obstetrics (Gyn/Obs), and 18 OP nurses work in Urology; all nurses in Urology and Gyn/Obs are cross-trained in some procedures in the other OP area. Urology and Gyn/Obs also share 15 CRNA nurses, who are fully cross-trained in both specialisms. Abdominal and gastric surgery (A-kir) have 28 OP nurses and 38 CRNA nurses. The CRNA nurses are cross-trained with the OP area Ear, nose, and throat surgery (ØNH). Of these, 29 CRNA nurses have A-kir as their primary specialism. The OP area thorax and heart surgery have 26 OP nurses and 17 CRNA nurses. THere the CRNA nurses are cross-trained with the OP area Mamma and plastic surgery (Mam/Pla). These relationship are showed in table 3.2.

		Gyn/Obs	**Urology**	**Mam/Pla**	**TV-kir**	**ØNH**	**A-kir**
CRNA	**Gyn/Obs**	Fully merged					
	Urology						
	Mam/Pla			Fully merged			
	TV-kir						
	ØNH					Cross-trained	
	A-kir						
OP	**Gyn/Obs**	Cross-trained					
	Urology						
	Mam/Pla			Alone			
	TV-kir				Alone		
	ØNH					Alone	
	A-kir						Alone

Table 1.1. Illustration of the current flexibility between OP areas for both CRNA and OP nurses. Only OP areas from community 2 are included, as well as OP area ØNH and Mam/Pla, as they currently are related with the nurses workforce capacity

1.2 | Problem Identification

This section will analyze the situation as-is at Aalborg UH to understand how the current performance may affect the performance at NAU, if no actions are taken.

As this project has taken place, some new software has been enrolled at Aalborg UH. The enrollment has meant that the Business Intelligence department, which has assessed and monitored data at Aalborg UH has been closed for data requests. Their lack of availability has resulted in limited access to quantitative data. Some data have, however, been possible to extract. This have been the data 'operation theater time stamp data' contains values from the 30/12/2019 to 24/03/2022. The data is extracted through access to the platform Qlik.dk, which is integrated with the Centrea. Centrea is Aalborg UH's flow management software, which

enables nurses to log timestamp within the OR. In the timestamp data were 22% of the dataset values either missing or faulty. This percentage is relatively high and too large to remove from the dataset. The report has used and excluded missing and faulty values based on the goal of the individual statistics. For example, when reporting on the number of cases per year, all data cases are included, whereas when reporting on the average surgery duration, both missing and faulty cases are excluded, as these could distort the average. The data only consists of two full years, which is not a lot, especially with both years being affected by COVID-19. In general, 2021 data is used as an estimate for today because of the assumption that it is less distorted by COVID-19. The other dataset which was possible to obtain were on OT cancellation, here no data errors found, but some caution must be used regarding the categorization. After reading through the column with comments in the data, and discussing the use of cancellation codes with system users, there is reason to expect that employees are not consistent in using the categories. The inconsistency is understandable, as many cause classifications overlap, which decreases the usability of this data set's cause classification. Further details about the datasets' values and validation can be read in Appendix E.

This initial analysis will use the quantitative data provided, together with the five field observations and conversations with nurses to gain a picture of the three expected challenges, these are:

- The low nurse retention
- The low OR utilization
- The high patient cancellation rate

Low retention of nurses

From the 19th of June to the 28th of August 2021 Danish nurses had a record-long strike for higher salaries. In the end, they lost the fight, and the salaries remained the same. In that period, the rest of Denmark did however come a bit closer to understanding the reality many nurses experience before and during covid-19. The strike led to many nurses leaving, and based on conversations with nurse managers, is some units already understaffed. In terms of competition, Aalborg UH does, like many other public hospitals, compete with private clinics, which have risen in popularity since the government took initiatives to enable more market dynamics in the healthcare sector in 2002 [Søgaard et al., 2009]. In most fields, public and private hospitals do not compete, as their product offerings are pretty different, but a troubling development has been seen in human resources, as public and private providers compete for the same skilled labor. As public hospitals lack nursing personnel country-wide and specifically the north region has seen a steep increase in cost because of the need for externally bought flexible nurses [Nordjyske, 2021]. Hiring flexible external nurses is not recommended as using agency nurses represents the biggest negative impact on continuity and quality of care because agency nurses are often unfamiliar with the particular work environment and the care setting [Inman et al., 2005]. Combined with the trend in of demographic where the workforce declines while the elderly population growths, must the supply of nurses be considered of strategic importance [Højgaard and Kjellberg, 2017].

Having more flexible nurses can both be a way to better utilize ones available nurse capacity, but it can also be a tool towards better retaining nurses, as continuous education is found to be important for retaining nurses McClain et al. [2021]

Utilization of ORs

Figure 1.3 shows the average utilization of available capacity and the number of surgeries performed each month, across the specialisms A-kir, TV-kir, Gyn/Obs and Urology. Here utilized time is considered when a patient enters to OR to when they leave the OR.

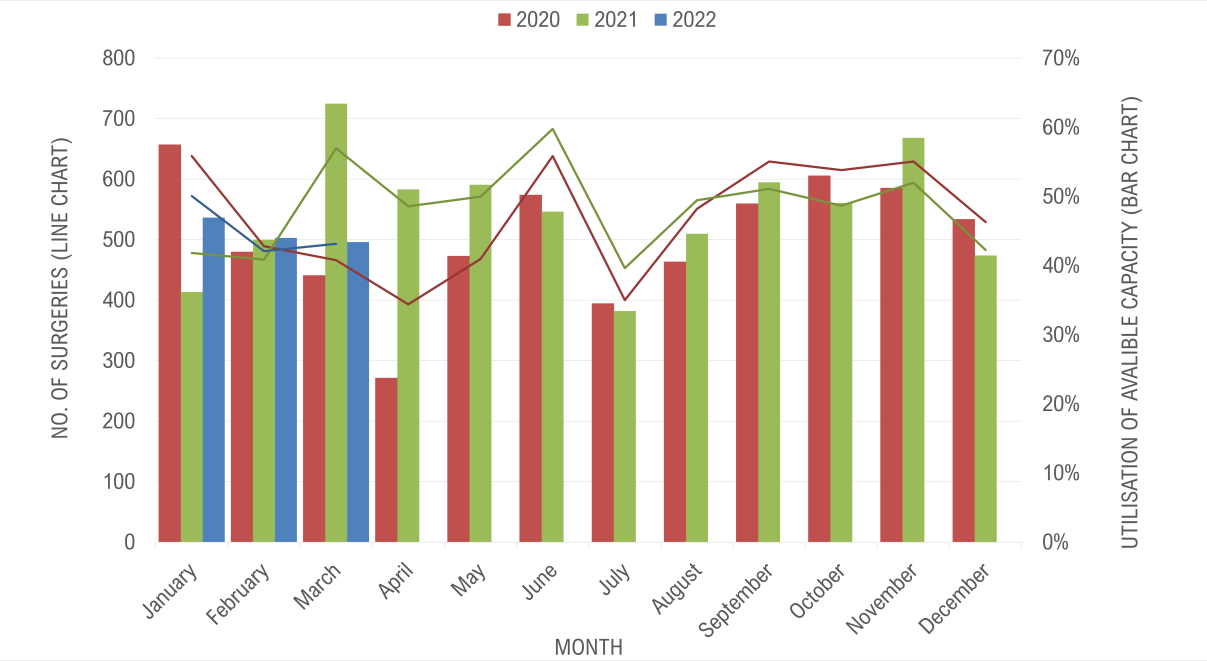

Figure 1.3. Illustration of OR utilization the bar-chart [%] and surgeries performed in the line-chart [#] across the specialisms TV-kir, A-kir, Gyn/Obs and Urology's 18 ORs from January 2020 to March 2022.

The chart in figure 1.3 shows that the number of surgeries performed is related to utilization. The number of surgeries is expected to indicate the patient demand but is not the actual demand, as patients are scheduled to fit the available capacity. The chart also illustrates some elements of seasonal demand fluctuations, though it is unknown if the patient demand has decreased or if the available capacity is decreased during this period. Decreased available capacity could be the case in July to handle employees' holidays. As the analyzed data have only been available from 2020 and forward, COVID-19 is a big liability, but looking at the three data points from 2022, which are placed either between or closely identical to be COVID-19 affected years, it is expected that COVID-19 has not largely affected the performance of the ORs. This is, however, an assumption, as it might as well be that the OT has not stabilized itself yet to its post-covid performance. Where the number of surgeries is a rather intuitive performance parameter, utilization is not. Utilization is measured based on the available capacity. The available capacity is used to define the period when the ORs are scheduled to perform surgeries. In this case, the available capacity

is calculated as Monday to Friday, from 7.30 AM to 3.15 PM, excluding known holidays. The surgeries included in the figure all start after 7.30 AM and before 3.15 PM, whereas the remaining surgeries are considered outside the available capacity. The average utilization is found to be 47% of the available capacity, which is rather low. The rule of thumb within operation management will be between 70-85%, depending on your process variation. Vissers and Beech proposes an utilization of 85%. Two elements are considered when grasping the daily utilization of the ORs. First, how often is an available OR closed? A closed OR decreases the overall utilization. The ratio of closed to open days for each OR in future community 2 can be seen in figure 1.4. Overall, the ORs closed 36% of the days they should have been operating. There might be days where the ORs identically have been closed or finished early, which is not considered in these utilization values, but this type of uncertainties are not expected to explain why the utilization is as low as it is. In Challenge 3, some causes to why the utilization is as low as it is, is explained.

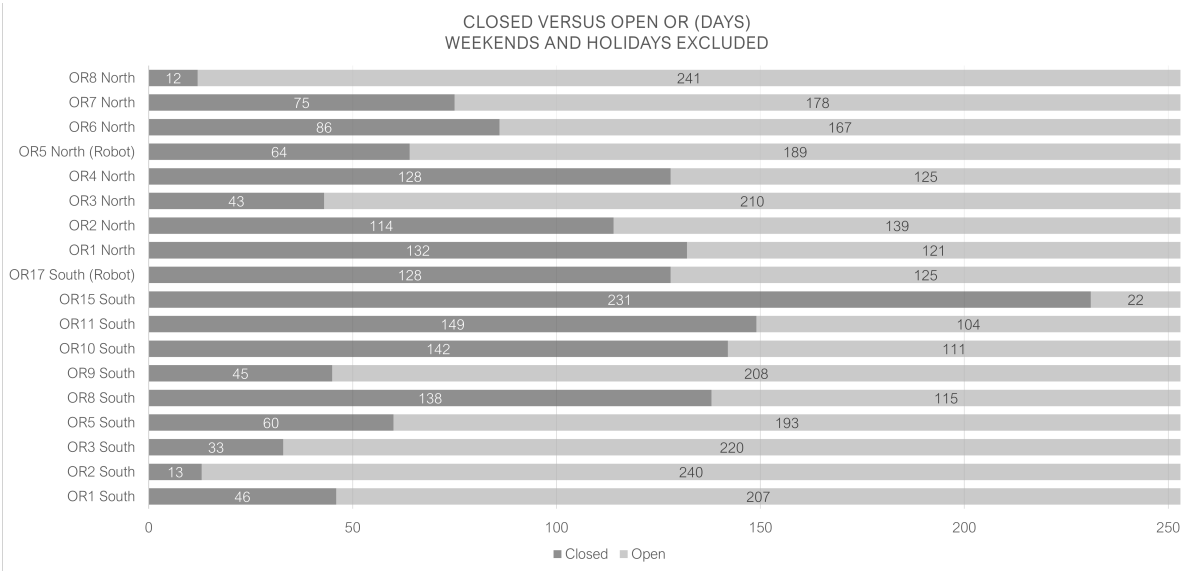

Figure 1.4. Open and closed days of all ORs at Aalborg UH's future community 2

The second element to better understand the utilization level is the utilization level when the OR performs surgeries, thereby being considered 'open'. An open OR will either express the planned OR program or the result of a closed OR, which is taken into use without a predetermined program, as would be the case if an acute patient arrives and an available surgical team can be found. An illustration of the utilization of open ORs can be seen in figure 1.5. On average, the utilization is found to be 69%. The two ORs able to deliver on the 85% are both ORs of high acuteness rate. In OR3 South 79% patients are acute, and in OR3 North, the rate is 41%.

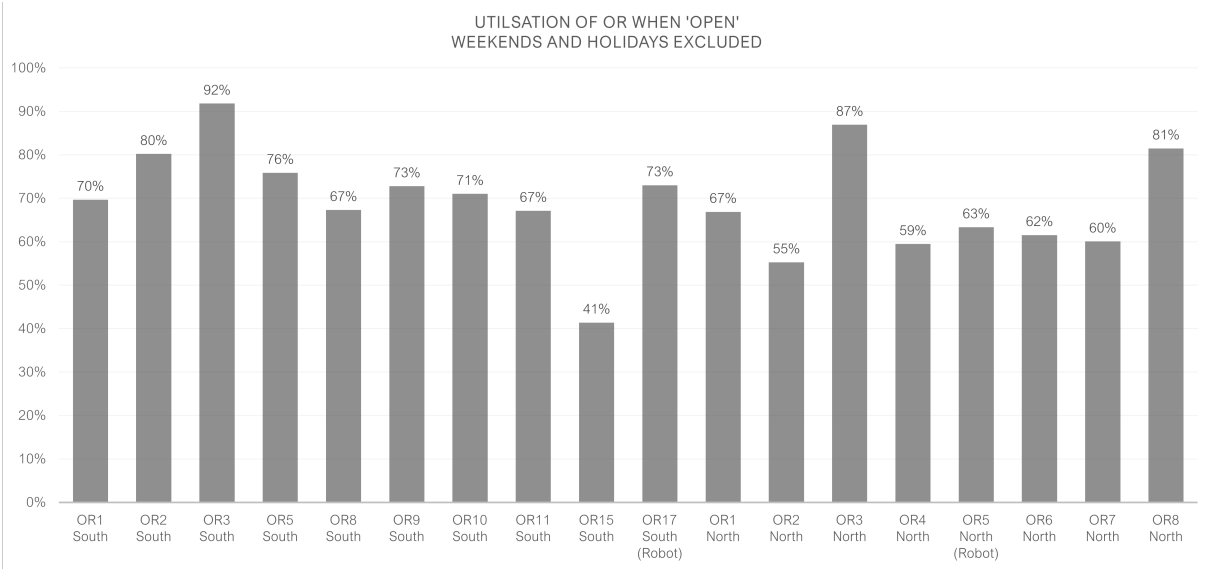

Figure 1.5. Utilization between 7.30 AM and 3.15 PM for ORs within future community 2

Thereby, it can be concluded that the utilization of ORs in Aalborg UH future community 2 is only 47% on average, as ORs are closed 36% of the days they should have been open, and when they are used, the utilization of the 7 hours and 45 minutes is only 69%.

