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The development of a decision-support tool for the performance optimisation of the operating room

Creating a holistic view of the operating room performance for the healthcare professionals by defining the objectives and assessment criteria of optimisation on the performance of the operating room

MSc. Biomedical Engineering & MSc. Science Education and Communication, Communication Design for Innovation
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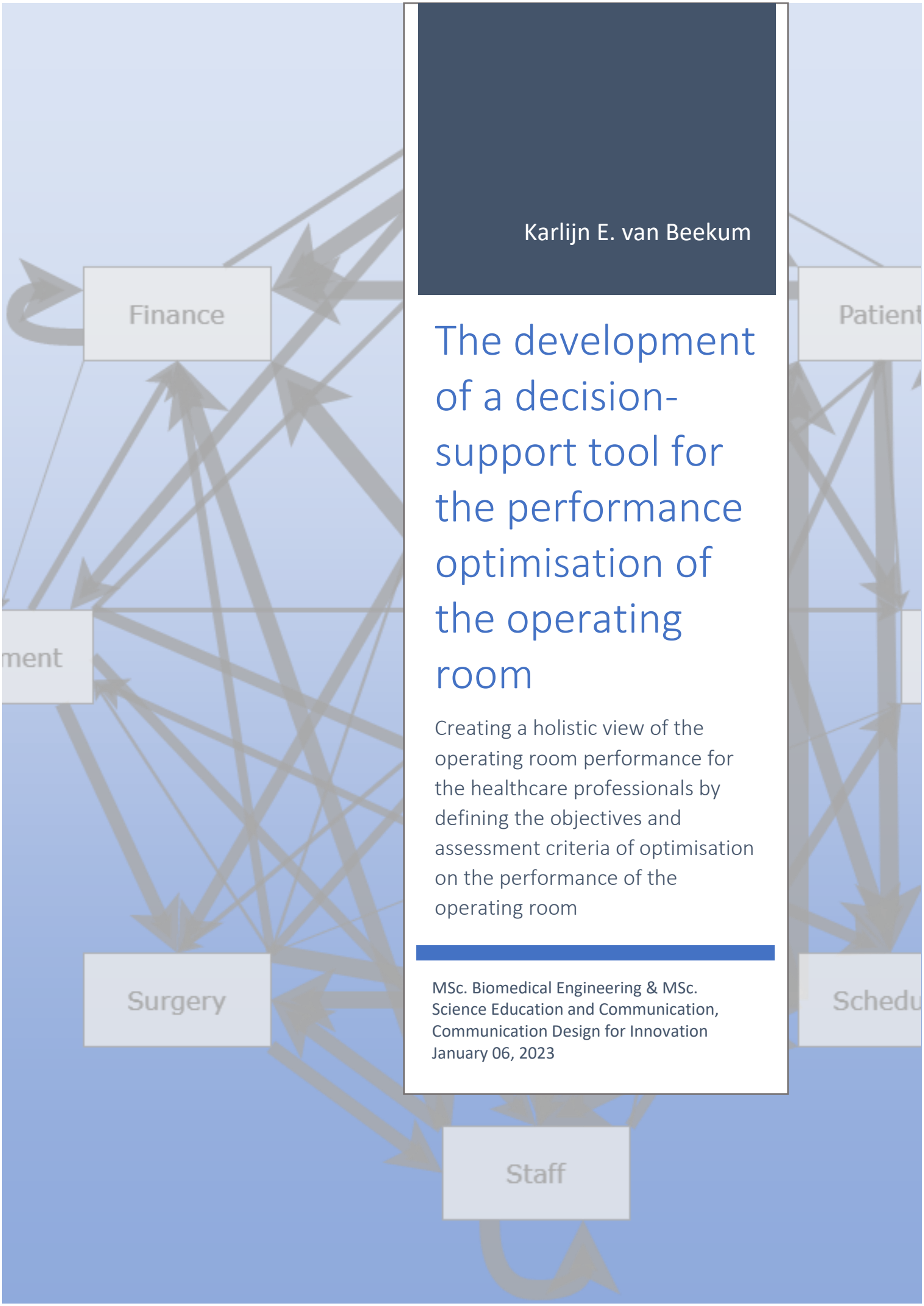

The development of a decision-support tool for the performance optimisation of the operating room

Creating a holistic view of the operating room performance for the healthcare professionals by defining the objectives and assessment criteria of optimisation on the performance of the operating room

By

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“A good decision is based on knowledge and not on numbers”

Plato

[Original in Ancient Greek: *“Μια καλή απόφαση βασίζεται στη γνώση και όχι στους αριθμούς”*]

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Preface

In front of you lies my master thesis about designing a tool that supports the decision-making on optimisation in the operating room (OR). This is the final assignment for the graduation of the master's Biomedical Engineering and master's Communication Design for Innovation at the University of Technology Delft. These studies satisfy me with a combination between the medical field, engineering and the society, what I missed in my bachelors and would have missed by doing one master's.

The misunderstanding and collaboration between biomedical engineers and medical physicians illustrate the necessity of communication, and therefore the connection between technique, healthcare and communication. Multidisciplinary collaborations could lead to improvements in the healthcare by more creative and out-of-the-box discoveries, and therefore aiming for the best (solutions). An expert solely can create amazing things; however, it does not matter how great the idea is, you always need support from the society to implement an idea. A multidisciplinary teamwork helps us creating more support for innovation. Therefore, the combination of the two studies helped me approaching problems from multiple perspectives and discovering more about the relation between research and society. It is enjoyable to work with people from multiple disciplines, and they thought me a lot of things (not only study related).

Since everybody deserves the best care possible and healthcare is and probably will always be (one of) my field of interest, I would love to get involved in optimising the healthcare. Surprisingly, there is not a widely applied tool that supports the decision-making on optimisations in the OR, even though this could save time, money and effort for many healthcare professionals. A decision-support tool could help us optimising the OR and the healthcare, as long as we work together, because I believe everything will work-out better with a multidisciplinary team. My internships and this thesis are my first baby-steps to reach the best healthcare by considering all the perspectives. During my thesis, I was given time and space to optimise myself as well, therefore I am super grateful to my supervisors, Anneke, Eva, John and Steven. Of course, I am also grateful for all their helpful feedback and support throughout this thesis.

My appreciation to my friends and family is indescribable. Last two years have been a rollercoaster, with ups and downs. Therefore, I am thankful for all the people that supported me and stayed with me. Also thank you, for maintaining my social life, with amazing drinks, deep conversations, delicious dinners, demanding football training sessions, frivolous chats, relaxing walks and relevant meetings. There are so many of you (and I am also afraid to forget someone), that I am not going to call names, but you know that I am talking about you and that I appreciate you so much!

Karlijn E. van Beekum
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Executive summary

The operating rooms (ORs) are an essential part of the hospitals, for among others the performance of the surgeries (Bovim et al., 2020; Kheiri et al., 2021) and their share in the hospital's revenue (Erekat et al., 2020; Makboul et al., 2022; Naderi et al., 2021; Zhang et al., 2020; Zhang et al., 2021). Since the medical world is in constant evolution (Chasseigne et al., 2020) and optimising the OR is a hot research topic in the whole (prosperous) world (Britt et al., 2021; Chasseigne et al., 2020; M'Hallah & Visintin, 2019; Sagnol, 2018), almost half of the innovations of the medical technology sector is focused on the ORs (Schouten, 2021). These innovations are necessary due to the regulations for the quality of care and the restrictions on the budget of hospitals and laws (Zhang et al., 2020; Zhang et al., 2021). Due to the complexity and the high number of innovations for the OR, it is necessary to choose between the several aspects and innovations, indicating that healthcare professionals (HCPs) should decide which optimisation is worth the money, time and effort to invest. These decisions are aiming to optimise the OR, a good implementation and a sustainable decision (Morgan & Angelos, 2022). Currently the decisions are influenced by the HCPs interpersonal relations and personal experience (Iacopino, 2018). Decision-making requires a mutual vision (Littlejohn et al., 2017) and should be based on evidence (Turner et al., 2017). To improve the well-informed decision-making, the aim of this study is to develop a decision-support tool for healthcare professionals that guides the selection of objectives and assessment criteria for performance optimisation of the OR and accounts for the impact of an optimisation on the total system.

The main research question is: "*How can a decision-support tool for optimisation in the operating room help a healthcare professional to select the objectives and the assessment criteria for performance optimisation of the operating room and the optimisation impact?"*. The evidence for the tool consists of the objectives, the assessment criteria and the causalities that express the impact. Hereby, the definition of the objectives of the optimisation states the purpose of the optimisation of the OR performance and the assessment criteria (metric) to quantify (the optimisation of) the performance of the OR. The objectives en assessment criteria (i.e. "metrics") are classified in general levels ("factor") and more specific levels ("characteristics"). Based on an extensive literature study (84 articles), this study found 14 objective factors and 19 objective characteristics, that express the objectives of the optimisation of the performance of the OR. Next to that, there are found 133 combinations between metric factors and metric characteristics, with 70 types of metric factors and 42 metric characteristics. In total 223 relations between the objectives and the metrics have been found, taking in account the objective and metric combination. It can be concluded that there is a high heterogeneous perspective on the objectives of the optimisation of the performance of the OR and the criteria of assessing the quantification of (the optimisation of) the OR performance, which makes it harder to create a mutual vision on the OR performance. To understand the impact of an optimisation on the OR performance, 56 articles have been studied to define causal relations between minimal two metrics. There are 42 metrics found with 253 causal relations, out of 56 articles. These causalities can be generalised into eight general metrics resulting with 51 general relations. Meaning that optimisations are most likely to impact other metrics, and therefore indirectly to (the optimisation of) the performance of the OR.

Due to the high heterogeneity in the perspectives of the objective and the metric of the optimisation of the OR performance, the causal relations between all the aspects and the complexity of the OR (Van Beekum, 2022), many aspects and a lot of information should be considered while decision-making. Besides that, the influences of the optimisation on the total performance of the OR are often unknown (Leinonen et al., 2008), and mapping the impact of an optimisation is a step that is often skipped in the decision-making process (Guo, 2020). The

perspectives of the HCPs are important, since they have the knowledge and the experience of the work setting. However, currently the professionals often focus on the metric and the desired result, without taking in account all the impacts (Leinonen et al., 2008) and take decisions based on personal experience. For a successful implementation of an optimisation, a mutual vision and support are required (Littlejohn et al., 2017). To achieve a mutual vision, a holistic view and consider all the perspectives, including the impact of optimisations, the HCPs should all share their perspectives on the objectives and the situation should be considered in its whole (Leinonen et al., 2008; Littlejohn et al., 2017). Therefore, the decision-making process could benefit of a decision-support tool, with as design aim: *"Designing a support tool that enables and standardised the decision-making process of HCPs on optimisation for the OR by providing a holistic view of the performance objective and its metrics"*. The three main design requirements are: Availability, Insight in impact and User-friendly, therefore the tool has to be easily applicable in several situation and by several HCPs and provide correct information for the decisions.

In this study a new tool is developed, namely the Performance Operating Room Counselling (PORC-)tool. This tool provides a holistic view of the OR performance (optimisation), to support a conversation about the perspectives on objectives and the metrics and stimulate a clarification of the objectives and methods for the optimisation. This enhances to share perspectives, which could lead to a mutual vision (Littlejohn et al., 2017). Therefore, creating a holistic view, causing HCPs to think about their objectives for the OR, how this could be achieved, and sharing (different) perspectives on the objectives or assessing criteria, contributes to a well-informed decision on the OR performance and evaluate options by indicating the (in)direct impact of an optimisation on the OR. The tool is based on the concepts flowchart, matrix table and Microsoft Excel. The matrix table provides an overview of the objectives, the assessing criteria, relations and causalities of the OR performance, the flowchart guides the HCPs through the steps and Excel is the running-programme. The PORC-tool consists of an Excel file, a brochure and a manual with a more elaborated version of the functionality and the steps. The PORC-tool provides a clear and structural overview with evidence, to gather information more easily, provides multiple perspectives on the OR performance and supports to gather more insight into the OR organisation and goals before the decision-making of the HCP. Therefore, this tool can accommodate the HCPs to better align and standardise the process and outcomes with the values, needs and expectations, to accelerate the constructive decision-making, and creates a simple opportunity for multidisciplinary learning. This tool can also be used during an implementation or a design process, to validate if the project is still on the desired track or if the HCPs are still on the same page.

The holistic view, created in the PORC-tool, is based on the objectives and the assessment criteria of the OR performance optimisation. The perspectives and opinions of stakeholders in practice are not considered. Co-design and multidisciplinary collaboration improve the results of studies (Leinonen et al., 2008; Sanders, 2008), therefore the PORC-tool should be validated in practice and the functionality should be approved by HCPs. In the future, the tool can also be extended on perspectives, field of interest, aesthetics and functionality.

To conclude, the answer to the main research question is that the HCPs should be facilitated to consider the whole complex system in their decision-making process. There are many perspectives on the objectives and metrics of the OR performance optimisation clarified, and relations between the objectives and metrics discovered, which is considered as evidence. Therefore, a tool that clarifies the holistic view facilitates the HCP to take a well-informed decisions. The PORC-tool supports decision-making based on a holistic view by presenting a list of the relations between objectives and metrics and a list of the impact of metrics on each

other. The PORC-tool supports starting the conversation on the perspectives on the objectives and metrics to create a mutual vision, considering the created holistic view of the OR performance. Besides that, it provides evidence for decision-making and supports the HCPs with structure and information for the decision-making process.

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List of abbreviations

Abbreviation	Meaning	Page[1]
BME	Biomedical Engineering	64
bpm	Beats per minute	26
CDI	Communication Design for Innovation	64
CRNA	Certified registered nurse anaesthetists	9
HCP	Healthcare professional	1
ICU	Intensive care unit	1
LUMC	Leiden University Medical Centre	8
MAYO	Maniacal All Yaoi Organization	8
MCDA	Multiple criteria decision analysis	41
mL	Millilitre	26
mmHg	Millimetres of mercury	26
MRQ	Main research question	3
n	Number (#)	11
OR	Operating room	1
PACU	Post Anaesthesia Care Unit	8
PMI	Plus, Minus, Interesting	41
PORC	Performance Operating Room Counselling	49
SRQ	Sub research question	3
VAC	Value Analysis Committee	10
WHO	World Health Organisation	1

[1] First-mentioned on this page.

Glossary

Description	Definition[1]	Page[2]
Causality	The relation between cause-metric and result-metric, in this study in the metrics.	4
Characteristic[3]	The specification of the general level of the objectives and/or metrics.	18
Code	The words that describe and represent the themes of the terms, written with a capital, which can be an objective or metric and factor or characteristic.	17
Combination[3]	The relation between the factor and the characteristics of the objectives and/or metrics.	18
Critical node	The aspect of the current situation that causes the problems.	4
Excel	Excel is a Microsoft 365 spreadsheet-programme focussing on calculating and data analysing.	17
Factor[3]	The general level of the objectives and/or metrics.	18
Healthcare professional	Staff that gathers information of the medical OR for a hospital or university research, including medical staff, scientist and hospital management.	1
Holistic view	The view of (the optimisation of) the OR performance concerning the complete system.	37
Innovation	All kind of optimisations that improve the OR by among others the technique, strategy, equipment, design, analysis and/or model.	1
Metric	The assessment criteria to measure the optimisation of the performance of the OR.	3
Operating room	A room in a medical hospital where surgeries are performed.	1
Performance of the OR	The functioning in/of the OR to reach the goals of a sufficient quality.	2
Phrase	The sentence that is marked in the scientifical articles, mostly explaining the purpose of the OR, the goal of the innovation in the OR, and the methods to quantify the performance optimisation of each article.	17
Terms	The level of specification for the optimisation, namely objective factor, objective characteristic, metric factor, metric characteristic and unit.	17
Unit	The determinate quantity that expresses a standard of measurement.	22

[1] The definition used in this study.

[2] First-mentioned on this page.

[3] Combined with objective or metric, indicating the level of the terms.

Term	Definition[1]	Page[2]
Accessibility	The ability to obtain or use healthcare at the OR, this includes services (range of diagnose, number of resources and safety) and geographical, financial accessibility.	19
Accreditation	The number of certifications for being officially recognised, accepted, or approved of performing a certain act, expressed in number or quality.	26
Authority	The degree of leadership during a treatment and who is in control and makes the decisions, mostly the surgeon.	26
Bed utilisation	The degree to which the ward-beds are used in an effective way.	25
Behaviour	The way the medical staff is treating or acting in the OR and the effects on the other stakeholders.	34
Cancellation	The number of surgeries that are annulated, expressed in number.	30
Care outcomes	The effects of the treatment on the patient and therefore the patient's health condition over time.	19
Coaching (#)	The feedback and coaching based on videos and audio, expressed in number of frequencies by the HCP to other staff.	26
Communication	The amount and the quality of information transmission between stakeholders.	25
Complication (#)	The number of complications occurring during and after the surgery.	26
Cost	The financial cost in/of the hospital.	27
Culture	The organisational environment of the hospital, including the general norms and values of a group.	30
Deaths (#)	The number of deaths during or after the surgery.	24
Decision-making	The process of deciding during the surgery about the treatment and the after-care in number and quality.	25
Discharge	The number of patients that can leave the hospital (ward) according to the medical professional, expressed in number of discharges.	33
Distribution equipment	The number of deliveries of resources to the OR.	47
Education	The quality and content of the education for the medical staff.	24
Equipment type	The number of (set of) tools for the surgery in the OR.	25
Ergonomics	The degree to which the staff can work in an appropriate posture or the posture of the staff during the surgery.	26
Finance	The management of money, the business and investments.	18
Hygiene	The degree to which people keep themselves or the environment clean, to prevent diseases.	22
Idle time	The period of time that the medical staff or the OR is not being used, despite the fact that it is available.	29
Inventory	The amount of equipment and resources in stock and available to use.	47
Length of stay	The number of days that the patient had to stay in the hospital for their treatment and recovery, expressed in numbers.	23
Maintenance	The amount of work that need to be performed to keep the OR and its equipment/resources in good condition and usable.	24
Management	The control of the organisation, including the administration, board and its policies.	19
Money ($, €)	The amount of money that a certain action or material costs, expressed in dollars or euros.	23
Morbidity	The degree of the patient's condition of chronic (long-term) and age-related diseases, expressed in numbers.	24

Term	Definition[1]	Page[2]
Mortality	The number of deaths caused by an event or illness over a specific period of time, expressed in numbers.	24
Operational performance	The arrangements and tasks required to control the operation of a plan or organisation.	18
OR block	The amount of time that is blocked in the OR schedule for a certain treatment, expressed in number of blocks.	47
OR break	The period of time that is used for an interruption in work shifts of the medical staff.	24
OR overtime	The period of time that the medical staff or the OR is being used, despite the fact that it should be available to be used for the next surgery.	24
OR time	The time period that the OR is in use, expressed in percentage.	24
OR utilisation	The degree to which the opening hours of the ORs are used in an effective way.	24
Patient (health) condition	The quality of the physical condition and fitness of the patient, including sickness and the life(style) circumstances of the patients.	19
Patient flow	The transfers of patients through the hospital; from the ward to the OR.	19
Patient health: Blood loss (mL)	The amount of blood loss from the patient during the surgery, expressed in mL.	26
Patient health: Blood pressure (mmHg)	The blood pressure of the patient during the surgery, expressed in mmHg.	26
Patient health: Heart rate (bpm)	The heart rate of the patient during the surgery, expressed in beats per minute.	26
Policy	The number and the quality of the guidelines for the treatment and the degree that these guidelines are followed up.	23
Profit	The amount of money that is earned in trade or business after paying the costs of producing and selling goods and services.	30
Quality-of-care	The value of healthcare services for individuals and populations to increase the likelihood of desired health outcomes.	18
Resources	The equipment, means and materials for the treatment and after-care.	19
Responsiveness	The time period and quality of the reaction to an emergency case and the degree of alertness of the situation.	29
Revenue	The amount of income that a hospital receives regularly.	30
Safety	Health services for individuals and populations providing a safe and risk-free healthcare, with the intention of the best outcomes for the patient and staff.	19
Satisfaction	The fulfilling/achieving the need or desire of the act for a certain stakeholder.	19
Savings	The amount of money that is not spend/invested and therefore is kept on the bank account.	24
Schedule	The quality of the OR schedule.	24
Service	All provided types of activities within the hospital and OR, except the task surgery.	19
Shift	The number, duration and type of working (hours) during the day or night, expressed in number of shifts.	29
Skill	The level of ability to perform or practised a treatment, this includes cognitive, nontechnical and technical skills of the staff.	24

Term	Definition[1]	Page[2]
Staff (health) condition	The quality of the physical condition and fitness of the staff, including sickness and the life(style) circumstances of the staff.	19
Staff performance	The performance of the individuals of the medical staff during the surgery or after-care.	18
Staff satisfaction	The fulfilling/achieving the need or desire of the act for the medical staff of the hospital	47
Surgery duration	The time period to perform a surgery.	29
Surgery efficiency	The level of time and staff is used in a good way (without any waste) during a surgery.	26
Surgery volume	The number of surgeries performed in a time period.	22
Surgical performance	The results of accomplishment and its quality of the surgery completes by the medical staff.	47
Survival	The number of patients that survive the surgery.	23
Tasks (#)	The number of tasks performed by the staff, expressed in number.	26
Team	The group of medical professionals that perform care in the OR.	19
Team structure	The type of medical professionals that are involved with the team during a treatment.	47
Teamwork	The collaboration of the group of medical professionals that perform care in the OR.	47
Time (days, hours, months)	The number of days, hours or months.	25
Time: Delay (hours, #, %)	The period of time that is spend to delay (later start as planned on beforehand) or the number or percentage of delayed surgeries.	25
Time: OR time (hours)	The period of time that is spend in the OR.	25
Treatment type	The types of surgeries that are performed.	22
Trust	The believe in capability and truth in the team or medical staff.	33
Turnover	The number of tasks that can be perform in a certain time period in OR.	23
Value-based healthcare	The aim to improve patient outcomes while optimising the use of hospital's resources among medical personnel, administrations and support services through an evidence-based, collaborative approach.	18
Waiting list	The number of people, who desire care, that are put on list since there is no care available yet, expressed in number of patients on the list.	29
Waste	The number of materials that is ditched or the amount of unnecessary or wrong used materials, expressed in kilogram.	30
Workforce	The number of medical staff who work in the hospital or department, expressed in number of staff per patient to provide work.	25
Workload	The amount of work and the number of tasks that needs to be performed by the medical staff.	25

[1] The definition used in this study.