High cancellation rate

Patient cancellations are considered as an parameter of variation in patient demand and resource availability. The most common reasons for cancellations and their frequency can be seen in table 1.2. If it is assumed that any patient is only canceled once and has the surgery that same year, then an estimate on the cancellation rate can be found. This value will be 11% for A-kir, 15% for Gyn/Obs, 20% for TV-kir, and 30% for urology. These values is however, only an estimate, as patients can be canceled multiple times, if their surgery is not considered as urgent, where others are canceled but never re-scheduled, in case of death, change of procedure, or natural recovery.

Based on the table, most cancellation causes are short-term; this means cancellations will daily affect the planning, which can help explain the low OR utilization. The most common reason for cancellation is capacity issues, which is a broad cause. General reasons which could lead to capacity issues are 1) short-term illness of surgeons and nurses, leading to ORs being cancelled if no replacement is found, 2) Acute patients leading to the elective patient being canceled if there is not an OR with a qualified team available the remaining day shift or, 3) Elective surgeries are taking longer than expected and there is again not an OR with a qualified team available the remaining day shift for the surgery to be performed. The second highest reason for cancellation, is caused by the patient, cancelling minimum two days before. The two days are important, as two days is enough for the planner to find a other patient to take the surgical slot, therefore is this cause not expected to cause the low utilization.

Surgery cancelled due to	**A-kir**	**Gyn/Obs**	**Urology**	**TV-kir**	**Total**
...capacity issues in the OT	80	62	201	53	**396**
...patient canceled min. 2 days prior	71	141	130	29	**371**
...change in treatment need	29	23	81	59	**192**
...patient have covid-19	4	41	96	4	**145**
...hospital, max. 1 day prior	91	6	21	21	**139**
...patient condition, max. 1 day prior	12	31	57	26	**126**
...capacity issues in the ward	20	1	12	74	**107**
...patient canceled max. 1 day prior	15	33	27	5	**80**
...other causes (combined)	144	66	108	192	**510**

Table 1.2. Cancellation causes and their frequency in 2021 for the OP area TV-kir, A-kir, Urology and Gyn/Obs. A full list causes can be found in appendix G

Another consideration is the number of cancellations per day. On average, 7.3 patients cancel or get canceled every day. This number has significant variation, as seen in figure 1.6. When the cause for cancellation is due to short-term illness, the remaining surgical team and an OR become available. In this case, will either a replacement for the absent employee be found and continue the program or redistribute the staff to other ORs who are missing a staff member. The surgeons are hard to replace, but as there are more nurses on a surgical team, it is expected that they are the cause of short-term illness more often than surgeons.

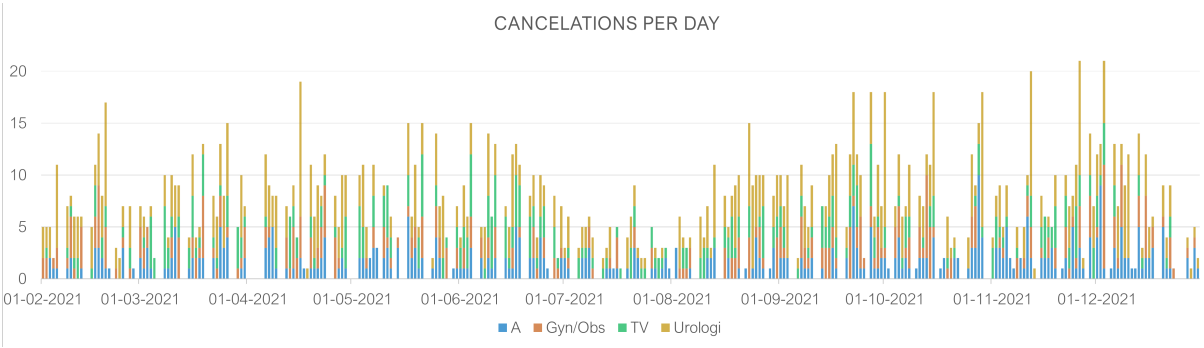

Figure 1.6. Cancellations per day in 2021, distributed on OP-areas in community 2

Based on the data on cancellations, it is expected that the online planning, also referred to as coordination, greatly impact the utilization of ORs. So even though most planning happens before the surgical date new information, such as the absence of employees, acute patients, and changes in patient conditions, will often make the initial plan infeasible. Online planning requires coordinators to find new ways to succeed with the schedule and optimize available resources. When it is impossible to identify a feasible way to succeed with the planned surgical schedule, elective patients are canceled.

Concluding remark

The utilization of ORs are found to be 47% of the available capacity, even through Aalborg UH states they scheduled after a full surgical program in all ORs each weekday. The low utilization is expected to be partly affected by patient being cancelled due to the cause 'capacity issues in the OT'. This cause can both refer to the OR capacity and the human capacity, but due to the general low utilization and number of days ORs are closed is the human capacity found most likely, as nurses account of four out of five members of the surgical team. The nurse capacity is also affected by increasing retention, due nurses changing job requirements and in the future this trend may be further elevated due to demographic changes. These challenges are all interconnected and it is expected that creating a more flexible nurse workforce can help mitigate 'capacity issues in the OT' and thereby increase utilization, as well as protect Aalborg UH against retention, by offering more education to nurses.

1.3 | Literature Search

Using search terms as "flexibility", "cross-training", "operating theatre", "nurses" and synonyms in research journal databases, a number of articles was identified within the scope of this research project. These can be found on the next page in table 1.3

The literature search showed how broadly defined flexibility in a workforce is. Flexible workers can be interpreted in multiple ways. It can refer to having a slack capacity of more general resources, as having a resource pool of internal float nurses or externally hired flex nurses. It can also refer to cross-trained resources with a primary function but which are cross-trained in a secondary function to help reduce potential bottlenecks. Flexible workers can also refer to workers with flexible hours; Thereby making flexibility something which can both be desired from the organization to better up and down scale their capacity, or a means towards higher employee satisfaction, enabling flexible schedules to the individual employees' needs.

Uncertainty

The most high-level view of cross-training in healthcare was by Jack and Powers. Who identify demand uncertainty to be the main driver for flexibility. If demand uncertainty fluctuates more than 10% per year, the environment is considered to have high demand uncertainty. Demand uncertainty is argued to be affected by demographic changes in the population, the population size of potential patients, and the changing professional standards caused by higher patient expectations and technological advances. Jack and Powers suggest four volume flexibility strategies depending on a department's internal flexibility and demand uncertainty. These strategies can be seen in figure 1.7.

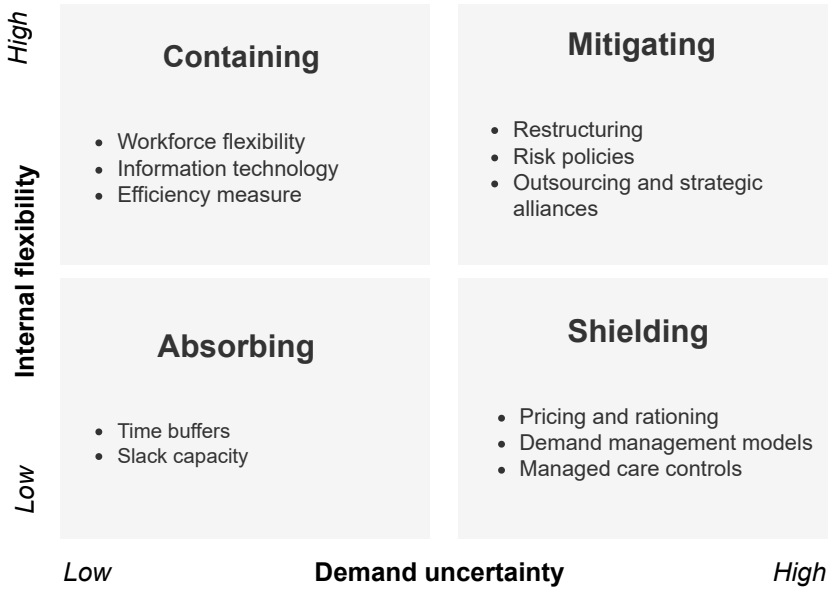

Figure 1.7. Illustration of the four strategies identified in healthcare settings by Jack and Powers

Study	Topic	Findings
Jack and Powers 2009	Flexibility	Identifies four volume flexibility strategies in healthcare, using a literature review and 11 field interviews in an American hospital. The strategies are based on internal flexibility and demand uncertainty.
Hopp and Van Oyen 2003	Flexibility	A framework for evaluating potential for an agile work-force, focusing on cross-training and coordination feasibility
Platt et al. 2019	Skills	The study explores the perioperative nurses' perceptions of cross-training. It finds that cross-training can lead to better teamwork, professional satisfaction, and patient care, but may cause trouble in the case of staffing issues, lack of confidence, and burnout. Protecting training from disruption is needed to ensure nurses develop the confidence and competencies
Klei et al. 2004	Skills	Nurses cross-training to assess patients' pre-operative health status compared to anesthetists. In 87% of the cases where the classifications of their answers were similar. The study proposes allowing nurses to diagnose a subgroup of low-risk patients, so the anesthetist can focus on who requires additional attention before surgery
Matheson and Levi 2011	Skills	The case study of cross-training highly specialized registered nurses in all phases of care to deal with a staffing shortage. The solution solved the temporary staffing shortage and reported benefits of interposition team knowledge and moral
Van Ravenstein 2019	Coordination	The study proposes a planning framework for nurse capacity to improve flexibility and workforce division, and this is done by incorporating seasonality, OT schedules, cross-nursing, and long and short-term illness. The framework concludes that there is a trade-off between the decrease in workload and postponement of planning due dates, as better plans can be made with later roster decisions.
Campbell and Diaby 2002	Coordination	Development and evaluation of an assignment heuristic for allocating cross-trained workers. The suggested heuristic has a robust performance and can enable beginning-of-shift allocations.
Lafontant et al. 2019	Collaboration	A qualitative study of nurses' feelings towards floating reports chaotic workflow process, unfair patient care assignment, unfamiliar work environment, social factors, and physiological and psychological components as barriers towards floating, a concluding remark where that nurses enjoy teamwork and friendship in their unit
Monteiro et al. 2015	Collaboration	Develop of multi-objective optimization algorithm of a surgical schedule with the antagonistic human resource objectives of nurses' skills (long-term objective) and team affinities (short-term objective) to be used in daily operational decision making. The improved affinities and skills should improve outcome quality over time.
Inman et al. 2005	Structure	Uses analytic approximation, confirmed with simulation, to calculate the cost-saving from externally hired nurses. The study finds that a chain-structured cross-training design outperforms reciprocal pairs and all-to-all structures
Iravani et al. 2005	Structure	Development and testing of the SF method to assess more detailed flexibility designs using their graph structure. The study concludes that a good detailed systems structure is important as it can outperform system structures with more capabilities.

Table 1.3. Overview of literature review

TO elaborate on figure 1.7 the 'containing strategy' involves flexible staff, information technology, and efficiency measurements if internal flexibility is high and demand uncertainty is low. The 'absorbing strategy' involves buffer capacity and slack time and is used when demand uncertainty and internal flexibility are low. The 'mitigating strategy' involves restructuring, risk pooling,

and strategic alliances in case of high demand uncertainty and internal flexibility, and last, the 'shielding strategy', involves pricing and rationing, demand management models, and managed care control. The actual demand of Aalborg UH is unknown, but it is expected they are currently within the low demand uncertainty, with the future risk of having a higher demand uncertainty. Developing their business towards the models of high internal uncertainty will enable reduced costs in case of uncertainty in demand. The strategies can be helpful, but the dimension 'internal flexibility' is not elaborated.

Workforce flexibility

To understand the dimension of workforce flexibility, the work of Hopp and Van Oyen is valuable. The framework suggests three dimensions to consider if your agile workforce has potential. These are 1) skill, 2) coordination and 3) teamwork.

Skills

Skill refers to the ability of your workers to learn another skill. There might be constraints such as individual learning paths, the complexity of skills, the need to certify skills, and the ability to maintain skills. In short, are the costs for training and maintaining a skill higher than the potential benefits? Study [Matheson and Levi, 2011] is an example of this, where nurses are cross-trained in all phases of care to deal with staff shortages, the skills needed can be considered easy to obtain, but they might be challenging to maintain if they are only used to handle a temporary staff shortage. The study by [Klei et al., 2004] is an example of nurses having to become certified to perform assessments of patients' pre-operative health status instead of the anesthetist. It is therefore a more challenging skill, but if it is used continuously to reduce a bottleneck, the costs of training the nurses might be mitigated. When reading the cross-training studies, an interesting observation is that two directions for the cross-training can be considered : 1) process-oriented or 2) function-oriented. A process-oriented cross-training teaches individual skills in other functions, whereas function-oriented cross-training will move an individual between departments while keeping the same function. Process-oriented cross-training is expected to enable better flow in one department, but if an organization has different demands and priorities there might be a need to move employees' cross-functions instead. The decision to move employees process-oriented or function-oriented to reduce a bottleneck is expected to be affected by the skill requirements. Learning a skill is essential as it is one of the main documented issues with cross-training. Platt et al. explored nurses' perception of cross-training and found that cross-training caused trouble when the training of the nurses was compromised. The training is needed for nurses to feel confident and maintain their competencies.

Coordination

The second dimension of cross-training is coordination. Coordination, in this case, refers to how the cross-training nurses are used. A study by [Van Ravenstein, 2019] found that nurses' rosters could be notably improved by incorporating known uncertainties, such as seasonality and illness. As more information became known, the roster also improved by postponing different

planning decisions. Cross-trained and pooled flex was considered in earlier planning phases to assure a balanced capacity. Campbell and Diaby tested an allocation algorithm that allows for the beginning-of-shift allocation of cross-trained nurses. The studies contribute to coordinating cross-training nurses from a strategic, tactical, and operational level. Information technologies, as mentioned by Jack and Powers, are also tools used to ensure the added complexity of cross-trained workers can be managed.

Collaboration

The last dimension of workforce agility proposed by Hopp and Van Oyen is collaboration. In collaborative teams, there is a goal that the productivity is higher than the individual productivity combined. The importance of teamwork is enforced by Lafontant et al., who found that nurses enjoy friendship and teamwork in their unit. Cross-trained or floating employees in this study meant they had to work with someone unfamiliar. A multi-objective optimization algorithm by Monteiro et al. showed how team affiliations and skill development could go hand in hand with the surgical program. The affiliation objective was chosen as a team who knows and trusts each other can contribute to better patient outcomes. However, as many surgeons can only perform a selection group of surgeries and nurses optimally should be able to assist with as many types as possible to have the highest level of skills, the second objective was to schedule nurses for different types of surgeries to ensure their skills were maintained. The researchers also identified those with cross-trained skills that were not insignificant for the algorithm's performance. This finding was the competence structure or cross-training structure. Therefore, this dimension will be included as a critical dimension of workforce flexibility.