[2] First-mentioned on this page.

Note: only the descriptions that occurred in the text are mentioned in this table. The other codes of the tool, including the definitions, can be found in Appendix B.

1 Introduction

The operating room (OR) is visited by 60-70% of the admitted patients (Bovim et al., 2020; Kheiri et al., 2021) and there are annually 234 million major surgeries in the world (World Health Organisation [WHO], 2021c). Therefore, the ORs of the hospitals are essential in the healthcare. Consequently, optimising the OR is a hot research topic in the whole (prosperous) world (Britt et al., 2021; Chasseigne et al., 2020; M'Hallah & Visintin, 2019; Sagnol, 2018); a lot of hospitals are aiming to improve the expenditures, time management, utilisation or quality of the healthcare (Britt et al., 2021). Due to the many aspects, as finance, instrumentation, scheduling and staff, and the impact on the care, ORs are important, but also complex components in hospitals (Van Beekum, 2022).

The budgets of the hospitals are restricted (Zhang et al., 2020; Zhang et al., 2021) and given that the ORs are one of the costliest departments of the hospital (Erekat et al., 2020; Kheiri et al., 2021; Makboul et al., 2022; Naderi et al., 2021; Xiao & Yoogalingam, 2021; Zhang et al., 2020; Zhang et al., 2021), the hospitals in prosperous countries aim for optimisation of the OR. However, the ORs and the intensive care unit (ICU; Zhang et al., 2020; Zhang et al., 2021), are one of the main revenue sources of the hospital (Erekat et al., 2020; Makboul et al., 2022; Naderi et al., 2021; Zhang et al., 2020; Zhang et al., 2021); probably somewhere between 40% (Erekat et al., 2020; Makboul et al., 2022) and 67% (Bovim et al., 2020) of the hospital revenues and therefore also qua finance essential for the hospitals. The optimal utilisation of ORs is vital for the costs/service delivery which can be increased by decreasing the waiting times (Naderi et al., 2021), reduce the number of required resources (Burdett & Kozan, 2018) and increasing the admissions (Burdett & Kozan, 2018; Naderi et al., 2021). Due to the restrictions, many hospitals are struggling to guarantee the quality and efficiency of their services (Zhang et al., 2020; Zhang et al., 2021), to achieve this the ORs should work quickly and efficiently, and use the resources wisely (Burdett & Kozan, 2018). To guarantee the quality, the World Health Organisation (WHO) called for more research to (improving) patient safety (World Health Organisation Europe [WHO Europe], 2021; WHO, 2021c), since half of the unintentional harm to hospitalised patients occurs in the OR (Boet et al., 2021) and one in ten patients suffers from a form of preventable harm in Europe (WHO Europe, 2021).

The medical world is in constant evolution (Chasseigne et al., 2020) and almost half of the innovations of the medical technology sector are focused on the ORs (Schouten, 2021). Even though they are facing the pressure to optimise (Xiao & Yoogalingam, 2021), the implementation of the innovations remains difficult (Morgan & Angelos, 2022). Some of the issues are the transition from innovation to acceptance in practice and the lack of responsibility for long-term oversight (Morgan & Angelos, 2022). Despite the difficulties with the implementation, the development of new techniques and technologies is crucial for the progress of surgery (Morgan & Angelos, 2022; Xiao & Yoogalingam, 2021). Nevertheless, the literature does not focus on one specific aspect of optimising the OR and therefore creates different innovations and optimising strategies (Schouten, 2021; Van Beekum, 2022). Besides that, the optimisations are all performed under different circumstances, like type of hospital, department, patients, staff, diseases and phase in the OR (Van Beekum, 2022). Since the opportunities for improving the OR are overwhelming, the many innovations and the complexity of the OR, a difficult situation is created for the healthcare professionals (HCPs); staff that has knowledge of the healthcare and the OR itself and gathers information of the OR for a hospital or (university research), including medical staff, scientist or hospital management.

1.1 Problem statement

The HCPs of prosperous countries often state that the ORs have to optimise (Naderi et al., 2021); however, it has not been defined in what aspect should be optimised (Van Beekum, 2022). The HCPs are trying to find the most preferably/best state of the OR (Guo, 2020), this state could be characterised as the performance of the OR and most preferably/best depends on the individual's perspectives. The HCPs have to decide what type of innovation or research they would like to implement/perform to optimise the OR performance. This (optimisation of the) OR performance can be defined as the functioning in/of the OR to reach the goals of a sufficient quality (Guo, 2020). Due to the complexity and the high number of innovations for the OR, it is necessary to choose between the several aspects and innovations for the OR for the optimisation.

Currently, many decisions about the optimisation are made based on emotions, individual reaction (attitudes and perception) and experience (Iacopino, 2018), but should be based on evidence (Turner et al., 2017). Social networks and social capital theory indicates that individuals' choices and behaviours, also in the medical field, are strongly affected by interpersonal relationships (Iacopino, 2018). This is leading to decisions that differ per person and situation, wherefore no standard policy can be defined. The evidence, research findings, local data or professional experience, can also be interpreted in different manners by different professionals (Turner et al., 2017). According to Littlejohn et al. (2017), it is important to have a mutual vision on the goal and method (of optimisation) before the decision is taken. Therefore, the decision should be taken in a well-informed and evidence-based manner, and it is good to anticipate on the effects of the decision as well (Guo, 2020).

The literature provides a lot of opportunities and options to optimise the OR; however, to the best of the authors knowledge, there has been limited research to the impact of an optimisation on the performance of the OR and to supporting the HCPs in their decision-making process. Therefore, more research is required to help the HCPs for the decision-making on the overwhelming options of the OR. Considering this all, the aim of this study can be defined as: *"To develop a decision-support tool for healthcare professionals that guides the selection of objectives and assessment criteria for performance optimisation of the OR and accounts for the impact of an optimisation on the total system".*

The OR is an essential part of the hospitals, due to the many surgeries that are required and due to their share in the hospitals revenue. However, the OR deals with regulations for the quality and restrictions on the budget. Therefore, the OR requires to optimise. Due to the complexity of the OR and the personal relations of the HCPs, the decision-making on optimisations could be hard. Therefore, the aim can be defined as: *"To develop a decision-support tool for healthcare professionals that guides the selection of objectives and assessment criteria for performance optimisation of the OR and accounts for the impact of an optimisation on the total system".*

2 Goal of study

The aim is to develop a tool to provide insight in the impact of an optimisation on the performance of the OR and guide the HCPs in decision-making on the OR optimisation process. To provide more understanding in the problem and to reach the aim, the research questions are defined in this chapter. Later on, in this chapter, the scope and the relevance of the study and the thesis structure of the rest of this report will be presented.

The intended result of this research is to produce a decision-support tool that helps the HCP to make an integral (design) choice and evaluate options by indicating the goals of the optimisation and the (in)direct impact of an optimisation on the OR performance. The output of the tool should provide insight in the several goals for the OR and the assessment to measure this optimisation on the performance by an innovation. From now on, the assessment criteria to measure this improvement on the performance will be called the metrics. Theoretically, this would provide more insight in the performance of the optimisation and the OR, and in practice, this could guide the HCPs with the decision-making on an optimisation to solve problems or optimise for the OR. The tool is intended for the HCPs that have a saying in the optimisation, the decision-making or the purchase of an innovation for the OR.

2.1 Research questions

In order to find the goal of this study, the main research question (MRQ) is defined as follows:

"*How can a decision-support tool for optimisation in the operating room help a healthcare professional to select the objectives and the assessment criteria for performance optimisation of the operating room and the optimisation impact?"*

For the intended tool, it is significant to state the objective (of the optimisation) of the performance of the OR, expected that there will not be found one singular objective, since "optimisation of the OR" had a high heterogeneous definition (Van Beekum, 2022). Afterwards, the assessment criteria of the performance optimisation (metric) should be defined and considering the results of Van Beekum (2022), it is assumed that they influence each other, which indicates the complexity of the OR. The following three sub research questions (SRQs) are linked to the MRQ (Figure 1) and are defined as:

SRQ1:		*"What is the definition of the performance of the operating room according to the healthcare professionals to identify the objectives of optimising the performance of the operating room?"*
SRQ2:		*"What are the assessment criteria to quantify the performance optimisation of the operating room?"*
	SRQ2a:	*"How are the assessment criteria and the objectives of the operating room related to each other?"*
	SRQ2b:	*"How are the assessment criteria of the operating room performance optimisation affecting on each other?"*
SRQ3:		*"What means can be developed to support decision-making on the impact of an optimisation on the performance of the operating room?"*

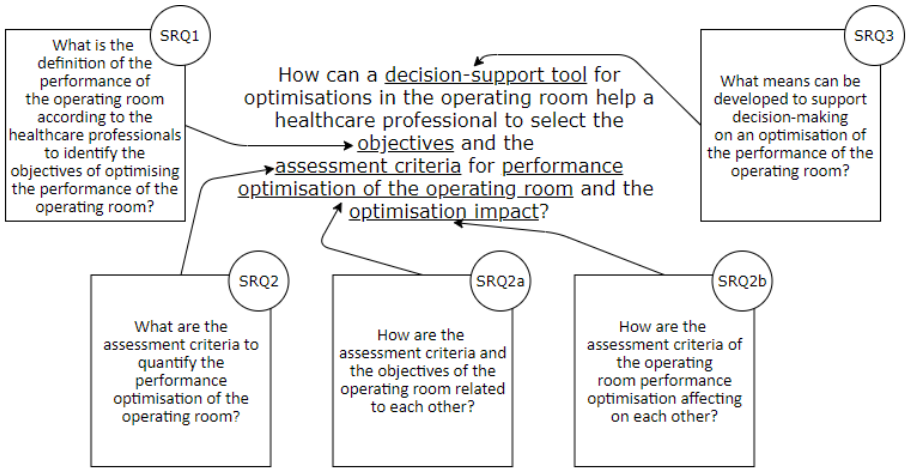


Figure 1: The main research question (MRQ) with the connecting sub research questions (SRQs).

The questions will be answered based on the double diamond concept (Design Council, 2021), as presented in Figure 2. The double diamond is a clear, comprehensive and visual description of the design process, that represents a process of exploring an issue more widely or deeply (divergent thinking) and convergent thinking focusses on action (Design Council, 2021). The project started with a challenge, namely the decision-making process in the OR. The first diamond is for "understanding the problem" by defining the goals of (SRQ1) and the measuring (SRQ2) of the OR performance optimisation and their relations (SRQ2a) and causalities (SRQ2b). The first diamond is larger than the second for this study, since understanding the problem requires more time and effort than the design process (second diamond). The second diamond is an iterative process, starting from the critical node (the problem in the current situation), to identify the means for the decision-making (SRQ3) and develop the tool. The end result is a decision-support tool, which helps to answer the MRQ.

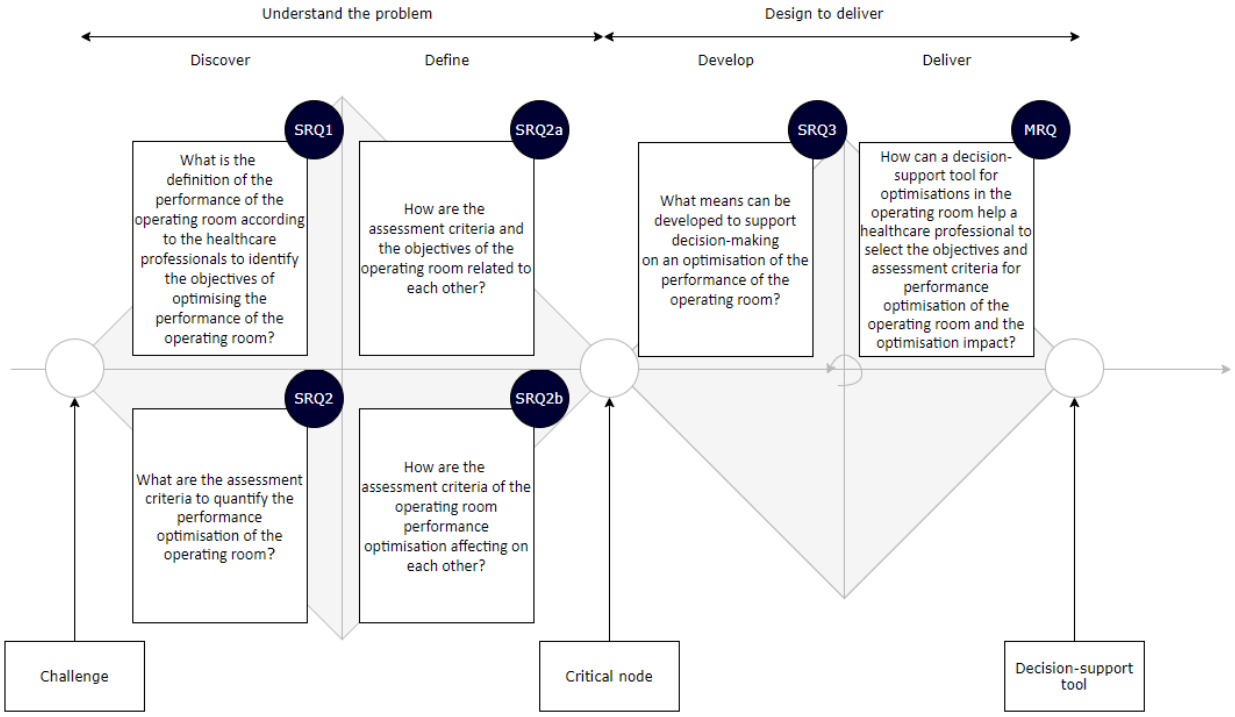


Figure 2: Overview of the double diamond (Design Council, 2021), including the research questions per step (in the black circles).

2.2 Scope of work

The focus of this study is on the decision-making of the objectives and assessing criteria of the optimisation of the OR performance and understanding the impact of an optimisation, since there is a limited amount of research covering this. In this study, the term optimisation will be used for all kind of innovations that improve the OR by among others the techniques, strategies, equipment, designs, analysis and/or models. There is focussed on the OR exclusively, indicating that, the acts performed (partly) outside the OR are not considered. Besides that, the ORs are general surgery area, therefore image equipment is not available and the innovations are not disease-, instrument- or surgery-specific. The ORs of academic and non-academic hospitals, excluding the private and military ones, are taken into consideration.

The studied ORs are in prosperous countries (located in Australia, Canada, Northern Europe, United States of America and Western Europe), since is assumed that those ORs are well-developed and optimisation is in a well-developed stadium. To take in account the most developed researches and most relevant innovations, the most recent time-period is considered, namely the last five years (January 2017 – March 2022).

2.3 Relevance

Currently, the hospitals have to consider many aspects when innovating, such as costs, quality of care, satisfaction of the patients and of the employees (Britt et al., 2021; Van Beekum, 2022). It is attempted to provide decision-support tool to provide insight in the impact of an optimisation on the performance of the OR and helping the HCPs to make decisions on the OR optimisation process. The relevance will be perceived from two perspectives; biomedical engineering and communication (design) perspective.

Due to the high costs (Zhang et al., 2020; Zhang et al., 2021) and the high global volume of surgeries per year (WHO, 2021c), the OR is required to optimise. To decide on optimisation, multidisciplinary teams need to develop a common goal/view on the performance optimisation (Littlejohn et al., 2017). This study should provide insight in the impact and consequences of an optimisation, by supporting the HCPs in their decision-making process, as among others aiming saving time and costs. In the comprehensive healthcare agreement 2022 of the Netherlands (Dutch: *Integraal Zorgakkoord 2022*) is stated that the government is aiming for more value-driven care, whereby the care is verifiable effective and has added value for the patient. This study could provide a tool to make the next step in this goal, since it should provide a more general vision on the performance of the OR and help the HCPs to define their goals for the OR. The tool can help the decision-making process on a research level and within hospitals, since it applies several aspects of healthcare, including finance, inventory management, information processing, outpatient clinics and inpatient setting.

This study helps to accelerate the decision-making process, by providing structure and information to the HCPs. The tool can support the decision-making process by anticipating on the consequences/impact of an optimisation, in order to better align with the goals and the desires of the hospital. The decisions will be more constructive and considered, and therefore, more sustainable (Guo, 2020). This tool can support (collective) decision-making and provides an opportunity for multidisciplinary learning (Littlejohn et al., 2017). With gathering an insight in the impact and consequences of an optimisation, the HCPs can better define their goals/desires, and better align the process and outcomes with the values, needs and expectations (Littlejohn et al., 2017). The several visions can be brought together and create a shared vision within the multidisciplinary team (Littlejohn et al., 2017). To create a more general vision, it is important to have substantive knowledge of the technical field, and clarify the knowledge to professionals or laymen.

2.4 Thesis structure

This thesis consists of 11 chapters, based on the double diamond structure, as can be seen in Figure 3. This project started with a challenge, namely the decision-making process in the OR, which is identified by a narrative literature study in Chapter 1 and leading to the research questions in Chapter 2. “Understanding the problem” starts with defining the problem with gathering background information of the OR and the decision-making processes (Chapter 3) and a systematic literature study to the objective of (SRQ1 in Chapter 4) and methods of measuring the performance optimisation (SQR2 in Chapter 5). The “discover” phase (converging part of the first diamond) is answered by a literature study to the relations between objectives and metrics (SRQ2a in Chapter 5) and the causal relations between the metrics (SRQ2b in Chapter 6) of the performance optimisation of the OR. The results of the decision-making process and the OR performance optimisation lead to a critical node and the design aim, by problem identification in Chapter 7. Chapter 8 is the starting point for the tool and will cover the design process. Based on design criteria, concepts and the Harris profile method (SRQ3; Roozenburg & Eekels, 1995), the “design to deliver” phase starts by developing the tool. After choosing between the concepts, the final design and answer on the MRQ, is the delivery of the design, which is done by design methods in Chapter 9. The tool and the process will be evaluated and discussed in Chapter 10 and 11. Every chapter ends with a blue outlined box, representing a summary of the chapter.