Structure

The number of cross-trained nurses and what they are cross-trained in is not insignificant. Inman et al. showed that using a chain structure in cross-training is superior to structures of reciprocal pairs and total flexible structures, where everyone can do everything. A chain structure means that a department is cross-trained in one other specialism, so they form a chain. This structure allows for the least number of cross-trained nurses while reducing the cost of externally hired personnel. These structures are illustrated in figure 1.8.

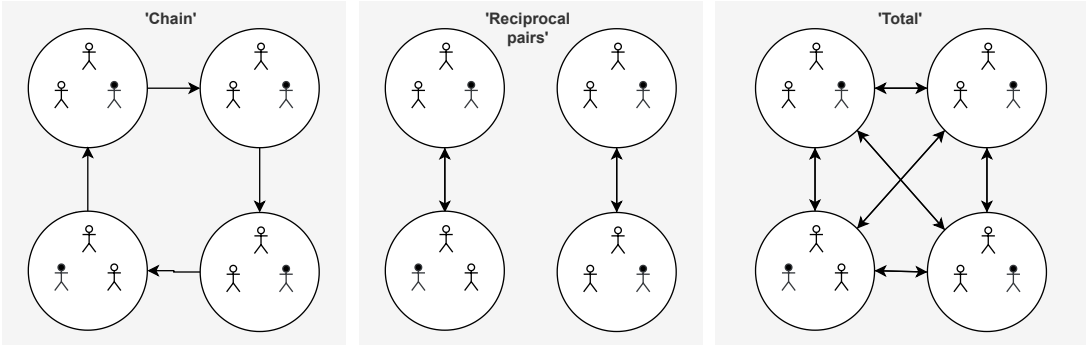

Figure 1.8. Illustration of different basic structures for cross-training personnel. The colored stick figure represents the ratio of flexible employees, and the arrows indicate what they are cross-trained in

Iravani et al. investigate this further by developing the structural flexibility (SF) method to assess the performance of a flexible structure. The study concludes that a good system structure can outperform other structures with more capabilities. However, an issue with these studies is that they focus on ward nurses whose tasks and work conditions differ from the OT nurses. It may be unlikely that a nurse can be cross-trained in a complete specialism, so the structural flexibility design is not tested on a lower aggregation level, where more details occur. A simple structure can make coordination and allocation decisions easier, but a more detailed structural flexibility model may be more effective in fitting demand variations, though it will complicate allocations.

Concluding remark

This literature search finds that a flexible workforce can help respond to demand variations and uncertainty as an alternative to slack time and buffer capacity. Factors that influence the success of creating a flexible workforce are 1) The coordination policies to plan and allocate flexible workers, 2) The collaboration context in with flexible workers are used, 3) The ease of requiring and maintaining the flexible skills, and 4) The structural design of which workers are cross-trained in other skills.

2 | Problem Statement

Based on the problem identification in Section 1.2 is the patient cancellations resulting in a OR utilization. Their currently utilization level is expected to be caused by 1) late changes in patient surgical need and 2) lack of qualified resources, which can adapt to a new surgical plan. Another challenge is the future uncertainty in qualified OT nurses supply, as retention and demographic changes poses upon the workforce. These challenges may create disruptions and decreasing performance at NAU if Aalborg UH continues as usual. Based on the literature review in Section 1.3 it is expected that increasing the flexibility of OT nurses can mitigate the uncertainty in qualified OT nurse supply and help increase OR utilization by better balancing nurse resources. This study hypothesize that *"flexibility in OT nurses is a feasible solution towards higher patient throughput and resilience"*.

This hypothesis will be tested by answering three research questions:

1. Which factors affect the feasibility of OT nurses to become cross-trained?
2. How could Aalborg UH create a more flexible workforce for OT nurses at NAU?
3. Will a more flexible workforce at NAU be considered as a feasible and beneficial solution towards higher patient throughput and resilience?

Thereby making the objectives of this report to identify factors that affect the OT nurses ability to become cross-trained, create a proposal of how Aalborg UH' could create a more flexible OT nurse workforce at NAU and lastly, to discuss the feasibility of implementing the proposed flexible workforce.

2.1 | Limitations

As flexibility is a rather broad term some limitations to the analysis have been made, these are:

- The report only considers a flexible workforce for nurses in the OT, thereby the OP and CRNA nurses.
- This report only considers one type of flexibility, which is the ability for nurses to assist to other procedures.
- The report only considers a flexible workforce for future community 2,
- The report only consider the OP areas A-kir, TV-kir, Urology and Gyn/Obs, and not cardiology, which is also a part of future community 2. This was advised as cardiology are considered extremely independent.
- Only nurses viewpoints are included in the analysis (chapter 3, but further viewpoints such as coordinators and planners will be considered in the proposal and the discussion (chapter 4 and chapter 5).
- Due to limited availability of quantitative data, the analysis (chapter 3) only considered qualitative data. Other approaches where considered, but not found feasible, this is elaborated in in reflection 7

2.2 | Research Structure

The report structure is inspired from the Design Thinking process model called 'The double diamond', as illustrated in figure 2.1. Here its shows how a project have two phases, the problem and the solution phase. Each phase diverge and converge, to first gather information and then make a choice. The next part of this project will be the solution space, which in this case is revolved around the three research questions. First question will be answered in the Analysis chapter 3, where information will be gathers, then the second question will be answered in the proposal chapter 4, where a proposal to a road map is made, this proposal are used as a prototype for one feedback iteration and at last will the third research question be answered in the discussion chapter 5.

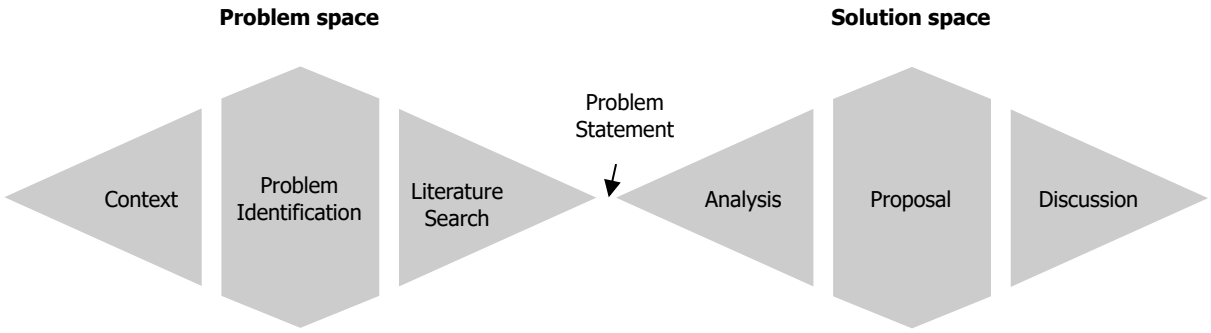

Figure 2.1. Illustration of the double diamond process model and its relations to the report structure.

2.3 | Research Design

The research philosophy has been identified as a mix of the paradigms' interpretative epistemological- and subjective ontological view. Interpretative epistemology is often used in social science when the scientific area has individuals socially interacting on multiple levels in complex ways. The subjective ontological view is used when organizations are seen as dynamic, and the organization's culture daily is influenced by interactions between individuals. The research approach is mainly inductive. Inductive approaches are often suitable for research where human behavior is essential, as in this report, where the main goal is to understand the role of nurses in a changing hospital setting. The research nature relates to the research purpose, which in this case is found to be exploratory and descriptive. Exploratory as the report seeks to develop new ideas and questions for future research and descriptive when describing the contextual factors and processes within the case hospital. The strategy used is experimental, as it is a single case study. This report's time horizon is the current moment in which the report is made, making the the study a contemporary phenomenon, as it only contain data from one period. The data collection method is mixed, as semi-structured interviews, structured interviews, quantitative data, and road-mapping methods have been used. See table 2.1 to gain an overview of the research design.

Research design	
Research philosophy	Interpretative epistemological- and subjective ontological view
Research approach	Inductive
Research nature	Exploratory and descriptive
Research strategy	Experimental, single case study
Time horizon	Current moment / Spring 2022
Data collection and analysis	Field observations, semi-structure interviews, structured interviews, quantitative data, desktop research and road mapping

Table 2.1. Research design overview

2.4 | Participant Selection

The report takes place at Aalborg UH's North and South locations. Here the specialisms Urology, Gyn/Obs, A-kir, and TV-kir are in focus. The participants for this study has been OT nurses from different specialisms and with different functions. There have been two contact points in this project, one of which is a nurse. This nurse has set up initial participant observations of nurses to follow. Later interviews have been a mix between directly contacted nurses and nurses chosen based on the reference of other nurses. The study carries a risk of the nurses interviewed not being general for the nurse-unit opinion, but this risk is mitigated as the number of interviewees increases.

2.5 | Methodology

The methodological considerations have been and will be presented as used, but the research question *"Which factors affects the feasibility of OT nurses to becoming cross-trained?"* which will be answered in the next sections, have had an structured interview will this protocol be further explained below.

Protocol for structured interviews

Structured interviews have been used to learn how the nurses perceive their ability to use cross-trained nurses from other specialisms in their procedures. The interviewees are all either managing nurses or elected by a managing nurse. The interviews performed can be found in Appendix F and the results in Appendix A and Appendix B.

Before the structured interviews took place the questions were tested on two nurses which reported feedback, so the questions were adapted when considering their expertise. Using nurses advice on the questions do potentially introduce some subjectivity towards their views and experience, but knowledge on critical variables in their field, was on the other hand, hard to obtain without their guidance.

The participants were contacted by mail, where the context, procedures used, and the meeting

questions were attached. Before each of the structured interviews took place, the categories were explained as well as the assumptions. The assumptions were:

- The cross-trained nurses are assumed to have the necessary education in the specific procedure, though they will not have the in-depth knowledge of all procedures in the specialism.
- In case only one cross-trained nurse can be used in a surgery, then the other nurse assumed to be well-experienced in the procedure.
- The cross-trained nurses will only assist if the procedure is elective and not acute.

The cross-training could have had a larger span if these assumptions were not made, but it was clear that these assumptions were needed for nurses to consider cross-training feasible. The categories in which the nurses could place the procedures were the following:

- *Not cross-trainable:* The procedure are considered of too high complexity within the current nurses or of too low frequency to consider using cross-trained nurses.
- *Only the scrub/monitoring nurse can be cross-trained:* Depending on the interviewee function, either the scrub or the monitoring nurse was used as an example.
- *Only the scout/circulating nurse can be cross-trained:* Again, depending on the interviewee's function, either the scout nurse or the circulating nurse was used as an example.
- *Both can be cross-trained:* Both the scout and scrub nurse can be cross-trained and assist in the same surgery in the case of OP nurses, and with CRNA nurses, both the circulating and monitoring nurse.

These categories were identified using the three questions below:

- Can this procedure be assisted by a cross-trained scrub/monitoring nurse?
- Can this procedure be assisted by a cross-trained scout/circulating nurse?
  - If yes to both questions, can surgery of this procedure be assisted solely by cross-trained nurses?
- Any comments related to your decided placement?

The comments and questions allow some additional information and peace of mind for the nurses, as they found the choosing a category difficult, as the decision in real life often had variables, than the structured interview allowed. The nurses overlooked the answers being filled and the comments being written.

3 | Analysis

This chapter will seek to answer the research question *"Which factors affect the feasibility of OT nurses to become cross-trained?"* stated in chapter 2. The first section 3.1 identifies the experienced factors against cross-training and is based on five field observations and conversations with nurses. The second section 3.2 investigates the nurses perception of which procedures could be used for cross-training and it based on the six structured interviews, the interview protocol is elaborated in 2 and an overview of the interview and conversations had in relation to this chapter can be found in Appendix F.

3.1 | Workforce flexibility factors

Based on the observations, conversations and comments received in the structured interviews where some challenges towards more flexible OT nurses identified, these are considered as key factors to accommodate, if more flexible could be possible. The factors are elaborated below:

Repetition
A constraining factor for a more flexible workforce is the need for repetition to maintain ones skills. For at nurse to feel confident in a procedure, they must practice the procedure with regular intervals. Especially for some procedures this is an issue, as they can take place rather rare. In these cases, some nurses have become specialized in procedures, as Aalborg UH cannot teach the procedures to all nurses in the OP area, as none of them would get repetition enough.

The head of TV-kir's OP nurses stated that both education and repetition were needed before a nurse could perform a procedure, and because some procedures have much variance, repetition is even more necessary to get familiar with the procedure and its variations. Her estimate of repetition would be to perform a procedure at least weekly, whereas other nurses who discussed repetition estimated every second week. This could indicate that TV-kir's procedures are more complex than other specialisms'. TV-kir differs from other specialisms, as they sometimes need three OP nurses instead of two because of the complexity of the procedure and there average surgery time is also much higher than the remaining OP areas, as seen on figure 3.1 on the next page.

An OP nurse in Urology also stated that only six OP nurses where trained in 'Perkut. endoscopist radical prostatectomy', as this procedure was very complex, which meant more repetition was needed, so even though the procedure had a high volume, not everyone could learn to perform it.

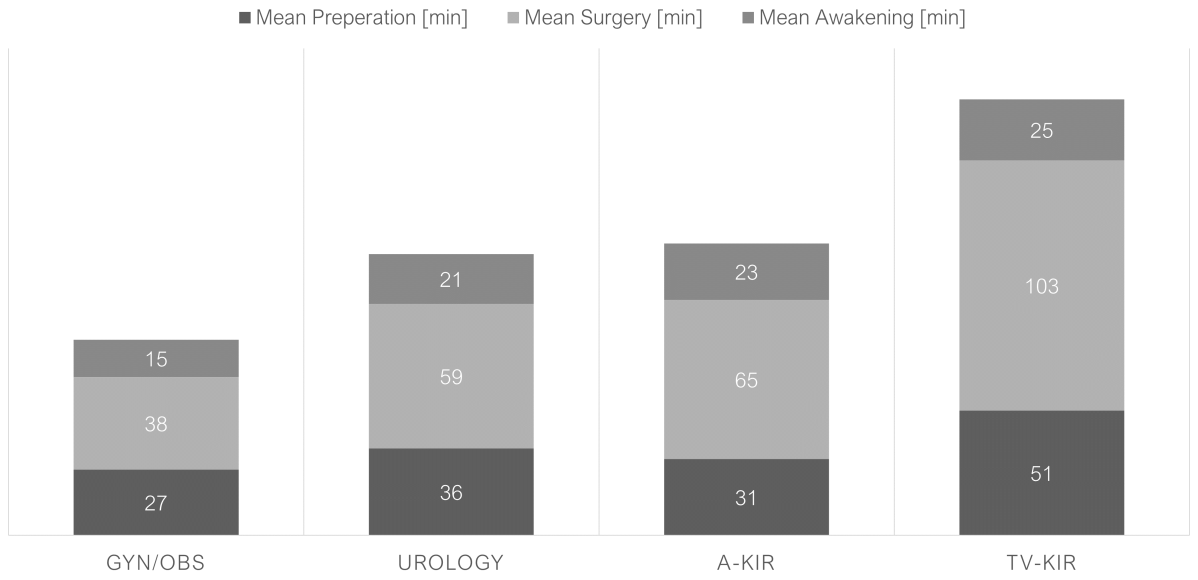

Figure 3.1. The rounded mean for preparation, surgery and awakening time, based on data from 2020 and 2021.