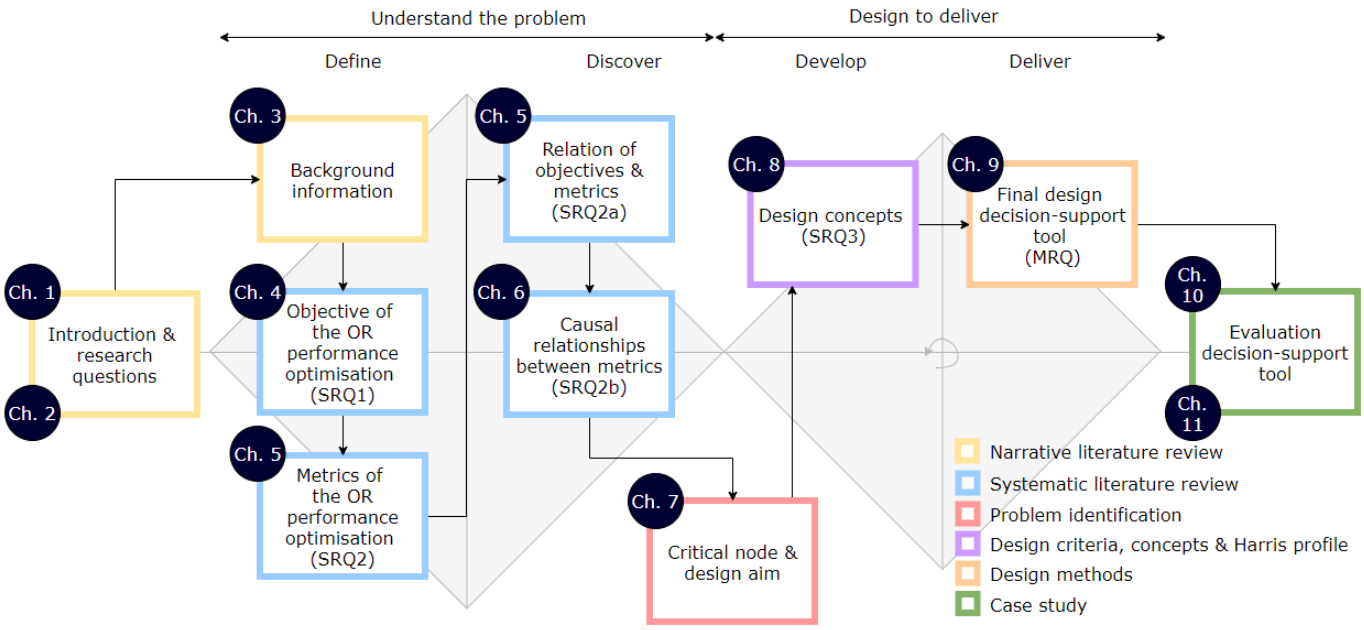


Figure 3: The approach for this study with the deliverables in the boxes, the colour of the outline of the boxes presents the method of receiving the deliverables. The corresponding chapters (Ch.) in the black circles. On the background the double diamond (Design Council,

This study answers the MRQ: "*How can a decision-support tool for optimisation in the operating room help a healthcare professional to select the objectives and the assessment criteria for performance optimisation of the operating room and the optimisation impact?",* by defining the objectives of the operating room (SRQ1) and the assessment criteria (SRQ2) to quantify the performance of the OR. The relation between the objectives and the assessment criteria (SRQ2a) will be studied. The impact of an optimisation on the OR performance will be studied by causal relations between the metrics (SRQ2b). To result intentionally in a decision-support tool that helps the HCP to make an integral (design) choice and evaluate options by indicating the (in)direct impact of an optimisation on the OR and the goals of the optimisation. For answering these questions, the double diamond approach is used and there is only looked into ORs exclusively from prosperous countries. This tool should support better, constructive and more sustainable decisions, due to knowing the optimisation impact, and accelerate decision.

3 The OR and its decision-making process

To create more insight in and background knowledge of the OR and the stakeholders, this chapter discusses the purpose, the team and the design of the OR. For performance optimisation of the OR, the HCPs are required to take decisions about optimisations for the OR, therefore, the decision-making process of HCPs in hospitals and universities is discussed.

3.1 Operating Room

The OR, also called operation room or operation suite, is a room in a medical hospital where surgeries are performed (Merriam Webster, 2021). A surgery is an invasive procedure; a procedure that penetrates the protective surfaces of a patient's body (Burlingame, 2014). Simultaneously, the patient will require physiological monitoring and is anticipated to require active life support (Langlands, 2021). According to Bovim et al. (2020) and Kheiri et al. (2021), 60 to 70% of the admitted patients will visit the OR, since they require a form of surgical intervention.

The OR has many facets in their regular care, as finance, instrumentation, scheduling and staff (Van Beekum, 2022), but besides all the planned surgeries, it is also expected that the medical professionals of the ORs act responsive to emergency arrivals (Xiao & Yoogalingam, 2021) and treat the patients quickly (Burdett & Kozan, 2018). The ORs are required to be in close contact with other departments, since the ORs function in synchrony with the postoperative hospital units, as the PACU (Debats et al., 2021; Kheiri et al., 2021). Everything together makes the OR a complex system (Van Beekum, 2022).

3.1.1 Design

An OR is defined as a room in the surgical suite that meets the requirements of a restricted area and is designated, and equipped for performing surgical operations or other invasive procedures that require an aseptic field (Burlingame, 2014). In 1884, the first OR was built out of wood (Clemons, 2000), fortunately, the OR has changed over time (Adams et al., 2016) and a picture of a current OR is shown in Figure 4. The requirements for the OR in prosperous countries include functional measurements, as lightning and area (WHO, 2021c); hygiene measurements for the OR, as air filters (Clemons, 2000; Langlands, 2021; WHO, 2021c); hygiene measurements for the staff, as protective equipment WHO, 2021c); and equipment requirements, such as a defibrillator, a MAYO and a stool (World Health Organisation [WHO], 2021b).

Figure 4: The interior of an OR in Leiden University Medical Centre (LUMC; LUMC, 2021), including an operating theatre table, operating theatre lights, vital signs monitor, pulse oximeter, stools and an electrocardiogram.

3.1.2 Team

A surgical team in prosperous countries consists of at least three different medical professionals (WHO, 2021c): surgeon, anaesthesiologist and nurses. The surgeons and the nurses can be divided into different levels of professionality. Within the group of surgeons, there are consultant surgeons, associate specialist surgeons, specialty surgeons, specialist surgical registrar and core training doctor, (Royal College of Surgeons of England, 2022). Nurses in the OR can be divided over certified registered nurse anaesthetists (CRNA) and operating nurse, sometimes complemented by a surgeon-assistant (WHO, 2021c). Per prosperous country the team can differ in number and in level of professionality; however, there will always be at least three type professionals present during a major surgery.

The process of a surgery in the OR can be divided in four phases for the team; scheduling, preoperative, operative and postoperative (LUMC, 2021; WHO, 2021c). The surgical team is involved in three stages of surgery; preoperative, operative and postoperative (WHO, 2021c). The patient has or undergoes several situations as well, although this will mainly be organised or directed by the operating nurse. In the scheduling phase, the administrative staff determine the location, timeslot and medical professionals (WHO, 2021c).

The surgeon, the medical doctor specialised in surgical training, performs the operation and is the highest in hierarchy (Wakeman & Langham, 2018; WHO, 2021c). The surgeon is responsible for the surgical performance (WHO, 2021c) and decide on the type of treatment by having a conversation with the patient (LUMC, 2021). They prepare the patient for its surgery and check the personal information, such as name, medical problem and date (LUMC, 2021; WHO, 2021c). The pain management and patient safety are the responsibility of the anaesthesiologist and the CRNA (WHO, 2021c). The anaesthesiologist performs the anaesthesia safety check, connects the patient with the pulse oximeter (WHO, 2021c) and gives the anaesthetics (LUMC, 2021; WHO, 2021c). During the operative phase, the anaesthesiologist is taking care of holding the stability of the bodily functions (LUMC, 2021). In an increasing number of hospitals, the CRNA takes the tasks of the anaesthesiologist (supervised) over (WHO, 2021c). The operating nurse supports and provides assistance to the surgeon by performing the comprehensive care, assistances the pain management during the surgery (WHO, 2021c). In the beginning, the nurse does a routine examination (LUMC, 2021) to check the patient's physical condition (WHO, 2021c) and prepares the patient for the surgery (WHO, 2021c). Besides that, the nurse is responsible for the instrumentation and administration during the surgery (WHO, 2021c).

The whole team is in the end performing the surgery and they are helping out each other during this process (WHO, 2021c). Besides that, the surgical team has to work with the staff members from the other departments, since they are in synchrony with the postoperative hospital units (Debats et al., 2021; Kheiri et al., 2021). In the beginning of the operative phase, they discuss the surgical and medical potential issues (WHO, 2021c). The surgeon and anaesthetist together provide the patient handover to the recovery practitioner (WHO, 2021c). In Appendix A, all the tasks of the team members, together with the goals and the process for the patients are presented.

3.2 Decision-making

Decision-making on an optimisation in the OR can be made at different levels: solving a problem, researching the current situation and inventing a new technique; or at different institute levels: as a hospital and a university. All of the HCPs start with the questions; what, when, where and why, to come up with a research topic (Sararaks, 2008). *"Who are taking the decisions?"; "What is decided?"; "Where are the decisions taken?"; "When are the decisions*

taken?" and "*Why are the decisions taken?".* In this study, the decision-making process is important, therefore an elaborated answer will be formulated to the "how" interrogative pronoun: *"How are the decisions taken?"*. The first five question will be (shortly) answered in the next paragraphs, for the last question a more elaborated answer is stated, since this explains the whole process. The questions will be answered from the two mentioned institutional levels in the prosperous world. In Figure 5, the answers on each question are displayed by a few words.

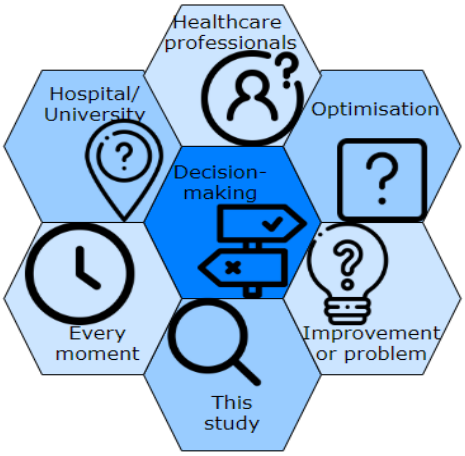


Figure 5: The answers on the five W-questions and the one H-question, starting at the top with who, going clockwise to what, why, how, when and where.

3.2.1 Who are taking the decisions: healthcare professionals

With decision-making on the OR, there are always HCPs present (Sararaks, 2008). The decision-makers differ per situation, since topics requires different (decision-making) qualities and knowledge. In case of the university, the decision-makers are often scientists that have a background in the medical field, or at least a wide knowledge of the medical sector. In most of these situations, a hospital is involved in such research too and therefore, HCPs of this centre participate and share their knowledge (Sararaks, 2008). However, the actual involved people and their involvement differ per study and university. The scientist will probably decide itself about the topic, whereby the professor or another person higher in hierarchy could think along (Hussin, 2009).

The decision-making group at the hospital is often called the Value Analysis Committee (VAC) or Value Analysis Team and is responsible for the management of medical and surgical products in hospitals (Advisory Board, 2022). This group can differ depending on the type and the goal of the innovation (Bionix, 2022; Dexter et al., 2020) and per hospital (Liberatore & Nydick, 2008). The analysis of an innovation should preferably be a multidisciplinary process and should consider a product or service total value (Pennington & DeRienzo, 2013). The decision-making process includes staff at all organisational levels (Pennington & DeRienzo, 2013) and from different departments (Greenlight Medical, 2022); material management (Advisory Board, 2022; Bionix, 2022; Feldstein, 2010; Greenlight Medical, 2022; Pennington & DeRienzo, 2013), OR management (Advisory Board, 2022; Feldstein, 2010; Greenlight Medical, 2022; Pennington & DeRienzo, 2013), financial management (Feldstein, 2010; Pennington & DeRienzo, 2013), surgeons (Advisory Board, 2022; Bionix, 2022; Liberatore & Nydick, 2008; Nassiri et al., 2020; Pennington & DeRienzo, 2013), nurses (Bionix, 2022; Greenlight Medical, 2022; Pennington & DeRienzo, 2013), technician (Pennington & DeRienzo, 2013), administrators (Advisory Board, 2022; Bionix, 2022; Greenlight Medical, 2022), surgical site infection specialists (Bionix, 2022; Dexter et al., 2020), purchasing agents (Advisory Board, 2022; Greenlight Medical, 2022) and reimbursement specialists (Advisory Board, 2022; Pennington & DeRienzo, 2013). Liberatore & Nydick (2008) advised to involve the patient as well in the decision-making process of the purchasing; however, they are often not part of the

VAC (Advisory Board, 2022). This team should be able to provide an integrated view, due to their multidisciplinary backgrounds (Bionix, 2022; Pennington & DeRienzo, 2013). The significance of the surgeon in the decision-making process will be elaborated on in the next paragraph. At the end, the decision-makers are often part of the management, since they are the highest in hierarchy (Turner et al., 2017).

The healthcare outcomes and safety are often enhanced by familiar products, due to predictability, reliability and efficiency of the process (Pennington & DeRienzo, 2013), and therefore the surgeons should agree with the purchase (Nassiri et al., 2020). In 61% of the supplies used in surgical services, the surgeons have a personal preference, which is often an excuse to justify the use of similar products from several vendors (Pennington & DeRienzo, 2013). Besides that, the surgeons are the practitioners, the main patient advocators and regularly evaluate the patient circumstances as disease-related improvement, safety, length of stay and quality of life outcomes (Nassiri et al., 2020). However, the surgeons often decided unrelated to the costs, but including the medical training, personal experience, perceptions of patients and vendor relationships (Iacopino, 2018; Nassiri et al., 2020; Pennington & DeRienzo, 2013). The acceptance of the implementation by surgeons is often the biggest obstacle and therefore the surgeons should be well-informed about and involved in the decision-making process (Liberatore & Nydick, 2008).

3.2.2 What is decided: optimisation

Almost half of the innovations of the medical technology sector are focused on the optimisation of the OR (Schouten, 2021). Innovation is defined as a new idea, method or device (Merriam Webster, 2022c), and in this study this could be a technique, strategy, equipment, design, analysis or model for the OR. However, the innovations are only considered if they exclusively affect the OR and changes are only considered as an innovation if they are conscious chosen. In a study to the optimisation of the OR, ten types of innovations were discovered: air ventilation, instrumentation, logistics supplies, performance, procedure in OR, scheduling, stress, teamwork, trusts, and waste (Van Beekum, 2022). In this study, there was not found a singular definition for “optimisation of the OR”; however, 68% of all studies involved the expenditures in a certain way in their definition. The innovations were mainly measured in cost (43%), time (48%) and utilisation of the OR (34%), or a combination of these methods (Van Beekum, 2022).

According to Ahmadi et al. (2019); Burdett & Kozan (2018) and Liu et al. (2019), there are performed broad and extensive (literature) studies to ORs planning and scheduling recently. Two third (n=37) of the considered articles of Van Beekum (2022) improved the scheduling for the OR, followed by innovations to instrumentation (16%). The innovation Scheduling had as aim to improve the logistics of the schedules of the OR, which is the planning of patients, staff teams and the resources to the correct OR, to improve the utilisation of the ORs (Zhang et al., 2020). Scheduling as innovation was also often combined with the goal to balance the cost and utilisation for the optimisation (Van Beekum, 2022).

The universities aim to understand situations, affecting individuals, communities or health systems in their research, among others to assist healthcare professionals to identify healthcare needs (Sararaks, 2008). A scientist would like to research the current situation, solve a problem or inventing a new technique (Sararaks, 2008). The scientist should start with a decision on if the topic is worth the time, effort and money that is required to invest. The decision-making process can also be about decisions within this research, determined by imposition by a professional or discovery of a progress (Sararaks, 2008). In both manners, decisions about the topic, the scope and the search terms are required.

In medical centres, the above-mentioned decisions could also be made, since it is a hospital that performs research as well (Liberatore & Nydick, 2008; Nassiri et al., 2020; Pennington & DeRienzo, 2013). However, the (public) hospitals also require decision-making on purchasing of innovations, which has been discussed frequently in the literature (Dexter et al., 2005; Dexter et al., 2020; Liberatore & Nydick, 2008; Nassiri et al., 2020; Pennington & DeRienzo, 2013). The focus has mainly been on standardisation, whereby the benefits of all practitioners using the same product outweighs the benefits of maintaining a personal choice (Pennington & DeRienzo, 2013). Also, the evaluation of products based on their total value, dividing the quality by the cost, should be taken into account (Pennington & DeRienzo, 2013). The decision-making is on the level whether a problem is worth to invest time and money or whether the innovation is worth to implement, money and time.

3.2.3 Where are the decisions taken: hospital/university

In this study, the decision-making for the OR in a hospital is the focus. The two described perspectives are within a university and a hospital, which are responsible for the decisions within their own organisation. However, in both situations, the other organisation could be involved to provide more information (Sararaks, 2008). At the universities, the involved departments are related to the medical sector or engineering, to develop a solution or innovation for the OR (Sararaks, 2008). In hospitals, the department OR management will most likely take the decisions (Turner et al., 2017). Medical centres are affiliated with (medical) universities, and therefore perform research and healthcare. Therefore, both perspectives can apply for medical centres.

3.2.4 When are the decisions taken: every moment

There is not set a specific timing or starting moment for the decision-making process. The process can start with a problem or (an idea for) an innovation (Liberatore & Nydick, 2008; Nassiri et al., 2020; Pennington & DeRienzo, 2013; Sararaks, 2008). In case of the hospital, the HCP is often inspired by an innovation or recognises a problem. Whenever a problem occurs, the HCP can individually search for an innovation or contact another HCP at any organisation to think along. The HCP at the university can start the process with a request, for example from the hospital, or with an idea from the HCP itself.

3.2.5 Why are the decisions taken: improvement or problem

Recently, the financial situation is the main reason to improve the OR or solve problems (Pennington & DeRienzo, 2013). However, according to Littlejohn et al. (2017), every decision is a balance between costs and rewards. The rewards are related to the health outcomes; the patient-centred value, expressed in health outcomes per spent dollar (Nassiri et al., 2020), is critical prior to analysis before purchasing an innovation. Besides the impact on the financial aspects and the patient's health, the surgeons are also directly affected (Nassiri et al., 2020), by the product value, standardisation efforts and proactively ensure compliance (Advisory Board, 2022). Therefore, the administrators of the hospitals have to examine their supply expenses carefully and evaluate the products and care processes (Pennington & DeRienzo, 2013). Pennington & DeRienzo (2013) stated that it is difficult to control the cost, and remain the patient care safe and effective, due to the rapid introductions of new technology, rising supply cost and patient acuity.

An innovation may affect the value of the surgical practice with a positive or negative value (Nassiri et al., 2020). To decide in favour of an innovation, the effects of the innovation should be positive and show improvements (Pennington & DeRienzo, 2013) in at least one of the following motivations: patient safety (Nassiri et al., 2020; Pennington & DeRienzo, 2013), staff safety (Nassiri et al., 2020; Pennington & DeRienzo, 2013), practical guidelines (Bionix, 2022;

Pennington & DeRienzo, 2013), productivity (Bionix, 2022; Pennington & DeRienzo, 2013), revenue (including case volume (Bionix, 2022; Nassiri et al., 2020), market standing (Pennington & DeRienzo, 2013), patient satisfaction (Nassiri et al., 2020; Pennington & DeRienzo, 2013), patient care quality (Advisory Board, 2022; Bionix, 2022; Greenlight Medical, 2022; Nassiri et al., 2020), sourcing (Nassiri et al., 2020) or cost (Advisory Board, 2022; Bionix, 2022; Greenlight Medical, 2022; Nassiri et al., 2020; Pennington & DeRienzo, 2013).

The university would like to increase the amount of understanding, with the goal to improve the current situation or the OR, give insight into the situation or solve problems, to help the hospital and society (Sararaks, 2008).

3.2.6 How are the decisions taken: decision-making process

Currently, the decision-making process differs per person and per situation. Mainly because the decisions are often made based on emotions, individual reaction (attitudes and perception) and experience, influenced by social networks and social capital and interpersonal relationships (Iacopino, 2018). It is important to have a mutual vision with all the stakeholders on the goal and methods of measuring the optimisation (Littlejohn et al., 2017) and therefore the decisions should be taken in a well-informed and evidence-based manner (Guo, 2020; Turner et al., 2017). This paragraph cannot specify how the decision-making process goes, since it differs much per situation. However, optimal decision-making process will be discussed. An elaborated answer to the how-question is necessary, since this is the overarching answer to the earlier mentioned questions. For the readability and because of the different goals and methods, this paragraph is divided into three parts: general decision-making, and the method of the hospital and of the university.

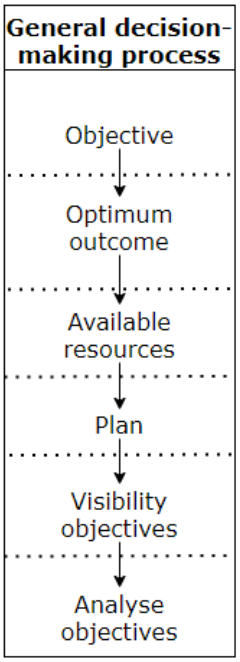


Figure 6: The general steps in the decision-making process (Guo, 2020). The dashed line represents the time-frames of each step.

The decision-making process and the participation in the process are more researched and participatory design practice is a more used method (Sanders, 2008). Group decisions are depending on three variables: objective tasks (clarity in the problem), group task (how the group behaves) and group structure (cohesiveness; Littlejohn et al., 2017). The requirements for diverse groups, including decision-making groups, is effective communication, among other equal participation, consensus-based decision-making, respectful communication (Littlejohn et al., 2017). Three obstacles can stand in the way this process: concerning with relationships in the group, poor information processing and personal interest (Littlejohn et al., 2017).

The decision quality is linked to understanding of the problem, understanding of the objectives, assessment criteria of the positive qualities and the negative qualities (Littlejohn et al., 2017). Decisions should be made well-informed, whereby it is important that all the participants act in a coherent way that leads to understanding of the situation and objectives (Littlejohn et al., 2017). The most researchers agree on the basic components of decision-making models are similar: defining the objective and optimum outcomes; discuss the available resources; establish a plan; check if the objectives can be met; and lastly, analyse the accomplished objectives (Guo, 2020), as presented in Figure 6. Within group decisions, the group should aim to achieve a convergence or agreement on the objective, methods and final decision (Littlejohn et al., 2017). Decision-making does not involve any magic of a quick fix, it requires skill, knowledge and understanding (Guo, 2020).

3.2.6.1 Decision-making process in the hospital

To guarantee a positive impact of an optimisation, the purchase should be decided on synthesising and analysing information (Pennington & DeRienzo, 2013); however, this can be a hurdle due to a lack of time, skills or knowledge (Pennington & DeRienzo, 2013). Therefore, the hospital should provide the resources and training that are relevant for the decision (Pennington & DeRienzo, 2013). The process can start from (an idea of) an optimisation or from a problem, that should be solved. The start point determines the first steps in the decision-making process; however, the main part is similar.

Whenever the process starts from the problem, the VAC includes five steps: assess, plan, design, implement and measure/sustain (Pennington & DeRienzo, 2013). The assess phase consists of the evaluation of the expectations of the situation, including the problems and solutions (Pennington & DeRienzo, 2013). Within the plan phase, the VAC establishes the optimal outcomes of the projects, with a goal, scope, value statement, gap- and stakeholder-analysis (Pennington & DeRienzo, 2013). The information will be gathered and reported to the stakeholders in the design phase (Pennington & DeRienzo, 2013). This stage is also called the unfreezing-stage, since it is the start to perform and design an innovation (Pennington & DeRienzo, 2013). Within the implementing stage, the appliance of the innovation will be succeeded and afterwards will be evaluate in the measure/sustain phase (Pennington & DeRienzo, 2013).

Another description of the decision-making process in hospitals start with a decision of a surgeon on the necessity of an optimisation. They send a formal request to the VAC (Bionix, 2022; Nassiri et al., 2020), with an evidence-based report (Nassiri et al., 2020) including information and data (Bionix, 2022) from themselves or the medical sales representatives (Greenlight Medical, 2022). The VAC gathers information from other departments (Greenlight Medical, 2022) or subspecialities (Dexter et al., 2005) about the optimisation, to perform an audit (Greenlight Medical, 2022). The information will be analysed for the clinical and financial benefits, and other set criteria, to decide on purchasing the innovation (Bionix, 2022; Greenlight Medical, 2022). Due to this process, the healthcare systems remain competitive and all innovations will be examined in the purchasing value (Bionix, 2022). As soon as the VAC trust in the worth of purchasing, based on examining the optimisation decisions in the context of safe, cost-effective, quality patient care, while considering the total value derived from reduced operational costs, better reimbursement, improved clinical care and quality, improved efficiency and enhanced safety from an interdisciplinary perspective (Pennington & DeRienzo, 2013). Afterwards, the negotiations with the sales representatives can start and the implementation phase should ensure the best clinical outcomes (Bionix, 2022).

Guo (2020) did research to an alternative decision-making model to help healthcare managers in the decision-making process. This model is called DECIDE: D = define the problem; E = establish the criteria; C = consider all the alternatives; I = identify the best alternative; D = develop and implement a plan of action; E = evaluate and monitor the solution and feedback when necessary (Guo, 2020). This model is similar to the earlier described basic components for the decision-making process.

The different theories (Guo, 2020; Liberatore & Nydick, 2008; Nassiri et al., 2020; Pennington & DeRienzo, 2013) of the decision-making process in hospitals are combined into Figure 7. The dashed line represents the time-frame, as can be seen the time-frames do not fully overlap.

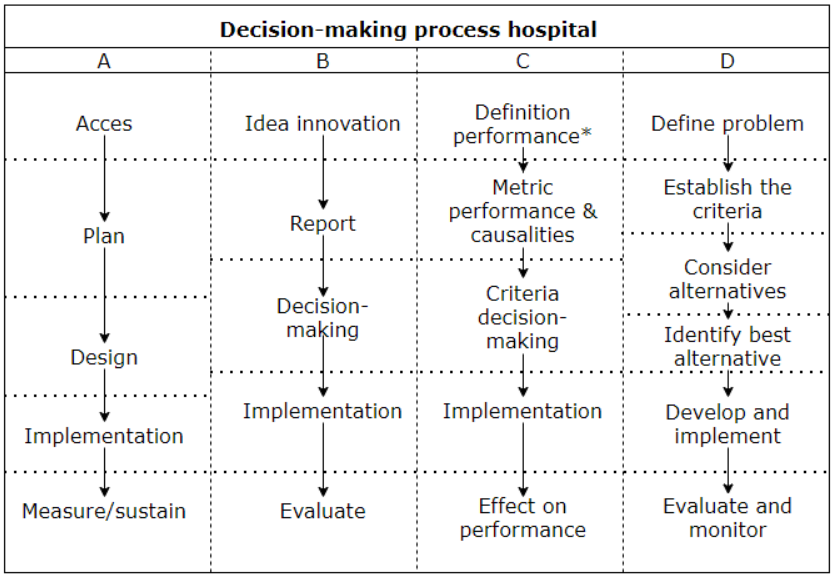


Figure 7: The different vision on the decision-making process in the hospital in one overview; A is from Pennington & DeRienzo (2013), B from Nassiri et al. (2020), C is from Liberatore & Nydick (2008) and D is from Guo (2020). The lines state the time-period and the overlap with the other methods. The asterix (*) is added by the author and the above-mentioned source does not mention this and the dashed line represents the time-frames of each step.

3.2.6.2 Decision-making process at the university

The process for universities differs from the process within hospitals, due to other goals (knowledge vs. optimisation). The decision-making process in universities is about research, including the topic, the scope and the method. However, this process and the goals of the process also differ per university, since they have other interests or methods (Hussin, 2009; Littlejohn et al., 2017), as also can be seen in Figure 8 with the theories of Johns Hopkins University & Medicine (2022); Sararaks (2008); and TU Delft Library (2022), with again the dashed line that represents the time-frame. For example, technical universities are often focused on designing; medicine universities improve the healthcare; and other universities more on gathering information (Hussin, 2009). The ratio between research, education, management and finance is different for all the organisations (Hussin, 2009).

To generalise; it often starts with identifying the problem or improvable situation (Sararaks, 2008; TU Delft Library, 2022), that come up through having dialogues and discussions with colleagues or professionals (Sararaks, 2008). The problem or research topic should describe the goal clearly, specific, socially relevant and useful to a certain target group (TU Delft Library, 2022). Based on the research goal, the research questions are formulated (TU Delft Library, 2022). By stating the sub research questions, the complete road map for the research is determined (TU Delft Library, 2022). Within this phase, the scope of the research should also be established. After formulating the research questions and the scope, the literature review is performed (Sararaks, 2008); with stating search queries (Johns Hopkins University & Medicine, 2022; TU Delft Library, 2022). According to Johns Hopkins University & Medicine (2022), choosing the search queries is the most important step in the research process. For each (key) concept, a list of related terms or synonyms is made (Johns Hopkins University & Medicine, 2022; TU Delft Library, 2022).

In all the above-mentioned steps, there are made decisions by the scientist, while selecting a problem, determining the scope, formulating research questions and selecting search queries. In the phases *Proposal: Objectives* and *Proposal: Methodology* (Sararaks, 2008), the most decisions are taken, as the objectives of the study, the scope and methods. However, in the follow-up of the research, *the actual study and utilising the study to make clinical, health & policy changes*, extra decisions have to be taken. However, in this study, this will not be further elaborated.

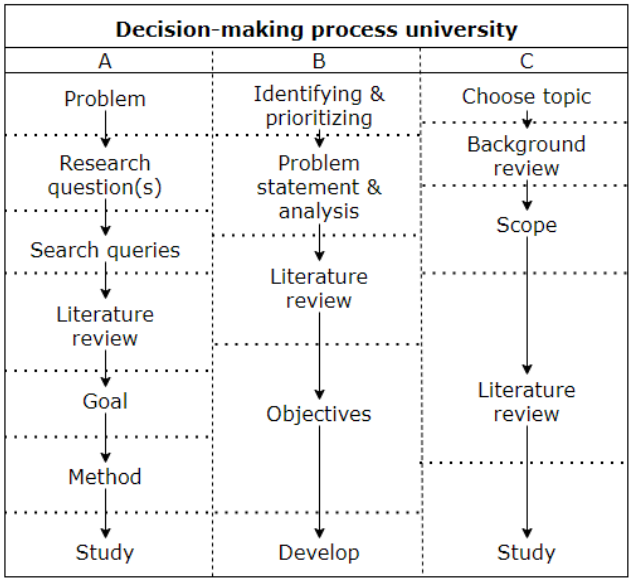


Figure 8: The process of doing research, with all different phases in the decision-making process, with A from Johns Hopkins University & Medicine (2022), B from Sararaks (2008) and C from TU Delft Library (2022). The dashed line represents the time-frames of each step.

The OR is a room in a hospital where surgeries can be performed. A surgical team in prosperous countries consists of surgeons, anaesthesiologists, and nurses, with all their own tasks during the operative process.

The decision-making process in a hospital or at a university for optimisation in the OR is performed by HCPs. The process often starts (at any moment) with a wish for an optimisation for a problem or an interesting innovation. This process goes via several general steps: determining the objective, defining the optimum outcome, research the available resources, plan the optimisation, check if the objectives can be met, and lastly, analyse the accomplished objectives.

4 Objective of the performance optimisation of the OR

In this chapter, the perspectives of HCPs on the OR performance optimisation will be reviewed, by defining the objectives of the performance optimisation of the OR. With these objective perspectives, the purpose and directions of the optimisation can be determined. This will be performed to discover the problem, as an element of the divergent part of the first diamond.

4.1 Aim

The first sub research question (SRQ1) is *"What is the definition of the performance of the operating room according to the healthcare professionals to identify the objectives of optimising the performance of the operating room?",* and is answered by performing a systematic literature review. The aim is to find the optimisation purposes for the OR, which can be defined as the objectives for the performance optimisation of the OR.

4.2 Method

An inventory of the current literature on the performance and the impact of optimisation on the medical OR is performed by searching on *Google Scholar* and *ScienceDirect* with the search terms '*Impact* AND *innovation* AND *"operating room"* AND *hospital*'. This search resulted in 366 articles. By applying the scope of this study, as said in Chapter 2, therefore were 84 extracted from all the articles via the PRISMA method, shown in Figure 9. These filtered articles have been inserted in Atlas.ti (2021).

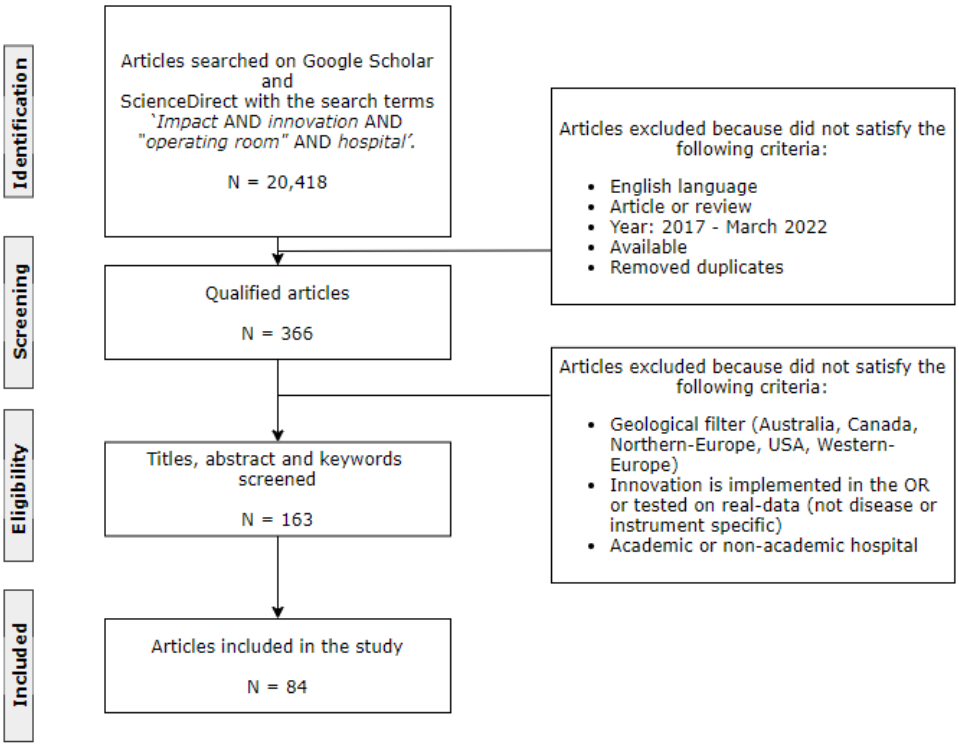


Figure 9: The method, according to the PRISMA checklist, used to make an inventory of the current literature about the optimisation of the OR performance.

In Atlas.ti (2021), the phrases of each article, that are explaining the purpose of the OR and/or the goal of the optimisation in the OR, are labelled with the code "performance". However, when a phrase is mentioned multiple times, this phrase is only labelled once. The phrases have been exported in Microsoft Excel (2021). Within Microsoft Excel (2021), the phrases have been labelled by use of inductive coding/open coding by rereading all the phrases. The codes, from now on written with a capital, have been clustered into levels of specifications (called terms)

and the descriptions of the codes are provided in Appendix B. The terms can be divided into two levels: the general level is from now on called “objective factor” and some of the objectives focus on a specific part of the general levels called the “objective characteristic”. The clustering is performed till every code was at least mentioned five times (n=5), causing the author to read the phrases at least three times. Not all the phrases have an objective factor and a characteristic, but often only the general term (factor) is mentioned. Whenever both terms are mentioned, it is called an “objective combination”. The codes that are only mentioned in one article are excluded from the further analysis. Below are presented some examples (Examples 1, 2 and 3) of labelled phrases. In Appendix C, the frequency of mentioning in an article is shown between the brackets.

Example 1: A phrase from Newsweek (2022) expressing the optimisation of the performance of the OR. The objective factor(s) and objective characteristic(s), underlined in the phrase, are overviewed in the table.*

“The quality reports provide in-depth information about the structure and services of each hospital, such as range of diagnoses and number of provided treatments, number of staff, hygiene measures, number of complications or barrier-free accessibility.”

Objective factor	**Objective characteristic**
Quality-of-care	Operational performance
Quality-of-care	
Quality-of-care	Surgical performance
Quality-of-care	
Quality-of-care	Operational performance

* The code Quality-of-care is mentioned two times on itself and twice with Operational performance. This indicates that these have been coupled with several metrics, see Chapter 5. The empty spaces implicate that no characteristic is mentioned. Those two notes will apply to all the following examples.

Example 2: A phrase from Cossio-Gil et al. (2022) expressing the optimisation of the performance of the OR. The objective factor(s) and objective characteristic(s), underlined in the phrase, are overviewed in the table.

“Methodologies were explicitly evaluated to minimize the impact of this project on provider workflow and comply with HIPAA requirements.”

Objective factor	**Objective characteristic**
Surgical performance	Staff performance

Example 3: A phrase from Frasier et al. (2019) expressing the optimisation of the performance of the OR. The objective factor(s) and objective characteristic(s), underlined in the phrase, are overviewed in the table.

“VBHC links outcomes to costs and so determines value. The focus on the value of medical services could be a key element to ensure the sustainability of high-quality healthcare systems in the future; moreover, value could continuously drive performance improvement in care.”

Objective factor	**Objective characteristic**
Finance	Value-based healthcare
Quality-of-care	

4.3 Results

Out of the 84 articles, there were selected 795 phrases that indicate a goal or purpose for the OR (objectives), which means that on average an article delivered more than nine phrases for the performance optimisation of the OR. There were 2,008 objectives mentioned, indicating that on average a phrase state more than two objectives, as also can be seen in Examples 1 and 3. There are in total 165 objective combinations, meaning a connection between the objective factor and the objective characteristic, even if there is no characteristic mentioned, or only the objective factor. The codes used for the factor and characteristic are in Appendix B and the number of phrases and articles per code are mentioned between brackets (# phrases (# articles)) in Appendix C.

4.3.1 Objective factor

There have been found 14 objective factors with a general focus on the performance optimisation of the OR, with Quality-of-care (350 (55)) as the most mentioned. The objective factors are presented in Table 1.

Table 1: The objective factors of the optimisation of the performance of the OR, with the frequency and proportion of occurrences of the articles and the phrases.