Defining skills

One nurse manager mentions that Urology expects to find some symbiosis with A-kir at NAU, as they both have a fair amount of robot surgeries in which fewer nurses are trained in. This could indicate that there are times where it is easier to train nurses from other OP areas in a procedure based on their skills. Another nurse, however, mentioned that both Urology and Gyn/Obs could assist robot surgeries, but they do it differently. OP nurses from Urology would change the robot's equipment under surgery, whereas the surgeon performed this task with Gyn/Obs OP nurses. Another example related to the other specialisms was that through most specialisms used, x-ray and diatermi, the settings are different across the specialisms. An OP nurse in A-kir mentioned something similar about the machines might be used in other specialisms, but the settings and machine generation differed across OP area. Based on these statements there is reason to believe that a common understanding of which skills a nurse should have is needed. What would it take to standardize technical stills?

Another skill to consider is the apparatus. Most apparatus may be the same across OP areas, but some have equipment who others do not use. As an example, A-kir has a lot of different tubes, so would it be possible to define some general apparatus everyone should know and define some equipment skills when some procedures use less general tools?

Adaptability

When discussing the procedures, a problem arrive. The procedural codes classification and the actual surgery can be very different. As with the 'explorative laparotomy', where the OP nurse from A-kir said the following: *"The procedure is not necessarily hard, but it requires many thoughts because of the complexity of the procedure. It may or may not be possible to use a cross-trained nurse based on the individual case"*. The same is the case with procedure

'Incision of perianalabces', where the nurse's statement was *"The procedure has a risk of fistula-search, especially those scheduled in the day-time tend to change character"*. This means that the procedure codes themselves can take on much variation, which is unknown when the procedure starts. The nurses have to adapt to the situation, by having an idea of what direction the procedure is taking so that they can prepare the right equipment. Therefore, it will not be enough for some procedures that the nurse have the skill-set to perform the procedure, as experience to predict what will happen next is also needed.

Team feeling

Nurses from Urology mentioned that cross-training was seen as undesirable as nurses want to feel they belong to a group, and floating around between departments would reduce this. This need for feeling like a team was mostly observed in OP nurses, where the sense of team also stretched to the surgeon. It meant a lot for them that they could predict what the surgeon did next and knew which equipment packages they preferred, if they where assisted in another OP areas, they might not be as fast.

Standardization

Another barrier observed in the OR was that doctors did not always fill in the patient file correctly. This meant that information on the planned patient placement was not available, which made the placement dependent on tacit knowledge and nursing experience. Some surgeons also wanted different equipment packages for the same procedures, making the correct decision dependent on nurse experience. Here a lack of standardization forces nurses to be dependent on tacit knowledge. The head of CRNA nurses from A-kir and ØNH underlined the importance of knowing where things are placed in boxes and drawers, when using cross-trained nurses. She had experience making flashcards and other tools to help A-kir nurses find their way into the facilities of ØNH, thereby making the nurses more independent of tacit knowledge. Also standardization of roles should be needed. Opposite TV-kir, Gyn/Obs, and Urology, A-kir would rather have a cross-trained nurse as the scrub nurse than the scout nurse. This is due to the fact that an A-kir scout nurse is often the OR coordinator and therefore has to take calls, find equipment, and coordinate with the outside. Thereby, the responsibilities are different between OP areas.

Experience

Sometimes standardization is not possible, as the there is not time to look up the information. Another barrier towards cross-training mentioned by a OP nurse in A-kir was that the ability to use cross-trained nurses would be dependable on the nurse's experience currently in the OR, which could be a limitation for specialisms who does not have many nurses with +5 years experience. Another example of the need of experience is that minimum one of the OP nurses from A-kir have to assist when the TV-kir performs gastric surgery to handle the equipment, as TV-kir does not regularly have this procedure. A-kir cannot take over the procedure, as it is only TV-kir's OP nurses who have experience in assisting in the procedure.

Individual learning paths

Another worry, which multiple nurses stated, was that it would unstrenghten their competencies if they had to learn the procedures in other specialisms. The nurse coordinator mentioned that most nurses already felt stretched thin and would rather become better at what they can than learn new things. Thereby, not all nurses are able to learn more procedures, if they were forced to do so.

Some nurses are also more interested in becoming better at the complex surgeries and there is a need for this, as some procedure are highly complex and have a low frequency. As an example eleven Gyn/Obs nurses are specially trained in the robot surgery 'Perkutan endoscopist cystectomy'. In Urology seven nurses are trained in 'Perkutan endoscopist cystectomy', just like the nurses from Gyn/Obs. Besides this, 16 nurses are trained in the robot surgery 'Perkutan endoscopist nefrektomi' and six are trained in 'Perkut. endoscopist radical prostatectomy'. In TV-kir there is also further specialized nurses, as they have three specializations where four nurses can perform MIX-surgery, five TAVI-surgery, and three AFA-surgery. This tendency is generally only seen for OP-nurses. The findings of the conversations, as well as comments from the structured interview have been grouped together based on the challenge they create for a flexible workforce.

3.2 | Workforce flexibility potential

The structured interviews were made to fill out a scheme able to indicate the potential of cross-training nurses. The goal was to identify which procedures were eligible for using cross-trained nurses. Due to repetition being mentioned as a critical factor against cross-training, only procedures performed fifty or more times were used in the scheme; these procedures do, however, count for 86% of A-kir's procedures, 84% of TV-kir's procedures, 92% of Gyn/Obs's procedures and 87% of Urology's procedures, which aligned rather well with the Pareto principle. The pareto priciple states that for many outcomes, roughly 80% of consequences come from 20% of causes, which in this case means that the majority of surgeries are the same few procedures. More information on the scheme's development can be found in the method section in Chapter 2. Eight schemes were made with each of the four OP areas and with both OP and CRNA nurses. The findings for CRNA nurses are showed in table 3.1 and for OP nurses in table 3.2.

	A-kir	**TV-kir**	**Gyn/Obs**	**Urology**
No, should be internal nurses	10	10	0	2
Yes, one can be cross-trained	13	12	0	0
Yes, both can be cross-trained	3	0	13	16

Table 3.1. Can this procedure use cross-trained CRNA nurses?

Table 3.1 shows the respondent of Gyn/Obs and Urology evaluates that almost all procedures could be fully assisted by cross-trained nurses from other specialisms. This evaluation can be affected by the fact that Urology and Gyn/Obs are already cross-trained in each others

specialisms and for that reason the mentality towards using cross-trained nurses is more positive. On the other hand, the positive result could also be due to the OP areas actually have easier procedures. This could very well be the case, as both Urology and Gyn/Obs are expected to have some procedures moved to the day surgery community at NAU. In the case of TV-kir and A-kir more than half of the procedures evaluated can used a cross-trained nurse as the circulation nurse, which is also considered quite good.

	A-kir	**TV-kir**	**Gyn/Obs**	**Urology**
No, should be internal nurses	10	16	3	6
Yes, one can be cross-trained	14	5	9	12
Yes, both can be cross-trained	1	0	1	0

Table 3.2. Can this procedure use cross-trained OP nurses? One procedure is missing from A-kir, as this procedure was only assisted by CRNA nurses

Table 3.2 shows than almost no procedures can be performed by only using cross-trained OP nurses. Especially TV-kir did not consider their procedures to be cross-training friendly, as only five procedures could use one cross-trained nurse. In the remaining OP areas the majority of procedures were able to use a cross-trained nurse, but in general the results from the OP nurses were less inclined to use cross-trained nurses.

The historical data from 2021 was used to estimate how many patients can be operated on using cross-trained nurses each year, see figure 3.2.

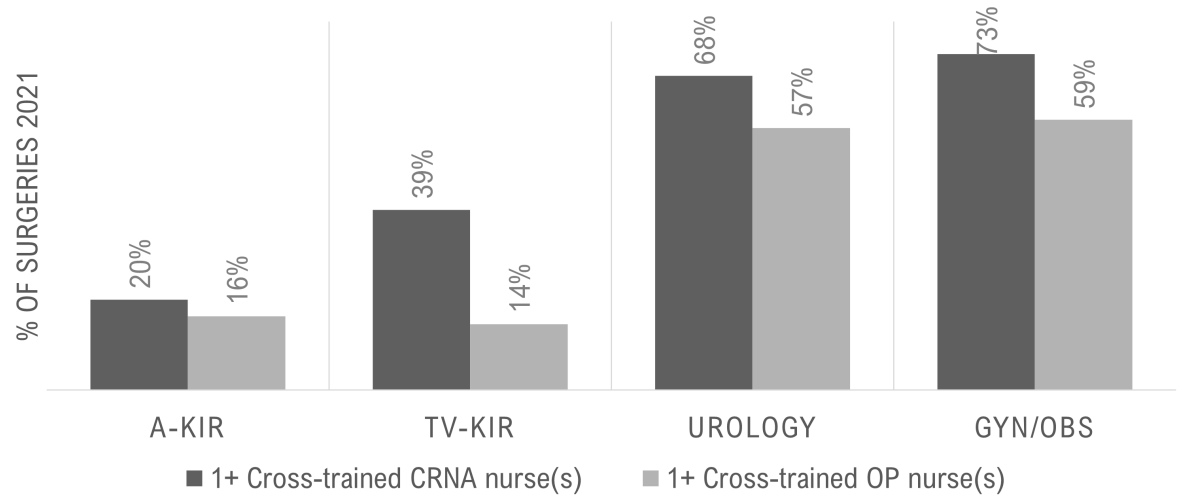

Figure 3.2. Illustration of the percentage of surgeries which could have been assisted by either one or two cross-trained nurses

In figure 3.2 all acute patients, children, and surgeries started before 7.30 AM and later than 3.15 PM were removed to best represent the daily situation in a future community 2. Overall could 48% surgeries in 2021 been performed using cross-trained CRNA nurses and 36% could have been performed using OP cross-trained OP nurses, see these number in Appendix H. The

figure below shows that around 70% of the surgeries perfromed at Gyn/Obs and Urology could have used a cross-trained CRNA nurse, an around 60% for cross-trained OP nurses. TV-kir and A-kir have much less procedures which could use cross-trained nurses, which may make it difficult for cross-trained nurses to gain enough repetition in the few procedures they can assist to.

Concluding remark

To wrap-up this chapter, is the identified factors which affect the feasibility of OT nurses to become cross-trained be stated, the following:

- Nurses need regular *repetition* of a procedure, estimated around weekly to biweekly.
- *Skills* needed to perform procedures are not defined, which makes it harder to identify procedures capable of cross-training
- Nurses want to be a part of a *team*, an especially OP nurses what to be able to predict the individual surgeon's next step.
- Some processes are not *standardized* across OP areas, making it harder for cross-trained to enter another OP area's procedure.
- Cross-trained nurses put higher requirements for the other nurse to have *experience* under the surgery.
- Nurses have *individual learning paths*, so some might not be able to or have any desire to know more procedures.
- There is a *screwed potential* in which OP areas find cross-training possible, which can make it difficult to find a fitting flexibility structure.

4 | Proposal

This chapter seeks to answer the second research question *"How could Aalborg UH create a more flexible workforce for OT nurses at NAU?"*, stated in chapter 2. To do this, road mapping was used. A road map offers a complex development path scenario and different cause-effect relations between elements. The problem with road-maps, often together with technology, is that they require deep knowledge and expertise [Machado and Paulo, 2020]. To help mitigate this issue, a more agile approach has been used in the solution development. Here the road map has been used as a prototype to visualize the solution. Having a visual solution enables testers to better comprehend an idea. The road map and its elements can be further iterated on by updating and expanding the prototype as feedback is received. Later stages will involve more testing of different user interfaces and tests of other solution elements. Later on a pilot can be performed to gain more information of the solution's impact. However, due to limited time only one iteration has been performed so the solution requires further development through iterations before it is ready to be implemented. The feedback sessions performed in the first and only iteration are illustrated in Appendix F The solution proposed has gone through one feedback iteration with three employees. The chosen employees are all individuals met in earlier project stages who seemed to have substantial insight into their field and the surrounding touch points. The solution is rather wide-ranging, so the employees have also been selected because they will become future users of the solutions, and therefore their input is crucial for the development and testing phases.

An overall framework of the road-map is made to capture the proposed ideas' dependency and illustrate the concept of maturity, see figure 4.1. Some ideas need adaptions in culture and knowledge, which does not happen overnight.

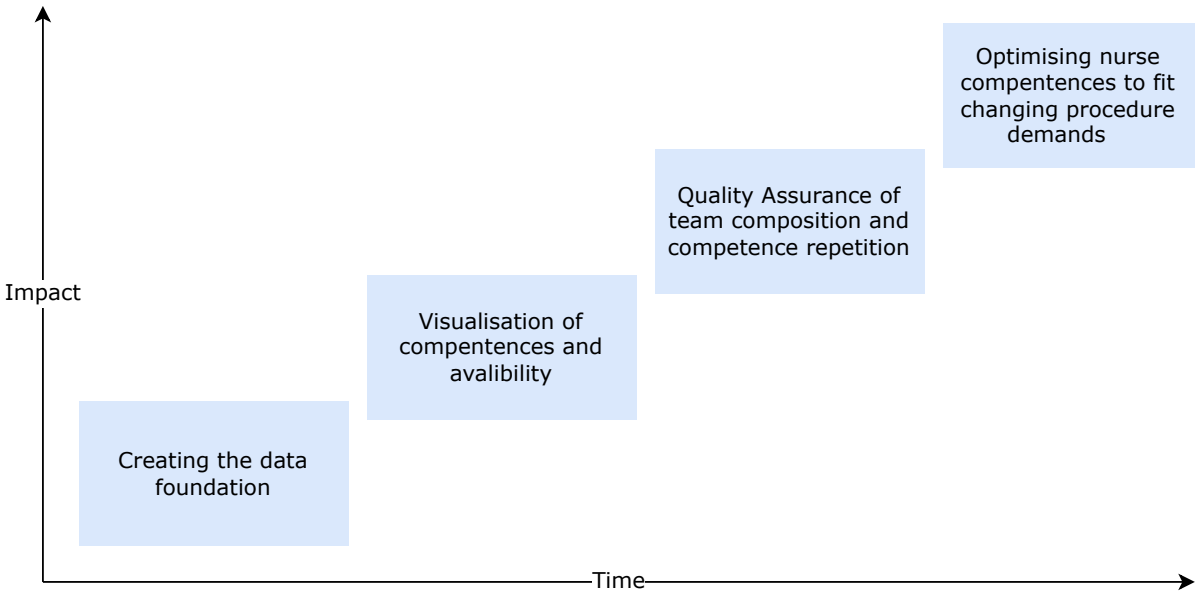

Figure 4.1. The overall framework for managing nurses' competencies

Four incentives should be implemented. Each step has multiple considerations and challenges on its own. Therefore each initiative is described further.