Objective	Frequency (# phrases (# articles))	Proportion articles of total (%)	Proportion quotes of total (%)
Accessibility	37 (12)	14%	2%
Care outcomes	164 (43)	46%	8%
Finance	227 (36)	43%	12%
Management	157 (20)	14%	8%
Patient (health) condition	6 (3)	4%	0.3%
Patient flow	21 (6)	7%	1%
Quality-of-care	350 (55)	65%	18%
Resources	83 (24)	29%	4%
Safety	190 (39)	46%	10%
Satisfaction	53 (21)	25%	3%
Service	132 (24)	29%	7%
Staff (health) condition	66 (16)	19%	3%
Surgical performance	371 (54)	64%	19%
Team	151 (25)	30%	8%

4.3.2 Objective characteristic

Eight objective factors are coupled to an objective characteristic, in total there are 19 characteristics. Operational performance has been coupled with seven objective factors (45 (20)) and Care outcomes with four objective factors (20 (13)). Those objective characteristics do not have the most phrases, that is the characteristic Staff performance (85 (23)); however, only with one objective factor, namely Surgical performance.

4.4 Discussion

The definition from Merriam Webster Dictionary of performance is: *"The execution of an action"* and/or *"The ability to perform"* (Merriam Webster, 2022b). In the OR, the action can be represented by the surgery (Merriam Webster, 2021), which is comparable to the prescribed objective factor Surgical performance: the accomplishment and its quality of the surgery completed by the medical staff. In none of the articles included in this study, the

author stated directly an objective for the performance optimisation of the OR. However, they stated the importance to optimise the performance, the goal of optimising and the reasoning, such as ageing (Abedini et al., 2017; Zhang et al., 2020; Zhang et al., 2021) and increased volumes of complex surgeries (Breuer et al., 2020). The literature had on average 13 phrases about the optimisation of the performance of the OR, but there is not found one overarching definition for the objectives of the performance optimisation of the OR. The objective factors and characteristics can provide a first step to a universal goal, especially considering the frequency of occurring and number of articles. The objective of the performance optimisation of the OR should cover multiple elements, since the OR is a complex system (Van Beekum, 2022) and many performance aspects have been mentioned.

The big variety in terminology and perspectives, and the fact that none of the articles stated the objectives of the performance optimisation of the OR, indicates that it is hard to make a singular objective. Within communities, each one has its own meaning for what is read, viewed or heard (Littlejohn et al., 2017). Commonly, the people with the same function within community have the same interpretation (Zhang et al., 2020); however, the individuals' choices and behaviours are strongly affected by interpersonal relationships (Iacopino, 2018) and therefore can differ. The interpretations of the objectives also depend on the situation of the professional (Littlejohn et al., 2017), such as the protocols, timing and wealth of the hospital and country. With a single objective, there would be less room for own interpretations and therefore, the professionals are more likely to be on the same page at the beginning of the project/innovation, which is required for an optimal result (Littlejohn et al., 2017). Remarkable is that only two articles Kim et al. (2019) and Scholte et al. (2021) mentioned one objective combination, three articles (Brüngger et al., 2021; Sateri et al., 2017; Shortell et al., 2018) had two objective combinations, and the other articles defined more than two objective combinations. This indicates that the authors of the most articles identify the performance optimisation of the OR as a multicomplex objective. Chrouser et al. (2018) has even 11 objective factors defined and 22 objective combinations, if you include the objective characteristics, this is the highest number of mentioned objective combinations in one article.

Schouten (2021) considered four facets of the performance of the OR workflow; patient safety, quality of care, cost-effectiveness and well-being of the healthcare profession. As can be seen, these are also a fraction of the objective of the OR performance optimisation mentioned above. However, workflow itself is not a mentioned part of the objective itself, but is included within Staff performance and Patient flow. Since no consensus has been found for the objective of the optimisation of the performance of the OR, this corresponds with the study to the definition of "optimisation of the OR" (Van Beekum, 2022). Similar to this research, none of the studied articles of Van Beekum (2022) stated an explicit definition, but indirectly the most articles defined the optimisation as a balance between several factors (64%). Optimisation and performance are related via the objective that optimisation should improve the performance (Merriam Webster, 2021). This objective focussed on many aspects and therefore was highly heterogeneity in perspectives; however, there are also many ways that one objective of performance could be improved; therefore, this research was still necessary/desired.

4.4.1 Objective factors

Although there have been found 14 objective factors, none of the articles stated the objective directly. This systematic review shows that there is large heterogeneity in the perspectives of the objectives of the performance optimisation of the OR. The most mentioned objective factors are the Surgical performance (371 (54)) and Quality-of-care (350 (55)). This is in accordance with the definition of the OR: *"A room in a hospital where operations are done*" (Merriam Webster, 2021), which is also focussed on the healthcare (Quality-of-care) and

operation itself (Surgical performance). The objective factor Patient (health) condition (6 (3)) is not mentioned often, even though it is the goal to improve this in healthcare (Merriam Webster, 2022a); however, Care outcomes (164 (39)) is closely related (since this is measured right after the surgery), and is mentioned as third in frequency.

Some of those objectives are closely related or at least correlated to each other; the Quality-of-care leads to better Care outcomes and Safety, an optimisation in the factor Team results in a better Surgical performance and Service; Management leads to a better amount of Service as well and is also related to the costs (Finance). Therefore, the distinction between the codes can be ambiguous, which illustrate the complexity of the OR and the multifacetedness in the objective(s).

4.4.2 Objective characteristics

There are 309 phrases with a characteristic, which is 15% of the total amount of phrases. In these phrases, 19 different objective characteristics are found, which link with eight objective factors. Therefore, it can be seen that the most objectives have a broad theme and do not include a specification (characteristic).

In this chapter, SRQ1 (*"What is the definition of the performance of the operating room according to the healthcare professionals to identify the objectives of optimising the performance of the operating room?"*) is answered based on an extensive systematic literature study. The objectives can be split in objective factors and characteristics, there have been found respectively 14 and 19 types. The most mentioned objective factors are Surgical performance and Quality-of-care. Therefore, it can be concluded that the objectives of the optimisation of the performance of the OR have a heterogeneity in the perspectives.

5 Metric of the performance optimisation of the OR

The objectives of the performance optimisation of the OR have been defined in the last chapter; whereby no collective perspective on the objective has been found. To measure the performance optimisation, the assessing criteria (metric) of the performance optimisation should also be quantified. These standard methods of measuring will be called metrics. The diverting part of the first diamond, supporting the discovery of the problem, will be finished in this chapter and a start to the converting part of this diamond will be taken, defining the problem.

5.1 Aim

The aim of this chapter is to figure out what kind of methods are used for quantification of the 14 objective factors of the performance optimisation of the OR. To specify the methods of measuring the performance, also called the assessment criteria, of the OR by an extensive literature search, the second sub research question (SRQ2): *"What are the assessment criteria to quantify the performance optimisation of the operating room?",* is answered. SRQ2a: *"How are the assessment criteria and the objectives of the operating room related to each other?",* will be answered by comparing the results of last chapter and this chapter. This identifies how the metrics are related to the found objectives, by which means the HCP can measure the impact of an innovation to optimise the OR performance.

5.2 Method

To find the metrics, the method and the articles from Chapter 4 are used; however, instead of labelling the objectives of the OR, the assessing criteria have been labelled with the code "metric". The indicative coding with "metric factor", "metric characteristic" and "unit", indicating the main theme of a metric, a more specific element of the theme and the settled quantity, was performed in Atlas.ti (2021). The codes were clustered in Microsoft Excel (2021) till the metric factors were mentioned at least three times (n=3). A combination between the metric factor and metric characteristic is called a "metric combination". In every article, all the phrases that mentioned a metric are labelled separately and the number is shown between the brackets in Appendix D. Again, the codes that only mentioned in one article (# (1)) are excluded from the further analysis. In the following examples (Examples 4, 5 and 6), the metric factors of the examples from Chapter 4 are shown. Underlined are the words that lead to those codes and the descriptions are provided in Appendix B.

Example 4: The objective factor(s), objective characteristic(s) and metric factor(s), underlined in the phrase, and overviewed in the table, of Example 1.

"The quality reports provide in-depth information about the structure and services of each hospital, such as range of diagnoses and number of provided treatments, number of staff, hygiene measures, number of complications or barrier-free accessibility."

Objective factor	**Objective characteristic**	**Metric factor**
Quality-of-care	Operational performance	Surgery volume
Quality-of-care		Treatment type
Quality-of-care	Surgical performance	Hygiene
Quality-of-care		Care outcomes

Example 5: The objective factor(s), objective characteristic(s) and metric factor(s), underlined in the phrase, and overviewed in the table, of Example 2.
"Methodologies were explicitly evaluated to minimize the impact of this project on provider workflow and comply with HIPAA requirements."

Objective factor	Objective characteristic	Metric factor
Surgical performance	Staff performance	Policy

Example 6: The objective factor(s), objective characteristic(s) and metric factor(s), underlined in the phrase, and overviewed in the table, of Example 3.
"VBHC links outcomes to costs and so determines value. The focus on the value of medical services could be a key element to ensure the sustainability of high-quality healthcare systems in the future; moreover, value could continuously drive performance improvement in care."

Objective factor	Objective characteristic	Metric factor
Finance	Value-based healthcare	Treatment type
Quality-of-care		

Below Examples 7 and 8 are given, with the objective combination and metric combination are shown, whereby the metric characteristic provides an extra accuracy to the metric, by indicating more specificity. In Example 8, the unit of the metrics were mentioned as well.

Example 7: The objective factor(s), objective characteristic(s), metric factor(s) and metric characteristic(s), underlined in the phrase, and overviewed in the table, of a phrase from Volk (2017).
"surgical performance and chance of mortality are strongly influence by the level of teamwork between OR personnel."

Objective factor	Objective characteristic	Metric factor	Metric characteristic
Surgical performance		Survival	Mortality
Team		Survival	Mortality

Example 8: The objective factor(s), objective characteristic(s), metric factor(s) and metric characteristic(s), underlined in the phrase, and overviewed in the table, of a phrase from Saporito et al. (2021).
"The introduction of the diagnosis-related group (DRG) in the 1990s overall helped in containing costs, aiming to increase turnover, lower the length of stay and perform more cases."

Objective factor	Objective characteristic	Metric factor	Metric characteristic	Unit
Finance		Surgery volume	Turnover	Money ($, €)
Finance		Length of stay		Money ($, €)
Finance		Surgery volume		Money ($, €)

5.3 Results

634 phrases in the 84 articles had a metric combination (metric factor, characteristic and/or unit). In these phrases, 2,153 metrics were mentioned, which means that on average one phrase includes 3.3 metrics. In total, there are found 70 metric factors and 42 metric characteristics, together leading to 133 metric combinations (in Appendix E together with the objective combinations).

There are found 133 metric combinations and the most common combination, including a factor and a characteristic, is factor Survival, with characteristic Mortality (47 (24)). If a unit should be included as well, the combination factor Survival, with characteristic Mortality and unit Deaths (#) is most common (44 (23)). The most common factor and unit, is metric factor Savings with unit Money ($; €; 37 (18)). If nothing from the elements of the metrics is obligatory (but still compared to all other combinations) in the metric combination, the factors Surgery volume (91 (39)) and Schedule (155 (22)) are most common.

5.3.1 Metric factor

The most common metric factors are Schedule (284 (26)) and Surgery volume (130 (43)). The factors Maintenance occurs the least (3 (2)).

5.3.2 Metric characteristic

Qua metric characteristic, Mortality (47 (24)), OR utilisation (27 (12)) and Morbidity (22 (14)) occur most frequently. Six of the 42 metric characteristics occurred on the stated minimum number (2(2)). The metric factor Schedule has 22 metric characteristics (129 (17)), which is 45% of all the phrases of the metric factor Schedule (155 (23)). Only one of the metric factors always occur with a metric characteristic, namely OR time (18 (7)) with OR break (11 (3)) and OR overtime (7 (4)).

5.3.3 Objective

The metrics are related to the objectives via the goal of measuring the metrics, these connections will be called relations in this study. Comparing the objective combination and the metric combination, there are 223 relations, as can be seen in Appendix E, the relation Management (objective factor) and Schedule (metric factor) occurs the most (54 (10)). There is no relation that includes both a characteristic of the objective and metric. The most common relation between the objective combination and metric factor is Surgical performance, with Staff performance and Education (6 (4)), and for the objective factor and metric combination, this is Care outcomes and Safety (objective factor) with Survival, and Mortality, respectively 11 (6) and 11 (7). 63 out of the 238 relations (26%) have a frequency of 2 (2) and 16 of those have a metric characteristic. 61 codes (in 412 phrases) did not include an objective at all and only a metric combination.

5.3.3.1 Objective factor and metric combination

Only considering the objective factors and the metric combinations, there are 238 relations. The most common relations between the objective factor and the metric combination are Management with Schedule (54 (10)), Finance with Treatment type (28 (15)) and Surgical performance with Skill (20 (14)), which do clearly not include a metric characteristic. If the characteristic has to be mentioned as well, the most common ones are objective factor Care outcomes, metric factor Survival and metric characteristic Mortality (11 (6)) and objective factor Safety, metric factor Survival and metric characteristic Mortality (11 (7)).

5.3.3.2 Objective factor and metric factor

Considering the both factors, there are 227 relations mentioned, whereby the objective factor Quality-of-care is mentioned with 40 metric factors and the objective factor Surgical performance with 30 metric factors. The objective factor Patient flow has the least metrics, four in total. The most frequent mentioned relation is Management with Schedule (116 (12)) and qua number of articles are Finance with Treatment type (31 (18)) and Surgical performance with Surgery efficiency (34 (18)) the most mentioned. The metric factor Schedule

is combined with 11 objective factors and Workforce with ten objective factors. A number of 13 metric factors have only one objective factor coupled.

5.3.4 Unit

There are 29 units defined in the articles, as shown in Appendix F. The most mentioned ones are Money ($, €; 276 (38)) and Time: OR time (hours; 117 (32)). There are eight units mentioned only twice. These units are still very specific, therefore they can be clustered in more general units, for example Time: OR time (hours; 89 (24)) and Time: Delay (hours; 9 (6)). Among others, these two units can be combined into the general unit Time. This led to a number of 17 general units, with as most common general unit Time (231 (39)).

5.3.4.1 Metric combination and unit

There are 101 relations found between the metric combination and a unit. The most mentioned are metric factor Survival, characteristic Mortality expressed in unit Deaths (#; 44 (23)) and the factor Treatment type expressed in Money ($, €; 37 (18)). The average for number of units per metric is 2.3 units, but the above two mentioned neglecting is this average around 1.7 units per metric.

5.3.4.2 Metric factor and unit

Excluding the metric characteristic leads to 92 relations between a metric factor and a unit. The metric factor Schedule is expressed in 17 units and OR utilisation in nine different units, which are the most heterogeneous measurable metrics.

5.4 Discussion

In this study, there are found 133 metric combinations for the performance optimisation of the OR. Due to the high number of metric combinations and the high number of objectives for the performance optimisation of the OR, it can be said that there is not one measuring method to cover all the aspects of the performance. However, this makes sense, since the OR and the optimisation in the OR have many aspects and services. For example, the objective factor Satisfaction cannot be expressed in Bed utilisation or Equipment type, but can be expressed in Communication and Workforce. However, those cannot correspond with the objective Resources. Altogether, it is unlikely, maybe even impossible, to define a singular optimisation objective and metric for the performance of the OR.

Most of the metrics are related to each other, similar as by the objectives. An example is that Workload and Workforce are related, since the more staff is working (Workforce), the less work one staff member has to perform (Workload). Workforce is also related to Finance, since the staff members expect salary. This example only shows two links between the Workforce; however, more relations could be found for this metric and other metrics. Another thing is that some of the metrics overlap with each other, this will be discussed further with answering the SRQ2b. For example, Communication and Decision-making, since the decision-making process requires communication (Littlejohn et al., 2017). Next to that, communication is part of Team and therefore overlapping.

5.4.1 Metric combination

There are 133 metric combinations, from which many do not have a metric characteristic, namely 64 (48% of the metric combinations). Whenever looking at the metric combinations, the two most common combinations do also not include a characteristic: Surgery volume (91 (39)) and Treatment type (86 (38)). This can also deductible from the fact that, seven of the eight metric combinations that occurred only three times in two articles had a characteristic. If a characteristic has to be included, Survival with Mortality (47 (24)) is most common.

5.4.2 Metric factor

If the metric characteristics are not combined in the metric factors, there are found 70 metric factors and the most common metric factors are Schedule (284 (26)) and Surgery volume (130 (43)). This could be justified by the fact that those are easily measurable, since it is just the patient count and administrative activity. For comparing ORs, Schedule could be a good method to measure, since it can be connected to 50% of the objectives. Besides that, Van Beekum (2022) found that two third of the optimisation strategies were focussed on scheduling, with as aim to improve the logistics of the schedules of the OR. Meanwhile, Maintenance occurs the least as metric (3 (2)), together with Accreditation and Hygiene (3 (3)), which are harder to measure, since they occur during an action or a specialist is required.

5.4.3 Metric characteristic

Qua metric characteristic, Mortality (47 (24)), OR utilisation (27 (12)) and Morbidity (22 (14)) are the most common. Mortality, OR utilisation and Morbidity are easy to measure, since Mortality and Morbidity require only counting and OR utilisation requires a calculation with information of the OR schedule and the opening hours. However, other metric characteristics are harder to measure, as Surgery efficiency, since this contains multiple aspects, as staff work, results, patients' reaction, which are harder to measure. The more complex the metric factor, the more metric characteristics are specified: for example, surgery scheduling is complex due to various factors (Zhang et al., 2021), therefore Schedule has many metric characteristics, namely 22.

5.4.4 Unit

Not all metrics can be expressed in or are not mentioned with a unit; however, 39 of the 70 metrics (64%) included a unit. Those 39 metrics are expressed in 29 different specific units. The unit Money ($; €) is most mentioned (156 (42)). A metric is not always expressed in just a singular unit. For example, Patient (health) condition can be a collection of three units, which specified the health condition by Patient health: Heart rate (bpm), Patient health: Blood loss (mL) and Patient health: Blood pressure (mmHg). The metric factor OR utilisation can be expressed in nine units and the metric Schedule is even expressed in 18 units.

From the top ten most occurring metric combinations, including units, just one of those metrics has a metric characteristic, namely metric factor Survival, characteristic Mortality and unit Deaths (#; 44 (23)). Therefore, the most relations are not specific. All of those most mentioned units are numbers and therefore straightforward to measure, such as Money ($, €), Time (hours) and Deaths (#). The high frequency of Time (153 (27)) can be explained by the ease to measure and the relation with other metrics. Notable is that eight of the 29 units are a version of a unit of Time. However, with some units, this is a different case, since the individual perspectives play a role. For example, Coaching (#): when is communication coaching; Complication (#): when is something a complication; and Tasks (#): how to divide one tasks in multiple small tasks. Remarkable is that some of the metrics would be expected to be expressed in a certain unit; however, they can also be expressed in another unit. An example is OR time (the time that the OR is occupied) can be expressed in Time: OR time (hours; 5 (4)), which seems reasonable and Money ($, €; 2 (2)). This last one is a less obvious unit; however, time always costs money due to occupation of the room, energy and salary. This example also shows that the units of the metric can overlap as well, similar to the objectives and metrics. Metrics as Authority (30 (16)) and Ergonomics (5 (4)) however did not state a unit at all (32 of the 70 metrics).

5.4.5 Objective and metric

The 14 objective factors, stated in Chapter 4, can be expressed in 70 metric factors, stated in Chapter 5, which indicates that on average one objective can be measured in almost 4.5 metrics (as an answer to SRQ2a). The most heterogeneous measurable objective is Quality-of-care with 38 metric combinations. The objective of WHO (2021a) is very broad: "*Health services for individuals and populations increase the likelihood of desired health outcomes*". This objective includes multiple aspects, therefore also able to measure in many ways. However, Satisfaction is an opinion and therefore there are less metrics related, namely six. Only 13 metric factors (19%) have a singular objective coupled, which also indicates that a metric can mostly be related to multiple objectives of the performance optimisation of the OR.

There are 223 relations taking in account the objective combination and metric combination. If the characteristics of the objectives and the metrics are eliminated, 238 relations are left, due to the relations that occurred only once or are mentioned in one article, are eliminated. Management (objective factor) and Schedule (metric factor) occur the most (116 (12)). This relation is quite plausible since the management is obligatory to provide the policy for the schedules. Some relations can only be explained in an indirect manner, as Finance and Treatment type (25 (14)). Finance is related to almost everything; however, the Treatment type is not the clearest one. The type of surgery determines the equipment, which all require different actions during the surgery, time and costs to produce. Some metric factors do not relate to an objective, respectively 79 phrases in 52 codes, as the metric factor Environment (16 (7)).

None of the most mentioned objective or metric combinations contain an objective or metric characteristic. Since these specifications do not occur that often, it can be stated that the most studies do not specify their objectives or metrics. Half of the metric combinations, which cover more than 80% of the phrases, do not have a metric characteristic. For the objective combinations, there are eight objective factors that include a characteristic, which includes 18% of the phrases. For that reason, it can be said that the HCPs prefer to have a more global objective and metric, instead of limiting their scope already.

Due to the overlap and the linkages between the objectives, innovations and metrics, the most codes were already related to each other and therefore formed a network of objectives and metrics. The most mentioned description for the optimisation was a balance between Cost vs. Bed utilisation (15 studies), which in objective factors (of this study) corresponds with Finance (227 (36)) and Service (136 (24)) or the metric factors Cost (26 (13)) and Bed utilisation (21 (12)). As can be seen, the number from the objective factors is more corresponding (with a correction for the number of articles that have been researched) with the results from Van Beekum (2022), than the metric factors; however, the goals of a metric are more corresponding to the description of the optimisation, namely an optimisation strategy.

An extensive literature has been performed to answer SRQ2 (*"What are the assessment criteria to quantify the performance optimisation of the operating room?"*). There are found 133 metric combinations with 70 types of metric factors and 42 metric characteristics, indicating a heterogeneity in the perspectives of the assessment criteria for the quantification of the OR performance optimisation. Schedule was the most mentioned metric factor, namely 45% of all the phrases. 56 metric factors (80%) are related to more than a singular objective, whereby the definition Quality-of-care is related to 38 metric combinations. In total there have been found 223 relations, taking in account the objective and metric combination. These relations form the answer to *"How are the assessment criteria and the objectives of the operating room related to each other?"* (SRQ2a).

6 Causal relations between metrics of the performance optimisation of the OR

As discussed in Chapters 4 and 5, there is found a high diversity in the perspectives on the objective of the performance optimisation of the OR and on the specific assessment criteria to measure this performance optimisation (metrics). The objectives and metrics are in some way related to each other, due to the influences from metric to an objective and from one metric on the other. This provides the HCPs with insight in the consequences and impact of their optimisation. This chapter finalises the first diamond from the double diamond, to fully understand the problem.

6.1 Aim

The aim is to find the causal relations between the metric factors (from Chapter 5), as an answer to SRQ2b: *"How are the assessment criteria of the operating room performance optimisation affecting on each other?"*, in order to find the impact of an optimisation on the performance. The relation between a cause and a result, will be called a causality in this study. By mapping the causalities as a causal diagram, there should be provided a clear overview of these causalities to show the HCPs the influences of an optimisation metric.

6.2 Method

The 56 articles used for finding the causalities are found with the search terms '*("Operation room" OR "operating room" OR "operating theater" OR "operating theatre") AND (optimization OR optimize OR optimisation) AND (hospital OR healthcare)'* on *PubMed*, *Scopus* and *Web of Science* data bases, and also used in Van Beekum (2022). In Figure 10, all the criteria for this research are shown in the PRISMA chart.

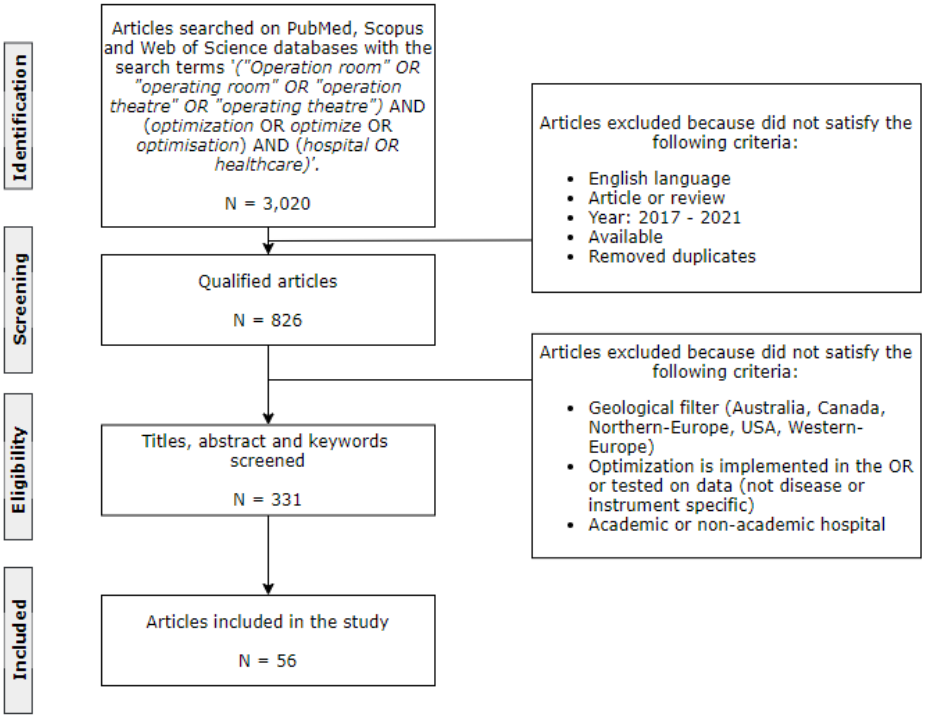


Figure 10: The method, according to the PRISMA checklist, used to make an inventory of the current literature about OR optimisation.

Those articles have been uploaded to Atlas.ti (2021) and all the phrases with a causal relation between minimal two metrics are labelled by the code “links metrics” and afterwards the cause and the result of the causal relation were coded by closed-coding with the metric factors from Chapter 5. A cause-metric, influencing the other metric, was coded by “@metric”, and result-metric, the metric that received the influence, was coded by “&metric”. Since all the causalities should be mapped, the metrics are only divided in cause- and result-metric, not specified to factors and characteristics. The link between the cause- and result-metric will from now on called “causality”. Those codes are transferred to Microsoft Excel (2021), and the cause- and result-metrics are labelled with the metric codes of Chapter 5. Two examples are provided in Examples 9 and 10. The causalities between metrics that only occurred in once in one article have been removed, which differs with the other methods.

Example 9: A phrase from Naderi et al. (2021), which presents a causality between the three metric factors Idle time, Waiting list and Patient flow. The causalities, underlined in the phrase, are overviewed in the table.

“Due to effective circumvention of idle and wait times resulted from the adoption of an open scheduling strategy in GORPS, surgeons’ throughput are on average 33% higher than those of ORs and anaesthetists.”

Cause-metric	**Result-metric**
Idle time	Patient flow
Waiting list	Patient flow

Example 10: A phrase from Burdett & Kozan (2018), which presents a causality between the two metric factors Policy and Operational performance. The causalities, underlined in the phrase, are overviewed in the table.

“Scheduling policies can have a great effect on hospital performance.”

Cause-metric	**Result-metric**
Policy	Operational performance

After clustering the causalities twice, the causalities that occurred in a low phrase frequency (n=2) have been relabelled with intermediate links, to understand the direct steps between the causalities. Those intermediate links can be seen as interim steps and therefore are in relation to the following metric and create the bonding from a cause-metric to a result-metric. These links are based on the previous found links, that occurred more than twice in frequency, starting with using the most occurring ones. Afterwards, the causalities with intermediate links are added to the remaining causalities. An example is shown in Example 11. In this process, the eliminated causalities, occurring only in one article, are removed after applying the intermediate links, since then more information was conserved before.

Example 11: A phrase of Kroer et al. (2018), that shows a causality between the two metric factors Responsiveness and Shift, with the intermediate links. The causalities, underlined in the phrase, are overviewed in the table.

“The overtime work includes emergency operations, which contribute with a lot of uncertainty and thereby increase the expected overtime work.”

Cause-metric	**Intermediate link 1**	**Intermediate link 2**	**Intermediate link 3**	**Result-metric**
Responsiveness	OR time	OR utilisation	Surgery duration	Shift

After the intermediate links, the metrics and causalities are clustered in more general codes by open coding, to make the overview more orderly. To provide a clear overview, the causalities have been mapped in Draw.io (2021), to a causal diagram.

6.3 Results

There are found 506 phrases in 56 articles, that describe the causality between metrics. In those articles, there are mentioned 2,282 causalities between metrics. The causalities between the cause- and result-metrics can be seen in Appendix G. Without the intermediate links, there were found 537 causalities between a cause- and result-metric. More than 50% of those causalities (n=1,290) occurred only twice, whereby the most of them were only mentioned in one article. The most common causalities were the Schedule to Cost (64 (19)); OR time to Cost (93 (16)); and Shift to Cost (97 (19)).

6.3.1 Intermediate links

The intermediate links are applied by 47% of the causalities and 58% of these had more than one intermediate link. This is resulted in 253 causalities of cause- and result-metrics, with 42 defined metrics. These are the same metrics as the metric factors from Chapter 5. The most common was still Shift to Cost (97 (19)). Also, the other two previous mentioned were most common, without a significant change of number of phrases; Schedule to Cost (64 (19)), OR time to Cost (95 (16)). By use of those intermediate links, the number of causalities that only occurred twice have been reduced to 113 causalities instead of 254 causalities.

The cause-metric Policy has the most linked result-metrics, namely 26 metrics. The cause-metrics Schedule (405 (27)) and Surgery duration (388 (35)) are the second and third metrics with most result-metrics, respectively 20 and 14 metrics. Seven cause-metrics (17%) have one result-metric: Culture (24 (2)); Operational performance (12 (2)); Care outcomes (2 (2)); Profit (30 (2)); Revenue (45 (2)); Waste (17 (4)); and Workforce (13 (2)). The result-metrics with the most cause-metrics are Cost (948 (64)), Surgery duration (348 (24)), Safety (170 (27)), respectively 26, 13 and 12 cause-metrics. The result-tric Length of stay is the only metric that is caused by just one metric, namely Cancellation (11 (4)). There are five result-metrics that are caused by two cause-metrics.

In Figure 11, an overview of the impact and consequences of a metric on the other metrics are presented, indicating that changing a variable (metric), can influence many other variables. The common causalities, mentioned in at least three articles and more than 20 phrases (20 (3)), between the cause-metric and result-metric are shown in a causal diagram. This number is chosen to provide a more orderly overview than with all the causalities presented. The grey boxes show the metrics and the direction of the arrow directs from the cause-metric to the result-metric.

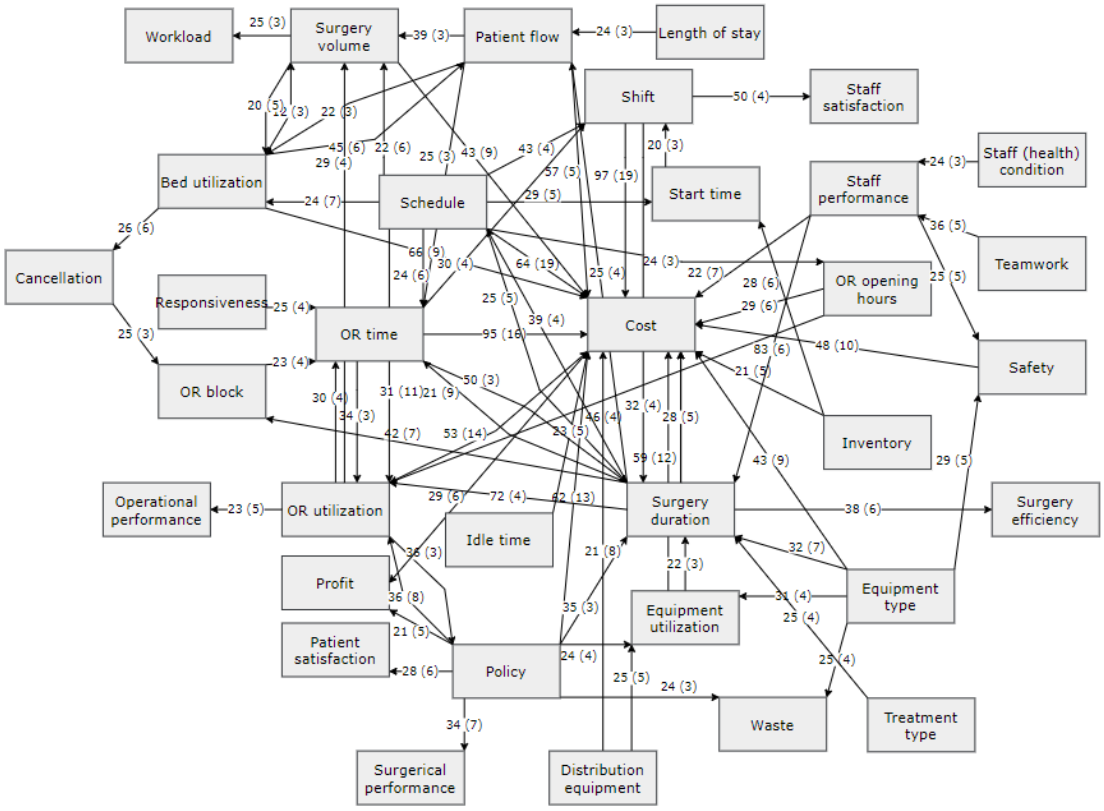


Figure 11: A causal diagram of the metrics presenting a causality. The causalities that are mentioned at least in three articles and mentioned at least in 20 phrases (20 (3)) are presented. The frequencies are mentioned within the arrows, whereby pointing to the direction of the influence.

6.3.2 Generalisation

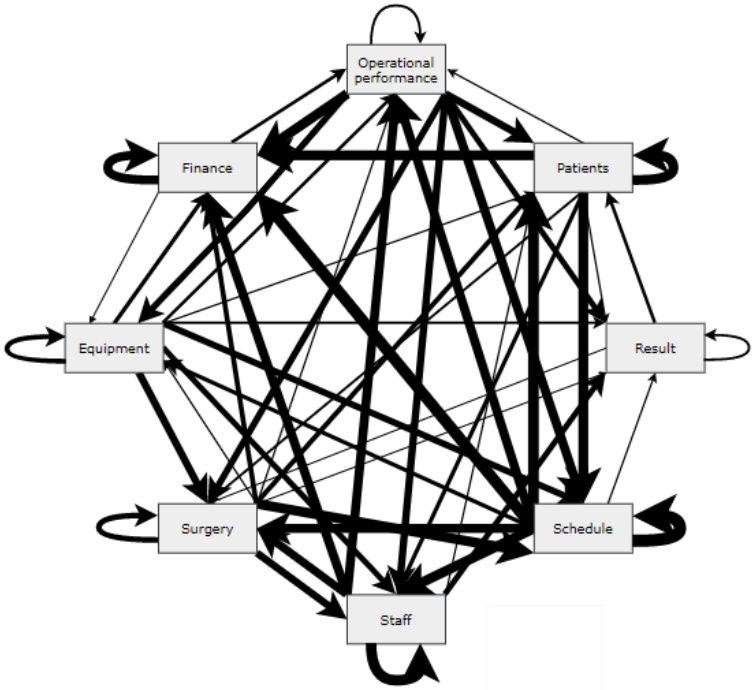
Generalising the metrics resulted in eight generalised metrics (Appendix H). These metrics are similar as the metrics mentioned before; however, right now they cover a broader aspect of the OR. The generalised metrics: Equipment, Finance, Operational performance, Patients, Result, Schedule, Staff and Surgery. Figure 12 gives a more orderly overview of the 51 generalised causalities. A short description of all the generalised metrics is followed:

- Equipment: all the material that is used in the OR;
- Finance: everything concerning money;
- Operational performance: the management related aspects;
- Patients: everything concerning the patients and its diseases;
- Result: the effect of the surgery;
- Schedule: everything related to time, planning and date of the surgery;
- Staff: everything concerning the people that are working in the OR and its acts;
- Surgery: everything concerning the surgery and its process.

The most common causalities all start with Schedule and lead to the following result-metrics Finance (305 (33)), Schedule (475 (33)) or Patients (218 (28)). The causality Staff to Staff (235 (19)) is the first causality without Schedule with the most phrases. Nine causalities were only mentioned in two articles, whereby Result to Surgery has the least phrases (2 (2)). This causality describes the probability on another surgery type (Surgery) after the surgery does not reach the desired outcomes (Result). Schedule has been mentioned in the most articles and phrases (1,441 (42)) as cause-metrics and for the result-metrics this is also Schedule (1,070 (44)). Also, for these causalities, there is made a flow-diagram, shown in Figure 12. This

diagram provides all the causalities between the metrics, whereby the width of the arrows represents the number of articles, which can be seen in Appendix H.

Finance, Operational performance, Patients, Result, Surgery are a result of all metrics, except one, and therefore are influenced by many metrics. Equipment and Schedule only were caused by five of them, and Staff by six (not towards Schedule). As the cause-metrics, the receiving boxes Equipment, Operational performance, Schedule and Surgery receive from all cause-metric at least two phrases. Finance and Result only receive three cause-metrics.



Generalised metric	Metric factors
Equipment	Distribution equipment, Equipment type, Equipment utilization, Inventory, OR design, Waste
Finance	Cost, Profit, Revenue
Operational performance	Operational performance, Policy, Responsiveness, Safety
Patients	Bed utilization, Length of stay, Patient (health) condition, Patient flow, Patient satisfaction, Surgery volume
Result	Care outcomes, Surgerical performance
Schedule	Cancellation, OR block, OR opening hours, OR time, OR utilization, Schedule, Start time, Waiting list
Staff	Culture, Idle time, Shift, Staff (health) condition, Staff performance, Staff satisfaction, Team structure, Teamwork, Workforce, Workload
Sugery	Surgery duration, Surgery efficiency, Treatment type

Figure 12: A causal diagram of the generalised metrics. The width of the arrows represents the number of references.

6.4 Discussion

With the 42 found metrics of the optimisation of the OR, there were found 253 causalities, whereby changing one variable (metric) influences other variables. This means that on average one metric has influence on six other metrics. Therefore, it can be stated that metrics have a lot of influence on each other and that many aspects of the OR are related to each other, similar as discussed in Chapter 4 and 5. It is good for the decision-making process to realise the impact of the metrics on each other (Leinonen et al., 2008), to anticipate on the possible coming changes. The professionals often focus on the metric and the desired result, without taking in account all the consequences (Leinonen et al., 2008), therefore an overview of this is from importance.

The most frequent stated causalities are Shift to Cost (97 (19)), Schedule to Cost (64 (19)) and OR time to Cost (93 (16)), Cost is mentioned in all of them as the result-metric. Cost is the most occurring result-metrics with 948 phrases (948 (46)). Therefore, it is not surprising that 10% of the causalities have Cost as result. However, Cost has in total only 83 phrases (83 (9)) as cause-metric, and is only for three metrics the cause-metric (Profit (29 (6)), Revenue (47 (2)) and Waste (7 (2))). Cost is mainly a result-metric for the performance optimisation of the OR instead of a cause-metric. The Shift to Cost (97 (19)) is due to the salaries of the staff members.

Next to Cost, the other financial related metrics are closely involved: Revenue (45 (2)) and Profit (30 (2)). Those two are mainly a result of other cause-metrics; however, Profit is related to Policy as cause-metric. Even though, Revenue and Profit are mostly related to the financial metrics, Profit is related to three other non-financial metrics as result-metric, namely OR utilisation (6 (2)), Policy (21 (5)) and Schedule (7 (2)). Therefore, it can be said that also Revenue and Profit, primarily behave as a result-metric, with Profit as cause (30 (2)) and result (108 (10)), and Revenue as cause (45 (2)) and as result (62 (4)). The causalities Schedule to Cost (64 (19)) and Policy to Cost (62 (13)) are predictable since those are also the most combined metrics. The cause-metric Policy is with 26 different result-metrics and Schedule with 20 result-metrics. The most receiving result-metrics are Cost (with 26 cause-metrics), Surgery duration (13 cause-metrics) and Safety (12 cause-metrics). The result-metrics, OR time and OR utilisation have the most cause-metrics, both mentioned as a cause to 11 result-metrics. Therefore, those metrics are mostly mentioned as a result, but not as directly impactable aspects.