4.1 | Data foundation

Creating the data foundation has no impact or value, but having such data can lead to the improvements seen in figure 4.1 and other nurse innovations and incentives as it improves. In this section the data and tables which are necessary for the following improvements be presented.

An essential change in this solution is the rejection of specialisms. The nurses will not belong to a specialism but have a list of procedures in which they are qualified. Of course, this list of procedures is expected to be related to their specialism initially, but with time, it is expected that more nurses will specialize themselves across specialisms. And the specialisms will no longer have a fixed number of ORs to only their availability, as this will reinforce the current specialization of nurses. Each OR will instead have a list of procedures that can be scheduled within it. The difference here will be that some procedures can be performed in more ORs than average and others in fewer ORs. In this way, nurses can learn competencies based on a selection of ORs, enabling them to have more diverse competencies profiles that better fit the requirements and demands of surgeries.

Table 1: Nurse to Procedures
This table gives nurses an overview of the procedures they can perform, but more importantly, it will give the coordinator of the OT the ability to search for nurses who can perform a procedure in case of emergencies.

In this table, nurses could be given a score to represent their experience in the procedure, as this variable significantly impact the planning. A proposal could be to give scores as:

0. None (Cannot perform procedure)
1. In training (Only as an extra)
2. Beginner (0-1 year experience)
3. Intermediate (1+ year experience)
4. Experienced (5+ years experience)

In the table 'experience' is based on years of experience, as this variable is often used to define experience in discussions with nurses. However, the repetition of procedures or mutual agreements between the nurse and their manager could also be the deciding factor. A proposal would be to let managers use the data on years of experience and repetitions as a guideline for negotiating if a nurse can increase their level earlier. The same logic could allow nurses to request to stay on a lower level if they need further repetition. This data would look something like table 4.1 on the next page.

Experience	Nurse 5676	Nurse 6735	Nurse 2563	Nurse 6735
KLCH03	0	3	0	0
KMCA10B	0	4	2	0
KJAH00	1	4	2	1
KKAE12	3	0	2	2
KUJD02	3	0	0	2
KJKA21	3	0	0	1

Table 4.1. Illustrative example of which nurses can assist to which procedures and their experience level

A consideration in these tables will be to define the procedures, as the procedures worked with in this project might not be on the right aggregation level, as nurses define procedures differently, even between CRNA and OP nurses. A solution could be to create another table of the skills needed for each procedure. This information would also allow a better understanding of how procedures are alike and different, but as mentioned in 3 defining skills can pose some challenges as well.

Table 2: Nurse to Skills

As mentioned above, a table of nurses' skills might be needed to translate nurses' tasks into specific procedure codes. This table would be unique for CRNA-nurses and OP-nurses, as their skills are different for the same procedure. These lists almost exist today as a checklist in education. They are, however, far from standardized across specialisms, which currently define skills in different documents and ways. A standardized list would clear differences and similarities in procedures across specialisms and allow for the identification of procedures in other specialisms requiring new skills to be taught.

This data would look something like table 4.2, which is based on the educational material of A-kir OP nurses's in the procedures Sigmoideoscopy and coloscopy.

Skills	Nurse 5676	Nurse 6735	Nurse 2563	Nurse 6735
Go-through of sigmoideoscopy	1	1	1	
Go-through of coloscopy		1	1	
Go-throgh of children coloscopy	1	1	1	1
Go-through of UPD	1	1		
Poly removal	1		1	1
Markering with marker		1	1	1
ballondilatation of colon	1			1
coagulation − argon/heastprobe as w. gastroscopy			1	

Table 4.2. Illustrative example of the current skills nurses have obtained

When developing the skill data base, it should be considered if any skills should be categorized as basic and taught cross specialism. This could especially be interesting for OP nurses as they do not have a shared educational program as with CRNA nurses. The skill data base can also assure better education in using clinical machines, as currently specialisms only learn to use a machine for their own procedures, but the

Table 3: Skills to procedures

A noteworthy mention is that having all the skills of a procedure should not lead to nurses being automatically qualified for performing a procedure, as this still will require training in the procedure. It could lead to identifying nurses who should be offered training.

The table skill to procedures would also help identifying the most commonly used skills, which could become the foundation for shared educational elements. Shared educational elements exist for CRNA nurses but are not present for OP nurses. A example of how this data could look is seen in table 4.3.

Skills	KLCH03	KMCA10B	KJAH00	KKAE12
Go-through of sigmoideoscopy	1			
Go-through of coloscopy		1		
Go-throgh of children coloscopy		1		
Go-through of UPD	1	1	1	
Poly removal	1	1	1	1
Markering with marker	1	1		1
ballondilatation of colon	1	1		1
Coagulation - argon/heastprobe as w. gastroscopy	1	1		1

Table 4.3. Illustrative example of skills needed before learning a new procedure

Table 4: Procedures to ORs

This solution should allow the scheduling of a selected group of procedures for the OR, not a specialism. This change means that each OR will have a list of potential procedures it can perform. A logical step from the current OR programs toward this vision would be to group new procedures based on some of the following principles:

- Robot surgery procedures across specialisms
- High volume, cross-trainable procedures grouped in shared ORs.
- Complex procedures from one specialism in one OR, so not all nurses in the specialism have to know the most complex procedures and the ones that do get enough repetition.

This data would look something like table 4.6

Programs	OR1	OR2	OR3	OR4	OR5	OR6	..	OR11
KLCH03	1	1	1	1				
KMCA10B				1	1			
KJAH00		1	1			1		1
KKAE12	1	1	1					
KUJD02				1	1			
KJKA21						1		1

Table 4.4. Illustrative example of which procedures can be scheduled to which ORs

Table 3: Nurse to ORs

If a nurse can perform all procedures potentially scheduled for an OR, he/she can assist in that OR. Nurses are expected education in procedures from two to four ORs, depending on the procedural overlap and complexity. Nurses are expected to become more general, covering multiple ORs, or more specialized, covering fewer ORs. This difference is due to the fact that the highly complex procedures are performed in fewer ORs, and fewer nurses will be qualified to perform these.

By locking the number of ORs the nurses can assist, nurses will experience uniformity with whom they work, which can mitigate the fear of losing their 'sense of belonging'. This way of working also ensures that the surgeon has the same group of nurses assisting, an element which has not been invested much in this report, but nurses have mentioned this multiple times as a surgical wish.

This data would look something like table 4.6

Coverage	OR1	OR2	OR3	OR4	OR5	OR6	..	OR11
Nurse 5676	1	1	1	1				
Nurse 6735				1	1			
Nurse 2563		1	1			1	1	
Nurse 2674	1	1	1					
Nurse 4533				1	1			
Nurse 2960						1	1	

Table 4.5. Illustrative example of which nurses are able to be scheduled to which ORs

Table 5: Team to Procedures

This table will help coordinators and schedulers in assuring that the daily team is qualified. The cross-training analysis clearly stated that nurses who worked primarily in another specialism could only be used if the other nurse had enough experience. Experience is vital with cross-trained and newly educated nurses, so the information in table 1 can help create better teams. The table will show the minimum experience level required of the scrub nurse, the scout nurse, the circulation nurse, the monitoring nurse, and potentially the assisting nurse. It will also have a minimum combined score for OP and CRNA nurses. This information will be available for

each procedure, requiring the planner to identify the minimum requirement for that day across the scheduled surgeries.

The goal is that the guidelines are always met, but if this is not feasible, it can become a quality indicator, leading to identifying educational needs.

This data would look something like table 4.6

Team Composition	$OP1_{min}$	$OP2_{min}$	$OP3_{min}$	OP_{min}	$RN1_{min}$	$RN2_{min}$	RN_{min}
KLCH03	2	3	0	**3**	2	4	**6**
KMCA10B	1	4	0	**5**	1	3	**4**
KJAH00	2	3	1	**7**	2	3	**6**

Table 4.6. Illustrative example of team composition of experience needed in procedures

4.2 | Visualization

The visualization tool seeks to aid the coordination in gaining an overview of variables that improve decision-making. When coordinators make decisions, it can end in two ways: 1) Patient operated or 2) Patient canceled. The goal is always that all elective and acute patients have their surgery, but this goal is hard to reach in practice. When patients are canceled, no feasible solution has been found where the patient could be. When coordinators re-plan, they have to consider the following factors:

- Do the nurses and surgeons have the right skills to perform the surgeries in the OR?
- In case of a misfit between skills and the surgeries, can anyone be rotated to create a fit?
- In case, not all surgeries can be performed in time, which surgeries are prioritized and which are canceled?

The coordinator must contact surgeons in the latter, as this prioritization currently lies with them.

Changing the skills of nurses and diversifying ORs make finding a feasible solution more complex, as coordinators do not know what skills each nurse has in a second. Therefore the goal is to help coordinators in identifying quality solutions in a time-efficient manner using visualization and a search function. To do this, information on nurses' availability and competencies are essential. This information is expected to be updated by coordinators responsible for nurses' roster and their position on the day. Logging this information will democratize it, so other specialism coordinators can see who is available.

Figure 4.2 is an example of how the current dashboard offered by Centrea could be modified to support the decision-making for coordinators. The top board is very similar to the current board and shows all employees in the OR, whereas only the surgeon is currently shown. The board gives the coordinators a better overview of the locations of their nurses. The bottom board is adapted to show a quick overview of all ORs, emergency surgeries, which must be prioritized, and

the available workforce. Here, coordinators can search and filter the nurse competence database to help find feasible solutions.

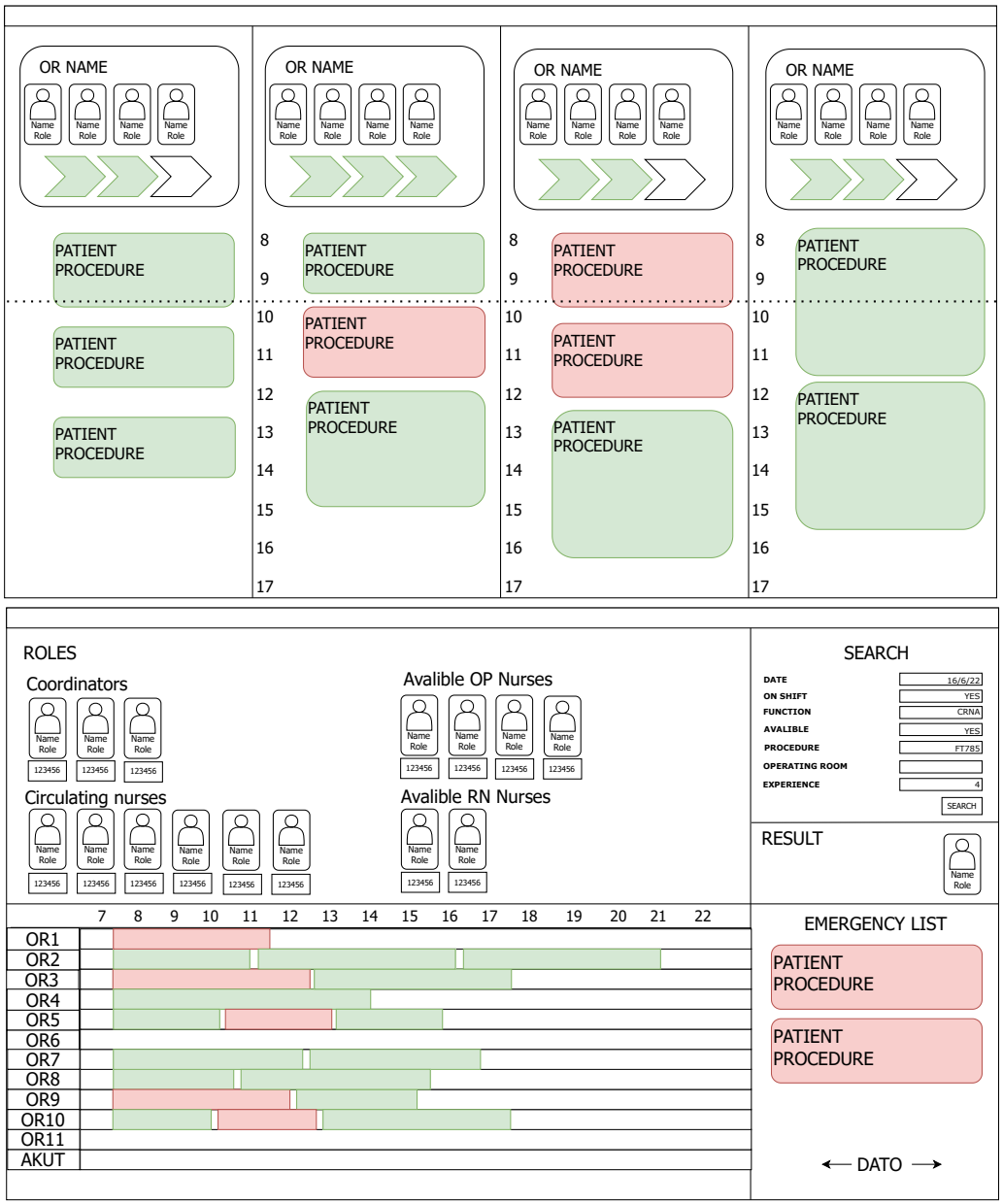

Figure 4.2. Visualization of dashboards to be used by coordinators

4.3 | Quality Assurance

The 'Quality Assurance' works tightly with 'Visualization' and could be developed simultaneously. The visualization mainly digitizes current ways of working, which democratizes knowledge and allows for better utilization of resources within community 2, but as the data foundation is put in place can, notifications alert coordinators when their plans do not fit the competence profiles of the nurses. Another element here would be tracking which procedures nurses assist in, which would allow for monitoring of repetition, alerting nurse managers if it has been too long

since a nurse has performed a procedure. Surgery simulations can support procedures that are hard to ensure enough repetition. The simulations would help assure that the nurses maintain their level of competence.

An application on a smartphone could be a way for nurses to access which procedures they are qualified to perform. In this way, they know what is expected of them. If there is a shift towards more continuous development of competencies, this could also be the platform for viewing skills, finding instructions, and seeing ones tasks.

4.4 | Optimization

At the highest level of maturity, it will be possible to manage the nurse workforce' competencies to fit the predicted surgical need. Meaning that if a procedure is found to have any of the following behavior:

- *Volume increase:* If a procedure seems to increase in volume, there might be a need to enable scheduling of the procedure in more ORs, therefore requiring new nurses to learn the procedure.
- *Volume decrease:* If a procedure is reducing in volume, either due to changes in demand or a strategic decision. A strategic decision would be if it needs to be moved to day surgery, then it can be gradually removed from ORs.
- *Other factors:* Some procedures might have other reasons to change where they are performed, this could be due to acuteness, which might require more ORs to be able to perform a procedure, or it could be due to procedures changing character, such as using new technologies which are better fitted for the competences available to others ORs, as robot surgeries.