As said before, there are used different articles for those causalities than are used to define the metrics of the performance optimisation of the OR. The message of the articles was different, namely optimisation instead of performance optimisation, therefore other metrics are found. However, within those 56 articles, there are three overlapping articles with the 84 articles from Chapter 4 and 5, namely Breuer et al. (2020); Feldstein (2010); and Koppka et al. (2018). The verification of the results of the earlier found metrics and reduction of the influence of one article is done by coding with the metrics from Chapter 4 and 5. Besides that, the causalities are based on intermediate links, which are added by researching the frequencies of other causalities. However, this can mean that a causality is missed or overwritten by an intermediate link, even though this included a direct link.

The number of phrases for the causalities have a higher number than the labelled phrases in the articles, due to one phrase could include multiple causalities. The number of phrases is increased due to clustering, the intermediate links and generalisation. Even though the number of phrases is inexact, this number can still provide an indication of the frequency of mentioning of the causality.

6.4.1 Metrics

When comparing the results of this chapter to the metric factors of Chapter 5, it can be concluded that the causality between metrics is well discussed, since the number of found phrases per article is higher (9 phrases per article for OR performance optimisation vs. 7 phrases per article for OR optimisation). One of the reasons could be that the articles used for the causalities were focused on the optimisation of the OR and therefore can have more focus on other aspects of the OR than the articles that focused on solely the performance optimisation of the OR (Chapter 4 and 5).

As said, there are 42 metrics related in this overview of the causality between metrics; however, in Chapter 5 is stated that there were 70 metrics found. This means that there is a difference of 28 metrics. There are two metrics mentioned in this chapter, that were not mentioned in the 70 metric factors of Chapter 5: Cancellation (cause-metric: 71 (8); result-metric: 69 (16)) and OR opening hours (cause-metric: 85 (9); result-metric: 38 (6)). These codes occurred as metric characteristic as by Cancellation, and as unit as OR opening hours, and have been added with open coding after clustering. So, 31 metric factors from Chapter 5 were not mentioned in a causality. It could be the case that some of the metrics were less often mentioned and therefore are eliminated. However, some of them has also been deleted due to a low number of references, for example for Discharge and Trust. Next to that, these

metrics are partly categorised under other metrics, such as Behaviour within Team, since the differences were not clear mentioned in these articles.

6.4.2 Generalisation

With those generalised codes, the number of metrics is reduced from 42 to 8 and the number of causalities reduced from 253 to 51 (Figure 12). This provides a clearer overview; however, this also reduces the details. The lack of details results in causalities within almost all the metric-blocks and causalities to its own metric-block; nevertheless, it provides a clear overview. The most mentioned causalities are Schedule to Schedule (475 (33)) and Schedule to Finance (305 (33)) and. The second one corresponds with the most mentioned ungeneralised causalities Schedule to Cost (64 (19)) and OR time to Cost (95 (16)). However, the ungeneralised causality Shift to Cost (97 (19)) is part of Staff to Finance, which occurred in 24 articles with 149 phrases (149 (24)), which is the fifth most mentioned causality. This indicates that generalising lead, as expected, to a loss of more detailed information and therefore can provide an inconsistent message. Accordingly, the generalised metrics can only be used for a quick overview and no rights can be derived.

Schedule has been mentioned in the most articles as cause-metrics (1,441 (42)) and as result-metrics (1,070 (44)). The causality Schedule to Schedule (475 (33)) is common. Schedule is as cause-metric related to all the result-metric; however, it is the result of five cause-metrics, since Staff and Finance do not directly affect Schedule. Before the generalisation, the cause-metric Policy (122 (39)) has the most linked result-metrics (26) and cause-metric Schedule (405 (27)) has the second most result-metrics (20). Schedule as a result-metric does not occur often before generalisation. For the cause-metrics applies that four of the eight (50%) are related to all the metrics; Equipment, Operational performance, Result and Surgery. This does not occur by any of the result-metrics, indicating that are not necessarily two-way and cannot be reversed. An example of this is Patients to Equipment, which does not occur; however, Equipment to Patients occurs in two articles with 18 phrases. This also implicates that the causes influence more to similar results, since the results are less common related.

To answer SRQ2b (*"How are the assessment criteria of the operating room performance optimisation affecting on each other?"*), 56 articles about optimisation in the OR are analysed. Within the 42 found metrics, 253 causalities of cause- and result-metrics are found, with as most common Shift to Cost. After generalising these causalities into eight general metrics, 51 generalised causalities, with Schedule to Schedule as most common general causality.

7 Critical node

The main goal of this study is to design a tool that supports the decision-making on optimisation for the OR performance. After establishing the objectives and metrics of the performance optimisation of the OR by a literature study, the decision-making process for optimisation in the OR should be analysed. Resulting to the discovery of the critical node in this chapter, since this is the current problem within the decision-making process for the OR performance. Based on this node, the design goal will be stated, as a start for the second diamond; design to deliver.

7.1 Aim

This chapter discusses critical node, the problem of the current situation, and the design goal of this study, to start the designing phase for answering MRQ: "*How can a decision-support tool for optimisation in the operating room help a healthcare professional to select the objectives and the assessment criteria for performance optimisation of the operating room and the optimisation impact?".*

7.2 Method

After finding the objectives and metrics of the performance optimisation of the OR and the causalities in the metrics, it is important to state the requirements of the decision-making for the OR and the current problem in this process. In Chapter 3, the decision-making process of the hospital and university are stated. In this chapter, the similarity in these processes is defined as finding the focus area. Within the focus area, the problem in the current decision-making process is searched, which is called the critical node. The critical node leads to the design aim for the tool.

7.3 Results

The decision-making process in a hospital and at a university are discussed in Chapter 3. There are several steps that are required in order to invest money or time in a new optimisation. The start focusses on the desire to optimise due to an innovation or a problem. To optimise, the goal of the studies should be determined, based on information from the (research) questions and literature or from the input of the HCPs (such as the objective of the performance and the optimisation metrics). This comes down to the information from Chapters 4, 5 and 6, which state the objectives, the assessment criteria and the possible impact of the optimisation. This information can be delivered in a report, in a meeting or in a literature review, this depends on the preference of the HCPs. Figure 13 provides an overview of three processes of decision-making per organisation, to simply compare the processes.

The steps can differ per hospital or process; however, they agree about sharing the necessity of the information about the problem, desired state and the methods (Liberatore & Nydick, 2008; Nassiri et al., 2020; Pennington & DeRienzo, 2013). Different HCPs think different about these goals, therefore there is unconsciously not a mutual vision between the HCPs. This mutual vision is important for reaching the aim and accepting the innovation (Leinonen et al., 2008). Besides that, the mutual vision helps the decision-making process (Littlejohn et al., 2017). To create a mutual vision, the HCPs should all share their perspectives on the objectives and the situation should be considered in its whole (Leinonen et al., 2008; Littlejohn et al., 2017).

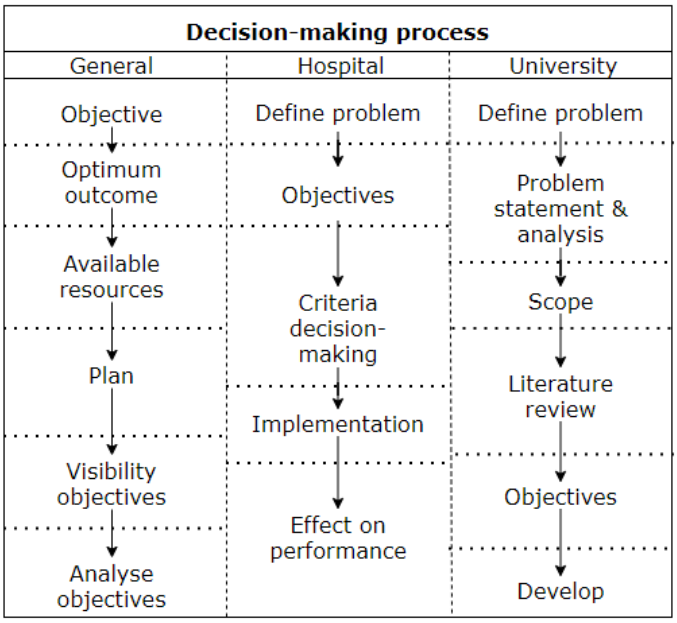


Figure 13: A combination of the decision-making process in the hospital and the university (a theory chosen from Figures 6, 7 and 8). The dashed lines state the time-frames of each step and therefore overlap with the other methods.

7.4 Critical node

With the desired state, the HCPs are trying to find the most preferably/best performance (Guo, 2020) of the OR. Therefore, the state could be characterised as the performance optimisation of the OR, and desired could be defined as most preferably/best, which depends on the individual. Accordingly, the desired state can also be expressed as "the best performance of the OR". Therefore, this report starts with the objectives of the performance optimisation of the OR and the related metrics. In the last chapters, there has been found a high heterogeneity in perspectives on the objectives and on the metrics of performance optimisation of the OR and in the relationship between those two. These metrics were related to each other by possible direct links or intermediated links, which shows the impact of adjusting a variable on the other variables, and therefore indirectly on the performance. Figure 14 provides a simplified systematic representation of the relations between the performance objective, the metrics and the causalities of the metrics, in order to understand the complete system.

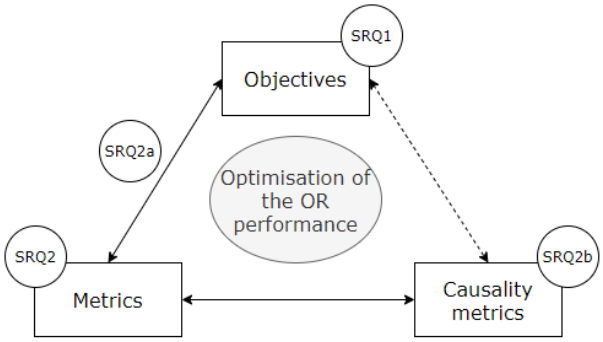


Figure 14: The relations between the performance objectives, the metrics and the influences on other metrics (causalities). The solid lines are direct relationships and the dashed line presents an indirect relationship.

A consequence of the limited research to the objective of performance and the optimisation metrics in the OR is that the impact on the performances by adjusting a variable are not well studied. This information is important for the decision-making process (Turner et al., 2017), since the HCPs should have a mutual vision of the objectives (Leinonen et al., 2008). The lack of a clear vision on all the facets of the OR by the HCPs could influence the decision-making in a negative way, since the optimisation does not fit the performance or staff members, does not improve the desired metrics or is a fruitless investment. To support a well-informed decision-making, a view of (the optimisation of) the OR performance concerning the complete system

should be presented to the HCPs. The impact of the optimisation on the total performance of the OR are often unknown (Leinonen et al., 2008), and mapping these consequences is a step that is often passed up in the decision-making process (Guo, 2020). Therefore, the area of the complication in the decision-making process is in the beginning of the process, as is presented with a red dashed line in Figure 15. The critical node of this study is: "*The HCPs do not have a complete vision of the performance of the OR and impact of optimisation, due to the lack of information of the impact of optimisation on the performance of the OR".*

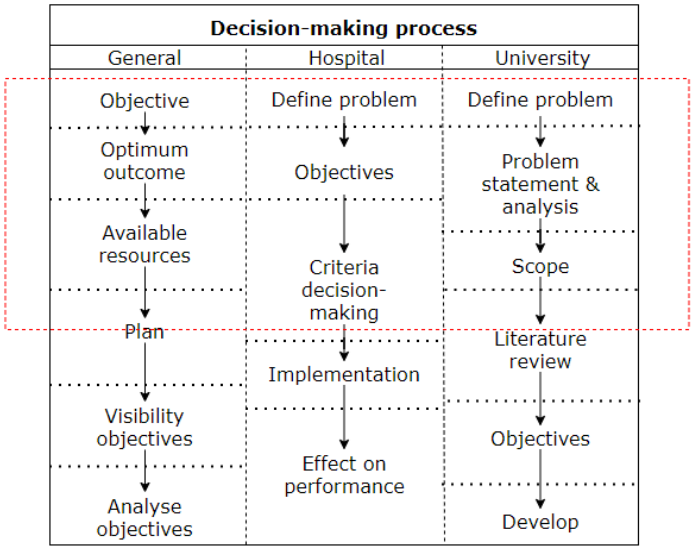


Figure 15: The critical node of this study is established, presented with a red dashed line in the decision-process, based on Figure 13.

7.4.1 Design aim

The aim of this study was to develop a decision-support tool for HCPs to guide the selection of objectives and assessment criteria for performance optimisation of the OR and accounts for the impact of an optimisation on the total system. Since there is a lack of a complete vision of the performance optimisation of the OR (critical node), an orderly overview of factual information is required (Turner et al., 2017), which are in this case objectives and assessment criteria for the OR performance (the relationships between those aspects are presented in Figure 14). This can help with covering-up the blind spots of the HCPs towards the OR performance and the impact of the optimisation. To help designing this overview, there should be an overview of all the relations between the objectives and metrics and causalities between the metrics, which could indirectly provide a link to the performance objectives (Figure 14). This view, considering the complete system, can be seen as the holistic view of (the optimisation of) the OR performance. This route from the problem to the tool is described shortly in Figure 16. Based on the critical node, the design goal can be formulated as *"Designing a support tool that enables and standardised the decision-making process of HCPs on optimisation for the OR by providing a holistic view of the performance objective and its metrics"*.

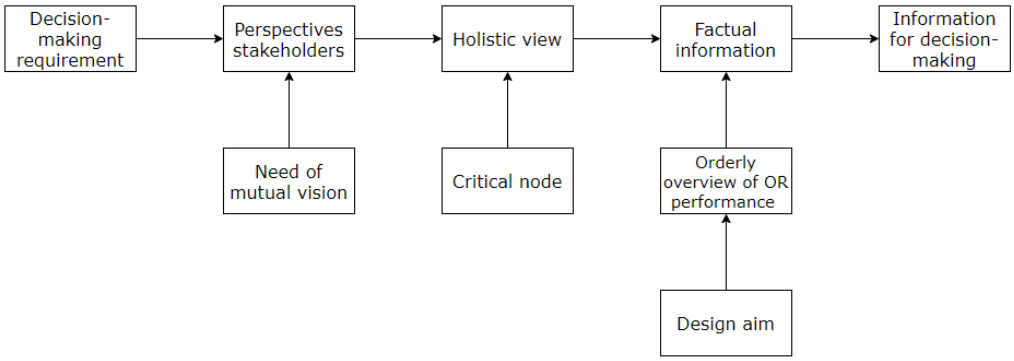


Figure 16: Relation between the decision-making process, the critical node, the design aim and the desired result.

The HCPs do not have a holistic vision of (the optimisation of) the performance of the OR and impact of optimisation, due to the lack of information of the effects of optimisation on the performance of the OR and the lack of mutual goals. Therefore, the decision-making process could benefit of a decision-support tool, with as design aim: *"Designing a support tool that enables and standardised the decision-making process of HCPs on optimisation for the OR by providing a holistic view of the performance definition and its metrics"*.

8 Design process

The design process is based on the double diamond of Design Council (2021), which covers the design phase from the problem via the critical node to the final tool. In this chapter, there will be an overview of the diverging part of the second diamond to develop a design and therefore, the concepts for the tool will be outlined.

8.1 Aim

In this chapter, the design criteria are stated to find the means for developing the decision-support tool, which is the answer to SRQ3: *"What means can be developed to support decision-making on an optimisation of the performance of the operating room?"* and fulfils the aim of this study: "*To develop a decision-support tool for healthcare professionals that guides the selection of objectives and assessment criteria for performance optimisation of the OR and accounts for the impact of an optimisation on the total system".* Therefore, the previous chapters and (sub) research questions are required. With the design criteria, a concept/multiple concepts will be chosen to lead to a design of the final tool.

8.2 Method

To understand what kind of means can be developed to support the decision-making process on the performance optimisation of the OR and the understanding the impact of an optimisation, the design criteria for the tool are stated. The literature, critical node, design goals, the authors intuitiveness and knowledge are taken into account to state these criteria. These have been clustered into general categories and design criteria, and weightings have been added according to the importance of the criteria. Considering the design criteria, there are selected some concepts, based on a personal brainstorm with influence of sources on the internet, with the search term "*matrix overview*" and the authors knowledge. The concepts will be reviewed and compared with the use of a Harris profile method. A Harris profile lists the criteria and interpret the criteria on a scale from -2 to +2, whereby -2 unsuccessful and +2 fully successful is, to visualise the quality level of the criteria (Roozenburg & Eekels, 1995). The scores are multiplied with the assigned weight per criteria. The concepts with the highest scores will be selected, whereafter these concepts have been discussed with the supervisor of this project and two potential users of the tool, to get a professional perspective from the practice field.

8.3 Results

Based on the above-mentioned method, the design criteria have been defined, followed by the concepts and the evaluation of these concepts. This leads to the selection of a concept for a tool to support the decision-making process in the OR.

8.3.1 Design criteria

Considering the design goal, the knowledge of the decision-making process and the authors intuitiveness, the design criteria have been set up. These criteria can be divided in three main design categories (in blue in Figure 17), with minimal two design criteria (in red in Figure 17). Herein, the design goal of this research is placed in the middle: creating a holistic view of the performance of the OR. In purple in Figure 17, the justifications are presented, which indicate the extra information of the design criteria. By explicitly outlining the basis for the information, it allows stakeholders and decision-makers to create a holistic view and consider all the facets of the OR during their decision-making process. The design criteria, written with capitals, will be explained below (in alphabetical order), including the reasoning, with three main design categories Availability, Insight in impact and User-friendly.

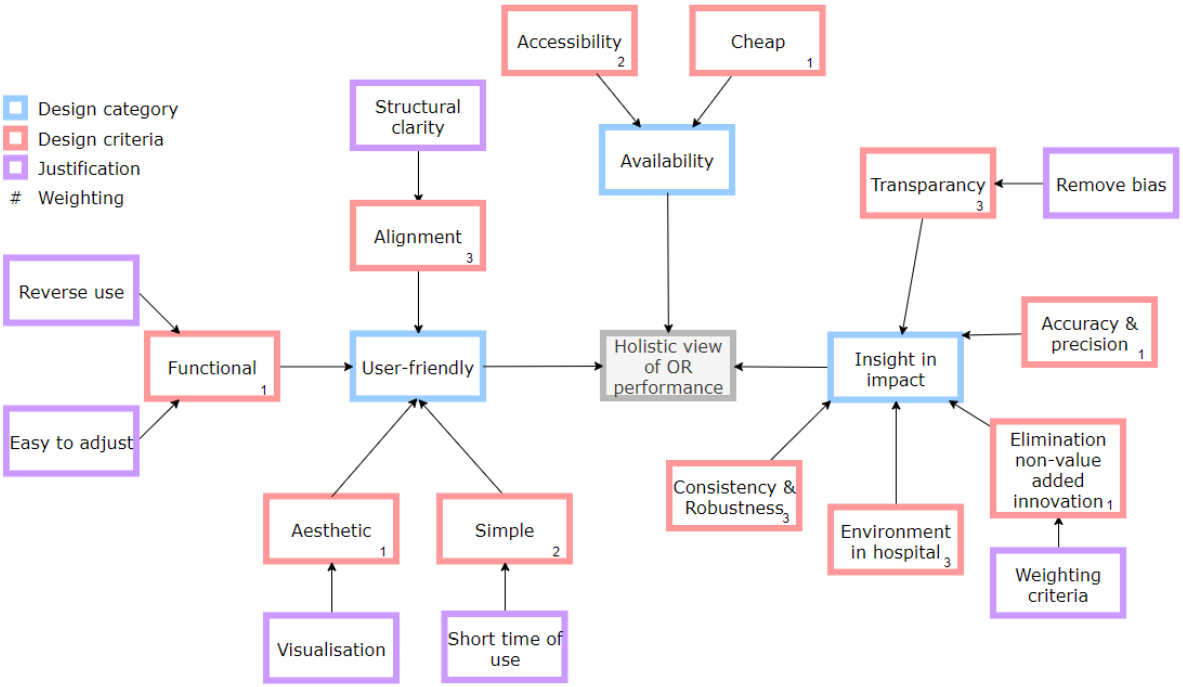


Figure 17: The criteria for designing the tool. With the colours that present the level of criteria and the numbers in the design criteria present the weightings of the criterion. Blue presents the main design categories, red the design criteria and purple boxes are the justifications, which present the extra information for the design criteria.