Managing which procedures are possible for the different ORs will allow the nurses who perform the procedures to get enough repetition.

Concluding remark

To wrap-up this chapter, a road map towards a more flexible workforce for OT nurses at NAU is proposed. The road map requires four overall steps which could mitigate the factors identified in chapter 3. How each step contributes with mitigating these factors are stated below:

1. Creation of data foundation: *Defining skills and standardizing processes and accommodating the screwed cross-training potential, as well as 'being part of a team' by having cross-trained ORs.*
2. Visualize competences and nurses availability: *Accommodates individual learning paths*
3. Create quality assurance of team composition and procedure repetition: *Assuring experiences levels are adequate*
4. Optimize nurses competences to fit with the changes in demand: *Supports individual learning paths*

5 | Discussion

This chapter will seek to answer the last research question *"Will a more flexible workforce at NAU be considered as a feasible and beneficial solution towards higher OR patient throughput and resilience?"* stated in chapter 2. This will be done by reflecting upon the feasibility and benefits the proposal from chapter 4 can provide.

To consider the benefits the proposal could bring, an overview of the enabling elements, the business changes, the mediate short-terms benefits, the long-term end benefit and finally the business objective is made. This can be seen in figure 5.1

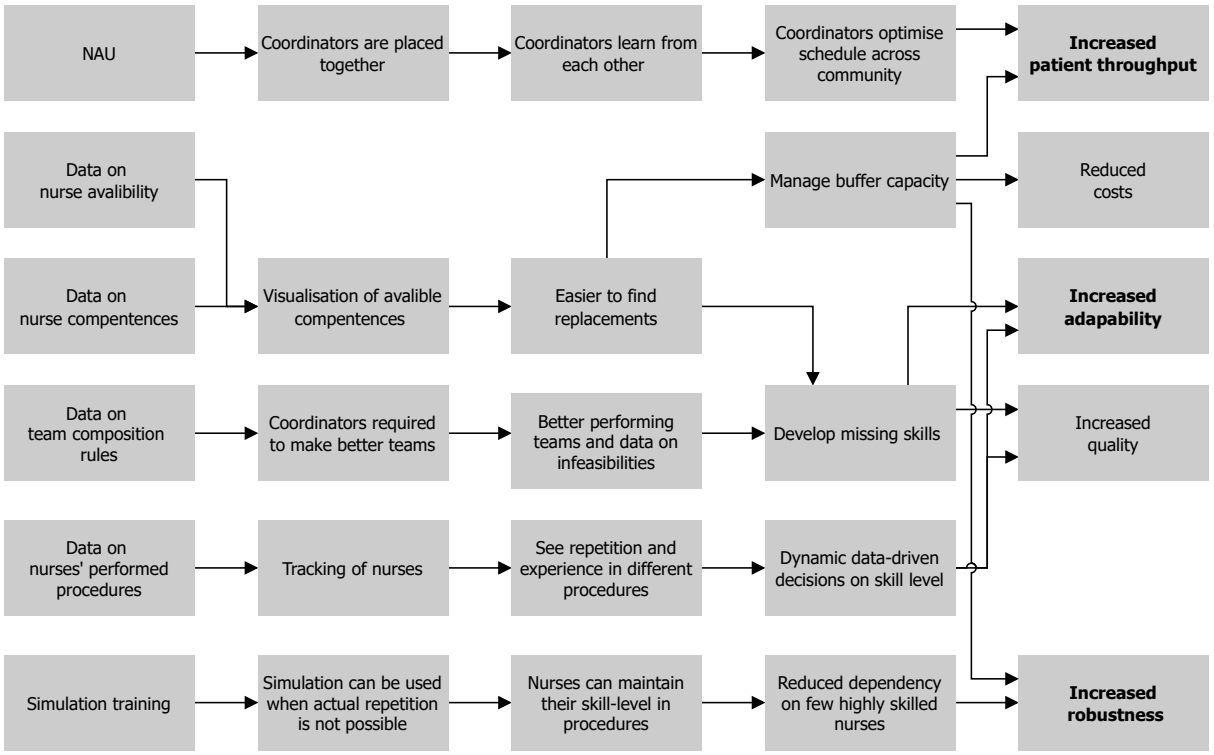

Figure 5.1. The projected benefits of implementing the proposed solution, model inspired by Ernst and Pedersen

The figure shows that a coordinating resources across OP areas, could increase patient throughput by expanding the solution space, in case of disruptions. This is a type of every-day resilience. The figure also show that data on nurses competences and availability can lead to increased adaptability, as missing competences are easier identified and trained and the extra capacity is known, which mean that it can be monitored and controlled. A proposal could be to have an initial goal of 70% percent utilization of available nurse capacity, meaning that if there is required 22 OP nurses to have all ORs open, then 29 nurses are scheduled that day. The buffer capacity should not be on stand by, but use the time on administrative tasks, education or other useful tasks, in case they are not needed. This value can be monitored, to identify what buffer capacity is most economical sustainable. The data on team composition and experience could enable

better quality, in terms of patient outcome. The compliance rate with the team composition can also be monitored as a quality indicator, assuring that the cross-training does not harm quality. Lastly, can the simulation training and managed buffer capacity increase robustness, which also help create resilience. To monitor if the solution delivers on the performance objectives, should nurse utilization, OR utilization and team composition compliance rate be monitored. If everything goes well, should OR and nurse utilization increase, and team composition compliance rate reduce over time. There will need to be established a baseline for nurse utilization and team composition compliance rate before these can be monitored.

However, some elements in the solution need to be taken into consideration before implementing the suggested proposal. The importance of this is underlined by the Inman et al.:

> "..behavioral effects of cross-training can reduce or even eliminate the theoretical benefits. Nevertheless, this dark side of cross-training can be mitigated through skillful management. Much of the potentially negative impacts arise not out of cross-training — but out of thoughtless implementations of it" Inman et al., 2005,118

This lead to the actual feasibility of the solution. The next sections will discuss the feasibility of elected elements of the proposal.

5.1 | How should resources be prioritized?

In some cases it is expected that there are different scenarios for how to create a feasible schedule. Two different OR might both be missing a nurse and if a nurse is available with the right competencies, then which OR should the nurse be scheduled to? This problem is already excising today internally in OP areas, but when nurses can be used across OP areas, it will create a need for new rules.

One proposal here might be that nurses should go to the OP area where they primarily belong. This would assure that the OP areas' internal performance is not reduced, due to other OP areas. This does, however, create an issue, as some patients are more urgent than others. In these cases, the safest rule would instead be to locate nurses placed on patient urgency, thereby minimizing the risk across OP areas of patients being treated too late, potentially with fatal outcomes. Currently the urgency classes put in place are not used properly. This was discovered as most doctors and nurses did not know what the urgency levels defined in their IT-system were or what they meant. The only urgency level they really could classify was named 'next available bed', which was an phrase used internally, which did not exist in their IT-system.

The coordinator always have to take contact to surgeons about the prioritization of patients in order to be able to prioritize resources. This can be a point of internal conflict, as surgeons often prioritize their own patients above others - and when the coordination becomes centralized across OP areas, this problem is expected to get worse. A suggestion would be to identify new patient urgency levels, which fit with the tasks of the coordinators, so the coordinator can use

the urgency levels, without coordinating with surgeons. Having updated urgency levels, should also remove some of the surgeons' discussions, as long as the urgency levels are updated. This could, however, still be a difficult task, but if it is left undone it might result in a longer decision making process for the coordinator, which is not optimal, when talking about a online planning process.

5.2 | How does a flexible workforce affect the planning?

The use of nurses on a operational level, also called online planning, is discussed above. There is, however, also considerations to be made on other planning levels. Though the proposal tried to focus solely on the coordination aspect of a flexible workforce, do the decision to nurses to ORs affect higher planning levels.

On *OT planning level* do the planners who currently manage scheduling of a OP area and a number of ORs have to change. They will have restrictions on which procedures they can schedule in which ORs and they will have ORs where they share the capacity with other OP areas. The restrictions on procedures are expected to be a manageable complexity, but the shared ORs require a new process. One way would be for the planners to split the capacity between them, by dividing the capacity into either time-slots or days. If time-slots are selected, the surgeon could need to be shifted throughout the day, which is not optimal, but on the other hand, having two different surgeons from each specialism available that day enable the OR to be more flexible if any changes occur. This could lead to an unnecessary capacity of surgeons, which should also be avoided. In the end, day capacity would be considered most optimal, but with the opportunity to use time-slots so planners can use the capacity more flexible if demand changes.

On *nurses roster level* changes should also be made on the shared ORs. A proposal could be that based on the two OP areas sharing an OR, each OP area supplies one OP nurse and one CRNA nurse to the OR, depending on the days the planners have decided to split between them. The OP area either provides the experienced nurses or the cross-trained nurses. In the long-term this distinction between being cross-trained or not is expected to go away as it will become a matter of which procedures a nurse can assist to and his/her experience in it. The creator of the rooster should include considerations on which ORs each nurse are trained in and consider rotation between the ORs to assure that nurses get both repetition and experience.

5.3 | How can the increased complexity be handled?

As the two points above point out, both the roster, the OT planning and the urgency levels need to be further supported by information technologies, which does not only visualize information, but help decision-making. The proposal itself would also benefit from decision support, as it is one thing to be able to make a good decision, but another thing to make it fast. The solutions needed might not be on the market yet. A potential software which could be used is for example the Centrea capacity module by Gettinge, which enables coordinators to see their capacity across

departments. As Centrea is Aalborg UH's current flow management system provider, Centrea could to be a good fit. In terms of competencies, it has not been possible to find many solutions focusing on the planning aspects of competencies. In general, most of these platforms seem to focus on education. Aalborg UH have, however, started a collaboration with the smaller IT-company named MyMedCards which have started developing competencies matrices, named MySkills, for the nurses to be used both educational and to coordinate resources in the daily planning. It is unknown if they be able to integrate their solution with both Centrea, the flow management system, and BookPlan, the planning and booking solution at Aalborg UH. A critical success factor for creating a more flexible workforce is definitely to assure the needed information technologies, as hospital planning is already complex, and flexible resources add complexity. The technologies to support this added complexity need to be ready.

5.4 | How to get nurses onboard?

Planners, coordinators and surgeons must all be involved in the proposal to achieve a successful implementation, but starting with the nurses, there may be things that can be done to ensure that most nurses agree with the concept. Learnings from other cases of flexible nurse workforces tells that education and training of nurses are essential for assuring nurses feel confident about being cross-trained [Lafontant et al., 2019; Platt et al., 2019]. Though most people need to feel some level of confidences in their skills, it can be argued that this is especially important for nurses. Hein have proposed that most nurses belong to the employee archetype called 'Primadonnas'. Primadonnas are motivated by existential factors, as they see their work as a 'calling'. This means that their motivation is controlled by a high desire to comply with their ideals and values. Therefore their work and identity tend to melt together, which means that a poor performance is a reflection of the fact that they do not live up to their ideal [Hein, 2019].

Due to 'primadonnas' respond to their own ideals above the management's ideas of what is important, they can be challenging to lead. For this reason two ideas are proposed 1)Support cross-training initiative with quality-focus to assure the quality will not reduce as a result, this will assure nurses that the cross-training will not compromise patient safety and 2) Make sure the proper learning is established and continuously maintained and improved, to assure nurses feel they can obtain high quality work.

All employees are not primadonnas and in these cases other incentives have to be made. Here economic incentives can be made for those who volunteer to be cross-trained. Some will also see the additional learning as an incentive to become cross-trained, again a reason to assure this training is made attractive. Alternatively cross-training can become a requirement for nurses who want to take on more administrative work, assuring that nurses performing administrative tasks are the ones who can be used most flexible, as they will be a buffer capacities the days they perform administrative tasks.

Concluding remark

To wrap-up this chapter, the feasibility of a flexible workforce at NAU, as well as its benefits as a solution towards higher patient throughput and resilience have been discussed. The proposal is expected to be a good solution towards higher throughput and resilience, but the performance of nurse and OR utilization, as well as team composition compliance rate should be monitored to assess if the expected benefits are taking place. In terms of the feasibility of flexibility workforce, it is difficult to state. The solution will however, be considered too complex, if a sufficient ICT able to be implemented and the acceptance of nurses could be supported by economic incentives, educational incentives, providing assessment quality continuously and potentially, be making cross-training a requirement for qualifying for administrative roles.

6 | Conclusion

Aalborg UH is expected to move into NAU in 2024. Here, the current OP areas will enter new communities, which are expected to work closer together. This report has focused on the second community, consisting of A-kir, TV-kir, Urology, and Gyn/Obs. On average, the OP areas only utilize 47% of the available capacity. Low utilization is expected to be partly caused by the a lack of resources with the right competences available, leading to patient cancellations. It is expected that creating a more flexible nurse workforce can help reduce the number of cancelled patients, and thereby increase utilization and patient throughput. A literature search suggests that a flexible workforce can help respond to demand variations and uncertainty as an alternative to the slack time and buffer capacity. Factors that influence the success of creating a flexible workforce are 1) The coordination policies to plan and allocate flexible workers, 2) The collaboration context in with flexible workers are used, 3) The ease of requiring and maintaining the flexible skills, and 4) The structural design of which workers are cross-trained in other skills.

A hypothesis is proposed *"flexibility in OT nurses is a feasible solution towards higher patient throughput and resilience"*. Three research questions answer the hypothesis.

The first research question was *'Which factors affect the feasibility of OT nurses to become cross-trained?'* and it was answered by the need for repetition, definition of skills, lack of standardization, the importance of experience, individual learning paths, and a screwed potential in which OP areas could use cross-trained nurses.

The second research question was *'How could Aalborg UH create a more flexible workforce for OT nurses at NAU?'*, exemplified by a road map of four stages. These stages were 1) Creating the data foundation, 2) Visualizing competencies and nurse availability, 3) Creating quality assurance of team composition and procedure repetition, and lastly, 4) Optimizing nurses' competencies to fit with the changes in demand.

The last research statement was *'Will a more flexible workforce at NAU be considered a feasible and beneficial solution towards higher patient throughput and resilience?'*. Here, the benefits enabled higher patient throughput and everyday resilience. Monitoring nurse and OR utilization, as well as team compliance rate should help indicate if these benefits are reached. In terms of feasibility, is the solution considered too complex if sufficient ICT is not implemented, but the Centrea capacity module by Gettinge and the MySkills module from MyMedCard could be some potential providers. It is suggested to that economic and educational incentives could be strategies to get the nurses onbroad. Alternatively is it suggested to make cross-training a requirement for qualifying for administrative roles

7 | Reflections

This chapter will provide some reflections on alternative directions the project could have taken, which could be considered for future research.

Defining skills using T-doc data

The initial goal was to identify which skills were needed in a procedure using data from the software T-doc, to extract which apparatus and machines were generally used in the different procedures. This information is assumed to be related to the different skills a nurse must have to perform a procedure; this would create a picture of what equipment and apparatus must be known before performing a procedure. The analysis could also create a picture of which skills are general and specialized, as well as a picture of the complexity of a procedure in case the equipment changes frequently. Unfortunately, the T-doc data were not yet available to track the procedure nor the OP area concerning the apparatus data. Alternatively, using nurses' training material to identify skills needed in procedures was considered, but these documents showed little consistency across specialisms and had significant differences in aggregation. The skills mentioned in procedures were a mixture of apparatus and familiarity with a procedure. The OP nurses in Gyn/Obs used a checklist of the procedures, whereas A-kir grouped procedures and other tasks into categories of procedures, administrative tasks, basic knowledge, and cleaning apparatus.

Exploring a flexible workforce in the day surgery community

The potential in cross-training based on the analysis may not be high enough to create enough value. Day surgery might have a higher potential, so if a pilot should be introduced, maybe day surgery should start. Thereby, the systems could be developed, and experience from the educational path could be gained. From here, the system can be scaled to the other communities and used. Here, their benefit might still not be high, but as cross-utilization between day surgery and community 2 would be visible, the benefit might be higher.

Looking at the process-oriented flexibility

As stated in the literature search 1.2, flexibility is many things. In this study, flexibility was considered between OT nurses, but flexibility could also be for the OT nurses to be able to assist in the pre- and postward when they are the bottleneck limiting surgeries. The same could be said for porters; if nurses wait for a porter to transport a patient either to or from the OR, the porter becomes the bottleneck. In this case, the nurses could transport the patients themselves, increasing flexibility. Testing the impact of the flexibility of the CRNA nurse and the porter could be a relatively easy project to pilot.

Simulating the benefit of a flexible workforce

A simulation was considered a way to evaluate the impact of a flexible workforce. A simulation would, however, require information on the nurses' rosters and the planned procedures, which were unavailable. If future students could access such information, it could be possible to estimate the need for flexible nurses based on the risk distributions of patient cancellation, employee absence, and acute patients. Such a simulation may also provide insights into how much buffer capacity is needed daily.

Estimating the initial flexible workforce design

The initial setup of a flexible workforce could be theorized, with some assumptions about which procedures will be moved to day surgery and which nurses can do what. The knowledge of which procedure could use cross-trained nurses could lead to estimations of what procedures each OR should have available. Based on this, it could also be possible to calculate how many nurses could be cross-trained. This can give insights on how many nurses can perform a procedure and how many procedures each can perform compared to today - thereby indicating if the flexible workforce makes a better coverage and if the nurses are required to learn fewer or more procedures?

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A | Cross-training matrix

	CRNA Answers						OP Answers					
A-kir	No	Circ.	Moni.	Both	Eith.	Com.	No	Scr.	Sco.	Both	Eith.	Com.
KUJD02		X				1)		X				1)
KJAH01		X	X		X		X					2)
KJKA21		X	X	X			X					3)
KJHA00		X	X	X			X					4)
KJAH00		X				2)		X				5)
KUJF32		X	X		X			X				
KJEA01		X	X	X				X				
KTJW99		X	X		X		X					6)
KUJK02	X							X	X	X		
BNPA92		X	X		X			X				7)
KJDF11		X						X				8)
KJFB47		X					X					9)
KJGA75		X	X		X			X				10)
KJFB31		X	X		X			X				
KUJF42		X	X		X			X				
KJDB10		X					X					
KJGB31	X							X				
KQBB10	X						X					11)
KJGB01	X						X					
KJCC10	X						X					12)
KJLC30	X							X				
KJFF27	X							X				
KJBC01	X											
KQAE10		X										13)
KJFB31	X							X				
KJGC01	X						X					14)

	CRNA Answers						OP Answers					
TV-kir	No	Circ.	Moni.	Both	Eith.	Com.	No	Scr.	Sco.	Both	Eith.	Com.
KGDC00		X	X		X	3)	X					
KGDB10		X	X		X	4)	X					
KUGC15	X							X				
KFNC10	X						X					15)
KQBB10		X	X		X	5)		X				
KGAA10		X	X		X	6)		X				
KPAF21	X						X					
KPEF10		X	X		X	7)	X					
KFMD10	X						X					16)
KPEH30		X	X		X	8)	X					
KPDG10	X						X					
KPWW99		X	X		X	9)		X				17)
KPBL20		X	X		X	10)		X				18)
KGAA31		X	X		X	11)	X					
KGDA11		X	X		X	12)	X					
KFWE00	X						X					
KFKB10	X						X					
KGEA00	X						X					19)
KPDQ10	X						X					20)
KGDB00		X	X		X	13)	X					
KPWE00	X						X					
KPEU81		X	X		X	14)						

	CRNA Answers						OP Answers					
Gyn/Obs	No	Circ.	Moni.	Both	Eith.	Com.	No	Scr.	Sco.	Both	Eith.	Com.
KMCA10		X	X	X				X				21)
KTLW99		X	X	X				X				22)
KJAH01		X	X	X				X				23)
KLCB25		X	X	X				X				24)
KLCH03		X	X	X				X	X	X		
KLCB28		X	X	X				X				25)
KLEF00		X	X	X				X				
KLEG10		X	X	X				X				
KLCD01		X	X	X			X					
KLEF96		X	X	X				X				
KLEF40		X	X	X				X				
KJAH00		X	X	X			X					
KLDC03		X	X	X			X					26)

	CRNA Answers						OP Answers					
Urology	No	Circ.	Moni.	Both	Eith.	Com.	No	Scr.	Sco.	Both	Eith.	Com.
KKCD32		X	X	X				X				27)
KKWW96		X	X	X				X				28)
KKBV02		X	X	X				X				
KKEC01		X	X	X			X					29)
KKBV05		X	X	X				X				
KKBE32		X	X	X				X				
KUKC05		X	X	X				X				
KKAE12		X	X	X				X				
KUKB05		X	X	X				X				
KQBB99		X	X	X				X				
KKAC01	X					15)	X					30)
KKCC01	X					16)	X					
KKDH70		X	X	X			X					31)
KUKC02		X	X	X				X				
KUKA05		X	X	X				X				
KKAE01		X	X	X			X					32)
KJAB00		X	X	X				X				
BJFZ45		X	X	X			X					33)

B | Cross-training comments

#	**CRNA comments**
1	Kan være mange ting. fx. en der bløder.
2	Det kan være frygtelig alvorlig eller ingenting.
3	Den modsatte skal være fagfaglig
4	Den modsatte skal være fagfaglig
5	Afkrydsning er sandt for de fleste indgreb, nogen vil ikke gå an.
6	Samme som kommentar 5
7	Samme som kommentar 5
8	Samme som kommentar 5
9	Samme som kommentar 5
10	Samme som kommentar 5
11	Samme som kommentar 5
12	Samme som kommentar 5
13	Vurderes til nej, da det er en robot operation
14	Vurderes til nej, da det er en robot operation

#	**OP comments**
1	Så længe operationen holder sig til gastroskopi, og den krydstrænet ikke er i vask. Edoskopiske kontrastundersøgelser kræver erfaring, og skal ske med jævne mellemrum.
2	Nogen er rigtig lette. Appendix kan alle hjælpe med.
3	De har kun de komplekse laktoskopier
4	Der er risiko for fistelsøgning, men det er oftest dem I dagtiden kan der udvikle sig. I vagten ville en krydstrænet vask med erfaring gå an.
5	Ikke svært alene, men kan kræver rigtig mange tanker pga. kompleksitet af indgreb. Baseret på det enkelte ingreb kan der potentielt bruges en anden.
6	Hvis det er sårskift kan alle gøre dette. Men dette er en paraply gruppe.
7	Kirugen vil evt. ikke kunne lide hvordan andre sygeplejerske udfører arbejdet. Samarbejdsproblemer.
8	Her er der ingen overraskelser. Igen, kirugen vil nok have en anden mening.
9	Kræver at den krydstrænet får det i hænderne ofte nok. (min. Hver 14 dage, gerne en gang om ugen)
10	Kaldes TEM, når den først er i gang er det ingenting. Instrumentaret er svært.
11	Har varierende sværhed
12	T kiruger indenover. Halv T/A på robot.
13	Den laver OP ikke.
14	udføres på robot
15	Kræver ugentlig vedligeholdelse og er svær internt.
16	Samme kommentar som kommenatar 15
17	Ikke så akutte, den ligger på grænsen på umulig.
18	Kirugen vil ikke være enig.
19	Måske kun én om måned. Kan risikere at være dødeligt.
20	dette er en røngent hybrid
21	kan skal kunnes 100%, da den gøres i vagten. Der er en del i vagten.
22	Hvis det er rød blødning, så er det det samme som kejsersnit.
23	ville osse være 1'er
24	Der er for få, det vil kunne læres, men ikke kunne vedligholdes
25	Urologiske kan hjælpe ved denne her
26	laves ikke længere - flyttet i ambulation. Få indgreb tilbage.
27	Alle bliver krydstrænet - i vagten
28	På sigt kan der være operationstyper i urologien som A på sigt vil være bedre til. Fx akut arbejde
29	Ikke nok, meget kompleks i udførsel.
30	Nyre operation på robot, et internt speciale
31	hver 14 dag er der én stue med to operationer.
32	de er sjældne
33	udføres ikke særlig ofte

C | Descriptions of procedures

Procedure ID and description
KGDC00 (Lobektomi på lunge)
KGDB10 (Kileresektion af lunge)
KUGC15 (Fleksibel bronkoskopi m. biopsi af bronkie el. trakea)
KFNC10 (Aortokoronar byp. m. enkelt distal anastom.)
KQBB10 (Skiftning af større sår på truncus)
KGAA10 (Indlæggelse af pleuradræn)
KPAF21 (Trombendarterektomi i a. carotis interna)
KPEF10 (Trombendarterektomi i a. femoralis communis)
KFMD10 (Indsættelse af biologisk aortaklapprotese)
KPEH30 (Byp. fra a. femor. til a. poplit. neden for knæet)
KPDG10 (Aneurismeoperation på infrarenale aorta)
KPWW99 (An. reop. eft. op. på perif. kar/lymfesyst)
KPBL20 (Anlæggelse af av-fistel fra a. brachialis)
KGAA31 (Torakoskopi)
KGDA11 (Torakoskopisk biopsi af lunge)
KFWE00 (Reop for dyb blødn. eft. op. på hjerte/store intrator. kar)
KFKB10 (Annuloplastik v. mitralklapinsuff. m. anv. af ring)
KGEA00 (Mediastinoskopi)
KPDQ10 (Indsættelse af endoprotese i infrarenale aorta)
KGDB00 (Resektion af bulla pulmonis)
KPWE00 (Reop. for dyb blødn. eft. op. på perif. kar/lymfesyst)
KMCA10B (Kejsersnit i isthmus uteri udført planlagt før fødsel)
KTLW99 (Anden mindre gynækologisk procedure)
KJAH01 (Laparoskopi)
KLCB25 (Hysteroskopisk eXcision af patologisk væv i uterus)
KLCH03 (Provokeret abort ved vakuumaspiration)
KLCB28 (Hysteroskopisk eXcision af endometrie)
KLEF00 (Forreste kolporafi)
KLEG10 (Vaginal uretrocystopeksi med slynge)
KLCD01 (Total laparoskopisk hysterektomi)
KLEF96 (Anden operation for prolaps el. descensus)
KLEF40 (Vaginal operation for enterocele)
KJAH00 (Eksplorativ laparotomi)
KLDC03 (Konisation af livmoderhals m. diatermi el. laser)

Procedure ID and description
KKCD32 (Transuretral resektion af patologisk væv i urinblære (TUR-B))
KKWW96 (Anden reoperation eft. urologisk operation)
KKBV02 (Translum. endoskopisk indsættelse af ureterstent)
KKEC01 (Perkut. endoskopisk radikal prostatektomi)
KKBV05 (Translum. endoskopisk skiftning af ureterstent)
KKBE32 (Translum. endoskopisk litotripsi af ureterkonkrement)
KUKC05 (Cystoskopi med biopsi)
KKAE12 (Transluminal endoskopisk pyelolitotripsi)
KUKB05 (Retrograd ureteroskopi med biopsi)
KQBB99 (Anden sårbehandling på truncus)
KKAC01 (Perkutan endoskopisk nefrektomi)
KKCC01 (Perkutan endoskopisk cystektomi)
KKDH70 (Plastik for urethrastriktur)
KUKC02 (Cystoskopi)
KUKA05 (Retrograd ureteronefroskopi med biopsi)
KKAE01 (Perkutan endoskopisk nefrolitotomi)
KJAB00 (Operation for ingvinalhernie)
BJFZ45 (Anlæggelse af peritonaldialysekateter)
KUJD02 (Gastroskopi)
KJAH01 (Laparoskopi)
KJKA21 (Laparoskopisk kolecystektomi)
KJHA00A (Incision af perianalabsces)
KJAH00 (Eksplorativ laparotomi)
KUJF32 (Koloskopi)
KJEA01 (Laparoskopisk appendektomi)
KTJW99 (Anden mindre gastroenterologisk operation)
KUJK02 (Endoskopisk retrograd kolangiopankreatikografi (ERCP))
BNPA92 (Sårbehandling med vakuum)
KJDF11 (Laparoskopisk gastric bypass)
KJFB47 (Laparoskopisk resektion af colon sigmoideum)
KJGA75 (Rektoskopisk mikrokirugisk eXcis. af pat. væv i endetarm)
KJFB31 (Laparoskopisk højresidig hemikolektomi)
KUJF42 (Fleksibel sigmoideoskopi)
KJDB10B (Perkutan endoskopisk gastrostomi (PEG))
KJGB31 (Laparoskopisk og perineal eXcision af endetarm)
KQBB10 (Skiftning af større sår på truncus)
KJGB01 (Laparoskopisk resektion af endetarm)
KJCC10 (Transtorakal øsofagusresektion u. interposition)
KJLC30 (Pankreatoduodenektomi)
KJFF27 (Laparoskopisk sigmoideostomi)
KJBC01 (Laparoskopisk gastroøsofageal antirefluksoperation)
KQAE10 (EXcis. af pat. væv i hud/underhud på hoved/hals)
KJFB31A (Laparoskopisk udvidet højresidig hemikolektomi)
KJGC01 (Laparoskopisk rektopeksi)

D | Qualitative data information

D.1 | Gynecology- and obstetric surgery and urology

There are 15 OP nurses in the gynecology and obstetric specialism (Gyn/Obs). Within these are eleven nurses specially trained in the robot surgery *'Perkutan endoscopist cystectomy'*. Everyone in Gyn/Obs is cross-trained in selected procedures from the Urology specialism, just as all OP nurses in Urology are cross-trained in selected Gyn/Obs procedures. In Urology, is there 18 nurses, whereas seven nurses are trained in *'Perkutan endoscopist cystectomy'*, just like the nurses from Gyn/Obs. Besides this, are 16 nurses trained in the robot surgery *'Perkutan endoscopist nefrektomi'* and six trained in *'Perkut. endoscopist radical prostatectomy'*. This last procedure has a high volume, but the complexity of the procedure means that sufficient repetition is impossible if everyone should be able to perform the procedure.

After interviewing an OP nurse from Urology, some psychological and structural barriers were found. For example, it was mentioned that Urology and Gyn/Obs both assist robot surgeries, but they do it differently. OP nurses from Urology would change the robot's equipment under surgery, whereas the surgeon performed this task with Gyn/Obs OP nurses. Another example related to the other specialisms was that through most specialisms used, x-ray and diatemi, are the settings and use different cross the specialisms. The conclusion here was, that just knowing the equipment was not enough. The same was said for the procedure *'laparoscopy'*, as both the abdominal specialism (A-kir) and Urology perform these, but A-kir's procedures are more complex than those performed in Urology, so A-kir might help Urology, but not the other way around. Another worry, which multiple nurses stated, was that they would water out their competencies if they had to learn the procedures in other specialisms. The nurse coordinator mentioned that most nurses already felt stretched thin and would rather become better at what they can than learn new things.

On the positive side, did the nurse manager mention that Urology expects to find some symbiosis with A-kir at NAU, as they both have a fair amount of robot surgeries in which fewer nurses are trained. They also expected that A-kir would be more qualified to perform some procedures in Urology in the future, as the procedure *'other re-operation after urology surgery'*. Through their skepticism about cross-training, it is mentioned that A-kir and Urology are more alike than other specialisms - even Gyn/Obs, as they are currently paired with. A barrier to being cross-trained with A-kir is the size of the specialisms. Compared to OP, nurses in Urology are A-kir's nurses' education twice as long because of the variance in procedures.

The CRNA nurses in Gyn/Obs and Urology are considered one workforce, as everyone can assist with all procedures. They are 25 nurses in total. These CRNA nurses also specialize in children, a specialism that will be moved to day surgery at NAU. The coordinator seemed optimized about the potential in identifying areas of cross-training across specialisms, especially between Urology and A-kir.

D.2 | Abdominal and gastronome surgery

In the Abdominal and gastronome surgery (A-kir), there are 28 OP nurses. After following and meeting with an OP nurse from A-kir, some observations were made. For example, do a minimum of one OP nurse from A-kir assist when the specialisms of lung, heart, and vascular surgery (TV-kir) perform gastroscopic surgery to handle the equipment, as TV-kir does not regularly have this procedure. A-kir cannot take over the procedure; if the surgery changes, only TV-kir is qualified to assist. A-kir has different tubes as equipment for surgeries like this and many others, as the sterility of the tubes is crucial for a successful surgery, therefore, does A-kir also always have one nurse on duty with the main task of sterilizing the tubes, which is found too complex for the general sterilization personnel. Some observations and answers are seen as barriers to cross-training as the OP nurse mentioned that the ability to use cross-trained nurses would be dependable on the nurse's experience currently in the OR, which could be a limit for some specialisms, which does not have many nurses with +5 years experience. Another barrier observed in the OR was that doctors did not always fill the patient file correctly. This meant that information on the planned patient placement was not available, which made the placement dependent on tacit knowledge and nursing experience. Some surgeons also wanted different equipment packages for the same procedures, making the correct decision dependent on nurse experience. The OP nurse also mentioned how the machines might be used in other specialisms, but the settings and generation differed across specialisms, just as the OP nurse in Urology mentioned. Opposite TV-kir, Gyn/Obs, and Urology would A-kir rather have a cross-trained nurse as the scrub nurse than the scout nurse. Responsibility differences across specialisms caused this decision. An A-kir scout nurse is often the OR coordinator and therefore has to take calls, find equipment, and coordinate with the outside.

When discussing the procedures, a problem arises. The procedural codes classification and the actual surgery can be very different. As with the *'explorative laparotomy'*, where the OP nurse from A-kir said the following: *"The procedure is not necessarily hard, but it requires many thoughts because of the complexity of the procedure. It may or may not be possible to use a cross-trained nurse based on the individual case"*. The same is the case with procedure *'Incision of perianalabces'*, where the nurse's statement was *"The procedure has a risk of fistula-search, especially those scheduled in the day-time tend to change character"*. This means that the procedure codes themselves can take on much variation.

The CRNA nurses of A-kir are around 29 nurses. The nurses grouped with the specialism ear, nose, and throat surgery (ØNH) as they are cross-trained. The cross-training is not as extensive as for Gyn/Obs and Urology but is mainly used during night shifts or with a personal shortage. As a combined group, there are 38 nurses. Some procedures could be performed with a cross-trained nurse from another specialism. The head of CRNA nurses from A/ØNH underlined the importance of knowing where things are placed in boxes and drawers when using cross-trained nurses. Here she had experience making flashcards and other tools to help A-kir nurses find their way into the facilities of ØNH. She also confirmed that cross-training

between Urology and A-kir would make much sense, as the cross-training with ØNH made little sense in terms of competencies, as the specialisms are very different. In most cases, the cross-trained nurse should take on the role of the circulating nurse.

D.3 | Thorax and vascular surgery

In TV-kir, there is 26 OP nurses, but three specializations are identified as only four can perform MIX-surgery, five TAVI-surgery, and three AFA-surgery. The head of TV-kir's OP nurses stated that both education and repetition were needed before a nurse could perform a procedure, and because some procedures have much variance, repetition is even more necessary to get familiar with the procedure and its variations. Her estimate of repetition would be to perform a procedure at least weekly, whereas other nurses who discussed repetition estimated every second week. This could show that TV-kir's procedures are more complex than other specialisms'. TV-kir differs from other specialisms, as they sometimes need three OP nurses instead of two because of the complexity of the procedure.

In TV-kir there are 17 CRNA nurses. These nurses are thoroughly cross-trained with the specialism mamma plastic, who are to be placed in community two at NAU. The specialisms are currently scheduled together, and the nurses are used in both functions daily.

E | Quantitative data validation

As this project has taken place, some new software has been enrolled at Aalborg UH. The enrollment has meant that the Business Intelligence department, which has assessed and monitored data at Aalborg UH has been closed for data requests. Their lack of availability has resulted in limited access to quantitative data. Some data have, however, been possible to extract. These are timestamp data on the operating theater and cancellation data. This section will go through the data quality of each of the data sets. The COVID-19 pandemic does affect most of the available data in an immeasurable way. The pandemic must be considered with the data, as the data is used to evaluate the performance, which might be significantly different in a post-covid time.

E.1 | OT time-stamp data

The data 'operation theater time stamp data' contains values from the 30/12/2019 to 24/03/2022 and comprises of the information below, where the text in the citation marks are an example value. The data is extracted through access to the platform Qlik.dk, which is integrated with the Centrea. Centrea is Aalborg UH's flow management software, which enables nurses to log timestamp within the OR:

- Date: "01/01/2022"
- OP area: "TV"
- Procedure: "KUJD02 (Gastroskopi)"
- Description: "AKUT-UJD02-Gastroskopi-Alb-Mave og Tarmkir-OP-8001121"
- Room: "AaCe02 (Stue 02 Syd)"
- Priority: "Acute"
- CaseID: "10326366"
- RoomStart: "08.06.00"
- KnifeStart: "09.22.00"
- KnifeEnd: "13.25.00"
- RoomEnd: "13.40.00"

While examining the data, it became clear that multiple timestamps were missing, so to assess the data quality, an appropriate number of dummies was created to count missing data points. The conclusion was that out of 25.791 data points was, 192 missing the timestamp 'RoomStart', 809 missing 'RoomEnd', 529 missing 'KnifeStart', and 614 missing 'KnifeEnd'. One thousand one hundred twenty-five data points miss one or more timestamps. This response to 4.4% of the data points being incomplete.

By examining at the complete cases can a number of new variables be created. These are:

- *Preparation time:* Caculated by sustracting 'KnifeStart' from 'RoomStart'
- *Surgery time:* Caculated by substracting 'KnifeStart' from 'KnifeEnd'

- *Awakening time:* Caculated by substracting 'KnifeEnd' from 'RoomEnd'
- *Shift time:* Calculated by substracting 'RoomEnd' of the previous surgery in the OR from 'RoomStart'

These processes have a high variation in time; some are even too high to be considered typical process outliers and are instead seen as data errors. It was again possible to find the number of data errors based on several dummies. Here, 1026 data points had a preparation time below one minute, or above three hours, 1437 data points had a surgery time below one minute or above five hours, 1684 data points had an awakening time below one minute or above three hours, and 1480 data points had a shift duration below one minute. In total, 17.8% of the calculated variables consider one or more faulty values.

In total are 22% of the dataset values either missing or faulty. This percentage is relatively high and too large to remove from the dataset. The report has used and excluded missing and faulty values based on the goal of the individual statistics. For example, when reporting on the number of cases per year, all data cases are included, whereas when reporting on the average surgery duration, both missing and faulty cases are excluded, as these could distort the average.

The data only consists of two full years, which is not a lot, especially with both years being affected by covid-19. In general, 2021 data is used as an estimate for today because of the assumption that it is less distorted by covid-19.

E.2 | OT cancellation data

The data on patient cancellations was extracted from the software BookPlan using TableExtractor.com, which transforms tables in picture formats into table formats. The general accuracy of this procedure was between 85-95% based on the homepage's assessment. Numbers were found as entirely accurate, whereas most strings needed manual correction, expectantly because of the danish language and letters. The data comprises 4326 data points and covers the period 02/01/2019 to 31/3/2022. The information included in the dataset was:

- CaseID: "30825048"
- SKS-code: "KKBE32"
- Specialisms: "Urologi"
- Description: "J9-URS-Stenfjernelse-ikkenr pgarøntgen-Alb-URO-OP-80013370-130 min"
- About: "U09 STENFJ likke nr. pga. rtg"
- Appointment Date: "01.03.2021"
- Appointment Time: "13:45"
- Reason for cancellation: "Aflyst grundet patientens tilstand"
- ReasonID: "ZPP32"
- Reason SKS-code text: "Procedure aflyst, pt's tilstand max. 1 dag før planlagt procedure"
- Reason comment: "Sten afgået"

No significant data errors were found, but some caution must be used regarding the categorization. After reading through the 'reason comments' and discussing the use of cancellation codes with users of the system, there is reason to expect that employees are not consistent in using the categories. The inconsistency is understandable, as many cause classifications overlap, which decreases the usability of this data set's cause classification.

F | Qualitative data respondents

The feedback sessions performed in the first and only iteration are illustrated in table F.1

Interviewee	Specialism	Function	Date
Other2		Quality Consultant	14th of June 2022
Nurse11	A-kir	OP	16th of June 2022
Nurse7	TV-kir	CRNA	17th of June 2022

Table F.1. Interviewee in first iteration feedback on road-map

The structured interview sessions performed are illustrated in table F.2

Interviewee	Specialism	Function	Date
Nurse6	TV-kir	OP	5th of April 2022
Nurse7	TV-kir	CRNA	26th of April 2022
Nurse8	Urology & Gyn/Obs	OP	2nd of April 2022
Nurse9	Urology & Gyn/Obs	CRNA	9th of April 2022
Nurse5	A-kir	OP	27th of May 2022
Nurse10	A-kir	CRNA	28th of May 2022

Table F.2. Interviewee to estimate cross-training potential

In table F.3 is a overview of the field observations/semi-structured interviews.

Following	Specialism	Function	Date
Nurse1	TV-kir	CRNA	8th of February 2022
Nurse2	TV-kir	CRNA	15th of February 2022
Nurse3	TV-kir	CRNA	16th of February 2022
Other1	TV-kir	Planner	17th of Februay 2022
Nurse4	Urology & Gyn/Obs	OP Date unknown	
Nurse5	A-kir	OP	Date unknown

Table F.3. Employees observed and interviewed to describe processes

G | Cancellations causes

Cancellations causes 2021	TV	A	Gyn/Obs	Uro	Total
aflyst pga kapacitetsproblemer på operationsgangen	53	80	62	201	396
aflyst, pt's afbud min. 2 dage før planlagt procedure	29	71	141	130	371
aflyst pga. ændret behandingsbehov	59	29	23	81	192
aflyst pga. COVID-19	4	4	41	96	145
aflyst pga sygehuset max 1 dag før planlagt procedure	21	91	6	21	139
aflyst, pt's tilstand max. 1 dag før planlagt procedure	26	12	31	57	126
aflyst pga. kapacitetsproblemer i sengeafdelingen	74	20	1	12	107
aflyst, pt's afbud max. 1 dag før planlagt procedure	5	15	33	27	80
aflyst af rekvirent	5	10	8	55	78
aflyst pga sygehuset min 2 dage før planlagt procedure	22	31	6	1	60
fremrykket til tidligere dato	11	12	8	25	56
afbr. pga. perop. tilstand. el tilst. u. procedure	12	20	1	6	39
aflyst pga. patientens udeblivelse	3	5	9	18	35
aflyst pga. patientens manglende forberedelse	8	12	1	14	35
aflyst, pt's tilstand min. 2 dage før planlagt procedure	1	6	10	15	32
aflyst pga. omvisitering	0	3	4	22	29
aflyst pga manglende intensiv kapacitet max 14d før planlagt procedure	20	3	4		27
afbrudt efter patientens ønske	3	20	2	1	26
afbrudt af personalemæssige årsager	4	1	12	8	25
aflyst af sygehuset pga. indlæggelse på anden afdeling	9	3		12	24
aflyst, pga. patientens død	1	4		10	15
afbrudt pga. tekniske problemer med udstyr	1	4		4	9
aflyst pga arbejdsnedsættelse på sygehus min 15 dage før planlagt	3	6			9
aflyst af sygehuset pga. indlæggelse på egen afddeling	3	2			5
aflyst pga manglende postoperative resourcer max. 14d før planlagt procedure	1	1			2
aflyst pga. forhold på assistende afdeling max. 14 dage før planlagt procedure	0		1	1	2
aflyst, sygehuset min. 15d før planlagte procedure	1	1			2

H | Cross training calculations

	A-kir	Gyn/Obs	TV-kir	Urology	Total
Total surgeries 2021	**4880**	**3593**	**2083**	**3300**	13856
CRNA = 1	860	0	813	0	1673
CRNA = 2	96	2617	0	2247	4960
CRNA = 1 | 2	956	2617	813	2247	6633
% CRNA = 1 | 2	**20%**	**73%**	**39%**	**68%**	**48%**
OP = 1	777	1848	296	1875	4796
OP = 2	4	256	0	0	260
OP = 1 | 2	781	2104	296	1875	5056
% OP = 1 | 2	**16%**	**59%**	**14%**	**57%**	**36%**

Table H.1. The table shows the number of surgeries which could have used either one or two cross trained nurses for both OP- and CRNA nurses and combined. The "=1" refers to one cross-trained nurse and "=2" refers to two cross-trained nurses