First of all, to ensure the application of the tool, the design category Availability is mentioned. This category can be divided into design criteria Accessibility and Cheap. Accessibility guarantees the tool to be applied without installing a new program, it should be easy to analyse at every moment and situation in the process and therefore, the tool should run on a well-known program for the current HCPs. This links closely to Cheap, since the hospitals have to limited their expenses (Zhang et al., 2020; Zhang et al., 2021) and accordingly should willing to purchase the tool.

The second design category is the Insight in impact, with the design criteria Accuracy & precision, Consistency & robustness, Elimination non-value-added innovations, Environment in hospital and Transparency have been defined. Accuracy & precision expects the tool to provide correct information in a precise manner. According to Consistency & robustness, this information should be consistent and should have a significant amount of certainty. Besides that, this design criterion suggests the improvement of consistency in the decision-making process over time by applying a standardised framework to different projects. The irrelevant information should be eliminated, according to the design criterion Elimination non-value-added innovations, which splits in Weighting criteria. This is to provide a manner to decide on the elimination since it provides overview, challenges assumptions and understand trade-offs between options. The design criterion Environment in hospital suggests that the idea should align with the company's production strategy and is usable in a hospital facility. Transparency describes the straightforwardness and clarity in the information, the user should be able to understand and process the outcomes, and the personal bias of the users should be minimised to influence the information.

User-friendly is the last design category, dividable in Aesthetic, Alignment, Functional and Simple. The Aesthetic is the appearance of the tool, whereby the information should be visible and clear (justification Visualisation), by the use of shapes, colours, decoration etc. Alignment describes the requirement to provide an understandable overview and a structural clarity (justification Structural clarity). The Easy to adjust and Reverse use are part of the design criterion Functional. This describes the necessity to solely provide the information that is desired, it should be easy to add or update information, when desired and the tool should be able to be used in the other way around, so that it does not matter what the starting point (problem or desired change in metric) is. Last but not least, the tool should be easy to use and should take a short time period (Short time of use), which is defined the design criterion Simple.

8.3.2 Concepts

This section is divided into two parts: programme and overview. The design criteria can be divided over those two topics as well. In programme, the programme wherein the tool could run is defined. Accessibility, Cheap, Environment in hospital and Functionality are related to the programme. In overview, the concepts that outline the information are presented and the other seven design criteria are considered.

8.3.2.1 Programme

The tool has to be developed in a computer software programme, to make it available for all the HCPs. Therefore, the software programme should be simple, user-friendly, relevant and recognisable for the HCPs, which also facilitate adjustments to the desires of the users. Based on the knowledge of author and the available software of the Delft University of Technology, five computer programmes have been selected as concept to run the tool. These programmes are LabVIEW; MATLAB; Microsoft Excel; Microsoft Word; and Python. LabVIEW is a graphical programming environment engineers use to develop automated research, validation and production test systems (N.I., 2022). MATLAB is a programming and numeric computing platform to analyse data, develop algorithms and create models (MATLAB, 2022). Microsoft Excel and Word are both programmes from Microsoft 365 (Microsoft Corporation, 2022), whereby Word is a word processing program and Excel focusses on spreadsheets and data analysing. Python is a programming language with an open source and many developed applications (Python, 2022).

8.3.2.2 Overview

Based on the seven design criteria for the overview, ten concepts have been outlined (Figure 18) and below they are described shortly (in alphabetical order). The causal diagram (also called an arrow diagram) presents a process to find the optimal order of events and their interconnectivity, which leads to finding the critical node (ASQ, 2022). The circle diagram (based on the table wheel of Plutchik's emotions wheel) describes relations between several factors, to understand the complex interconnectivity between all the factors (Sixseconds, 2022). The decision tree is a planning overview that provides an overview of the hierarchy of tasks or factors, which can help by decision-making (ASQ, 2022). A flowchart is defined as sequential order of process steps in a descriptive manner (ASQ, 2022). A chart for deciding between several solutions by comparing the impact and effort of all the solutions is the impact-effort-matrix (ASQ, 2022). The interrelationship diagram is similar to the causal diagram; however, it shows the cause-effect relationships, to identify all the relations between factors (ASQ, 2022). The matrix table is the well-known type of table and displays the relationships by the use of a diagram with columns of information (ASQ, 2022). The multiple criteria decision analysis (MCDA), also called the decision-matrix, evaluates options based on the criteria and its weights (ASQ, 2022). Plus, minus, interesting (PMI technique) is also known

as the Naranjo scale, supports decision-making by assigning the positive, negative and implications of a concept (Murali et al., 2021). The success & effect diagram is a fishbone structure that helps discovering the critical node, due to making an overview of the process from the beginning to the success (ASQ, 2022).

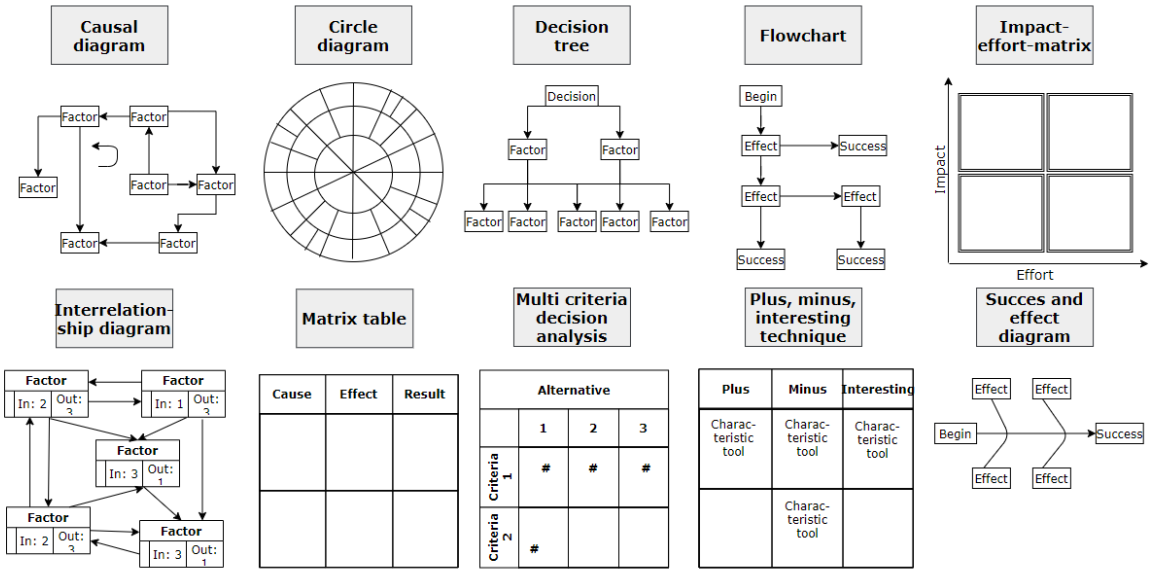


Figure 18: The overview concepts for the tool in alphabetical order.

8.3.3 Selection

After all the concepts were defined, the selection procedure was started. This was done in two phases: discussing concept and working out the Harris profile. The concepts have been discussed with a fellow master student and a PhD-candidate at the Utrecht Medical Centre, Utrecht, The Netherlands, whom could be a potential user of the tool. Four overview concepts, causal diagram, circle diagram, PMI technique and success & effort diagram, could be eliminated, due to the alignment, simpleness to use and functionality of the overview. For the programme, all the concepts have been considered. The Harris profile (Tables 2 and 3) is filled in for all the concepts of the programme and the leftover overview concepts. The Harris profile is a chart to support decision-making, based on criteria (comparable to the above-mentioned MCDA). The criteria are scored on a five-steps scale between -2 and 2 per concept, which resulted in a total score for each concept.

As can be seen, Microsoft Excel, also called Excel, has been graded as the best programme for the decision-support tool. Excel is a spreadsheet programme for the computer system Microsoft Windows. The Microsoft programmes are well known in the society and easily usable. For the overview concepts, there have been two concepts with the highest score (namely 24 points); flowchart and matrix table. A flowchart describes a process and helps deciding by the use of covering multiple steps. This scheme is a clear roadmap for the whole process and provides the user to start at a later step in the process. With these steps, the process becomes clear and the missing or required information is easily discovered. The matrix table is more focused on providing an overview in the information base. This is done by rows and columns that both describe a certain subject, the cell in between states the relation between those subjects.

Table 2: The Harris profile for the programme concepts, whereby the weight of the rows defines the importance of the criteria. The height of the rows represents the weight of the criteria. The highest scores are selected in blue.

Design category	Design criteria	Weight	LabVIEW	MATLAB	Microsoft Excel	Microsoft Word	Python
Availability	Accessibility	**2**					
	Cheap	**1**					
Insight in impact	Environment	**3**					
User-friendly	Functional	**1**					
Total			**-8**	**-10**	**12**	**11**	**6**

Table 3: The Harris profile for the overview concepts, whereby the weight of the rows defines the importance of the criteria. The height of the rows represents the weight of the criteria. The highest scores are selected in blue.

Design category	Design criteria	Weight	Decision Tree	Flowchart	Impact effort matrix	Interrelation-ship diagram	Matrix table	MCDA
Insight in impact	Accuracy and precision	**1**						
	Consistency decision-making	**3**						
	Elimination	**1**						
	Transparency	**3**						
User-friendly	Aesthetic	**1**						
	Alignment	**3**						
	Simple	**2**						
Total			**20**	**24**	**12**	**9**	**24**	**14**

The combination of the concepts, Excel, flowchart and matrix table, have been discussed with a supervisor of this project, who is also a potential user of the tool. There is agreed on those concepts, whereby the flowchart indeed can show the process, the matrix table can provide the extra information, and Excel is a usable platform.

8.4 Discussion

In this chapter, the first steps to answer SRQ3, *"What means can be developed to support decision-making on an optimisation of the performance of the operating room?"*, are made. The goal of the tool consists of two parts: providing the information and providing a roadmap for the decision-making process. For answering the MRQ, the critical node (lack of information of the impact of optimisation on the performance of the OR), and the design goal (enable and

standardise the decision-making process by a holistic view) are taken into account. In Chapter 9, the tool will be finalised, in such manner that the decision-makers know how to act and what kind of information is necessary.

The concepts have been chosen based on the design criteria, which could be split into criteria for the overview and for the programme. The design criteria Accessibility, Cheap, Environment in hospital and Functional are graded for the programme. The tool should be applicable without installing a new program and in a well-known program for the current HCPs (Accessibility, Cheap and Environment in hospital). The tool should be functional for the HCPs, without a strict starting point and easily adjustable (Functional). Those points have been criticised by use of the design criteria and its weights. Based on the Harris profile, Excel has been chosen to continue with. Excel is a well-known programme and easily adjustable. Besides that, the most computers have the Microsoft software (already) and therefore is assumed that Finance is not an obstacle. All the concepts and the selection with use of the Harris profile are performed by the author, which indicates that no HCPs were involved. Therefore, the selection process could contain personal bias.

The criteria for the overview can be split in criteria for flowchart and matrix table to analyse the concepts. The flowchart agrees fully to the design criterion Consistency decision-making, since it provides clear steps; Elimination: easy to skip a step without forgetting the next steps; Transparency: the clearness for other in the decision-making; Aesthetics: the appearance of the chart; and Alignment: showing a clear direction of the steps. For the matrix table, the most design criteria are met (45% fully graded). The Accuracy and precision criterion is met, since the matrix table could provide all information in an orderly manner; the criterion Elimination is fulfilled, since the user could easily remove one row or column; Transparency is met, since the relations could be shown in a understandable manner; Alignment and Simpleness are also met, since the rows and columns are a clear structural manner Consistency decision-making and Aesthetic are graded with one point, since the matrix table does not provide clear steps and there could be too much information within a table.

Answering SRQ3 (*"What means can be developed to support decision-making on an optimisation of the performance of the operating room?"*) started with specifying 11 design criteria, dividable over three design categories, in order to create a holistic view of (the optimisation of) the OR performance. With help of the Harris profiles and the design criteria, three concepts have been selected out of five programme concepts and ten overview concepts, to create a holistic view of the OR performance. The flowchart is selected as a roadmap for the decision-making process, the matrix table will provide the information in an overview and Microsoft Excel will be the running programme.

9 Design of decision-support tool

The tool and its functionality will be discussed in this chapter. The tool is built upon the on the concepts Excel, flowchart and matrix table, that has been selected in Chapter 8. This tool is supposed to be a guidance for the HCPs in the decision-making on optimisation for the OR.

9.1 Aim

Aiming to answer the MRQ: "*How can a decision-support tool for optimisation in the operating room help a healthcare professional to select the objectives and the assessment criteria for performance optimisation of the operating room and the optimisation impact?"*, and fulfilling the aim of this study: *"To develop a decision-support tool for healthcare professionals that guides the selection of goals and assessment criteria for performance optimisation of the OR and accounts for the impact of an optimisation on the total system",* the final support tool is developed. With the tool, the HCPs should be able to create a holistic view of the performance of the OR and recognise the impact of an optimisation, as was stated in the design aim.

9.2 Method

Based on the results of the Harris profile, Excel, flowchart and matrix table are used to design a support tool. Those three concepts have been connected into a final concept, whereby the flowchart explains the process and the table matrix provides the specific information, running in Excel.

Given the design goal (enable and standardise the decision-making process by a holistic view) and the critical node (lack of information of the impact of optimisation on the performance of the OR), the tool is developed leading to providing insight in the performance objective and its metrics. The design goal and design criteria have been checked with the tool. Next to that, the competence of the tool has been validated by the author. The tool is discussed with the supervisors of this study, to address issues and revise the tool, with the goal to upgrade the tool and help the HCPs to easily use the tool, by mentioning what is missing. To validate the tool, a case from the LUMC, the Netherlands, have been accomplished.

9.3 Results

The tool has as goal to support decision-making of HCPs on optimisation for the OR performance by counselling in creating a holistic view of the performance objective and its metrics. This holistic view is required since many stakeholders are involved in the performance optimisation of the OR and have different perspectives. Decision-making requires a mutual vision (Littlejohn et al., 2017) and should be based on evidence (Turner et al., 2017). Therefore, it is important that the decisions will be based on information acknowledging the whole OR. Currently, the information is provided by the decision-makers or the initiator, with the use of this tool the information can be gathered by determining the goal of the performance (an optimisation) and create a mutual vision on the optimisation.

9.3.1 Step-by-step-plan

There were two overview concepts selected: the flowchart provides an overview of the steps that are required and the matrix table provides a list of all the causalities. The flowchart starts with a problem or an idea for an optimisation, following by the user thinking of describing terms for the objectives or metrics related to the main goal of the optimisation. These terms can be selected in the matrix table, whenever none of the terms are not presented, closely related terms should be selected. Those terms can be corresponding to the codes of an objective or a metric of the OR performance optimisation. After selecting this in the matrix

table, a list of relations will appear. The found relations and causalities can be compared, and lead to a target performance and finally to a holistic view.

Every step is related to a box, those are the numbered boxes in Figure 19, and to a question, as can be seen in the text below. These steps are part of the decision-making process, when the tool is used. They exchange some other steps from Figure 16, as “Define problems”, “Objective” and “Criteria decision-making”.

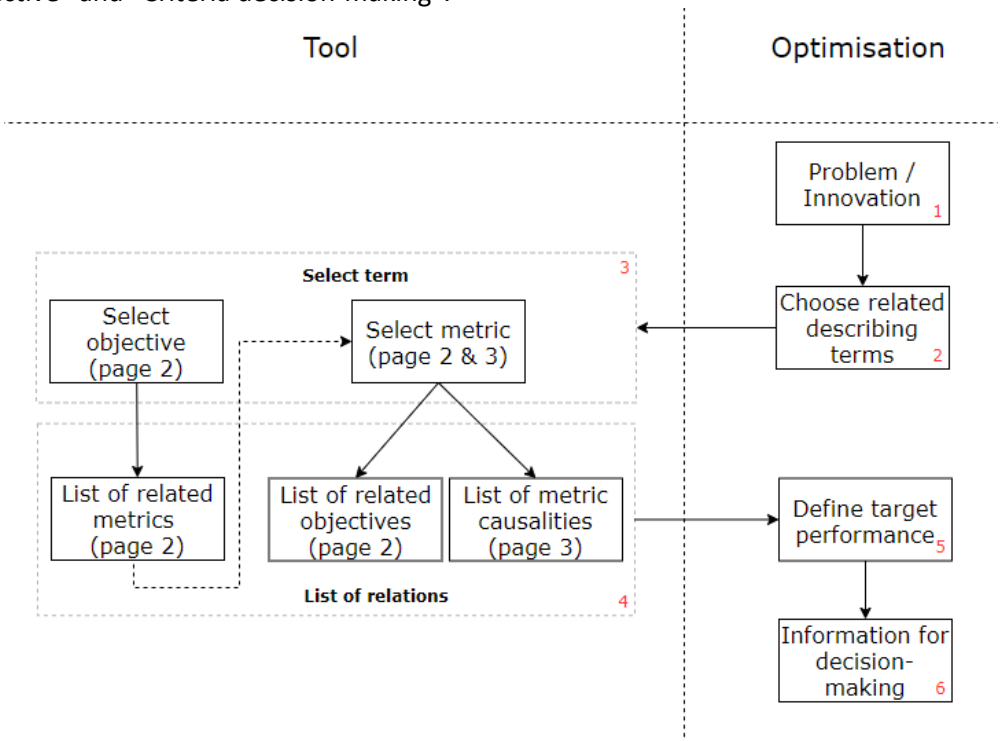


Figure 19: A flowchart that provides the step-by-step-plan (the steps) of the tool, to reach the information for the decision-making.

9.3.1.1 Step 1: Problem/innovation

As soon as a HCP of the OR identifies a problem or discovers an innovation (box 1), the HCP should look at the flowchart, for the process steps. With the questions: “*What is the problem? What kind of innovation are we considering?*”, the initiator can start their research to an innovation. The HCP gathers background information about the topic (problem or innovation) and informs the decision-makers about this topic.

9.3.1.2 Step 2: Choose related describing terms

The next step aims to defining the objectives or measurements for the optimisation. The decision-makers plan a meeting and get as much as information as possible about the topic. The group should come up with related terms to the problem or goal of an idea (box 2). Those terms should come up in a conversation answering the question “*What is the focus of this problem/innovation?*”. During the conversation, the group writes down words related to the main objectives or measurement to this topic, for example in a mind map. Afterwards, the group decides on the describing terms that are most related to the problem or innovation. This should be in a conversation with multiple stakeholders, to be sure that there will not be a personal bias of the designer in selecting the related terms to the problem or the innovation.

9.3.1.3 Step 3: Select objective or metric

The third step (box 3) involves selecting a term in the tool, to create input for the tool. It is required to again involve multiple stakeholders (advised is to have at least three people), but

can be done in the same meeting as step 2. The group should decide on what level they are focussing, improving a metric or unit (metric), or more focussed on a general aspect of (the optimisation of) the OR performance (objective). The HCPs should compare their own describing terms to the pre-selected terms in the tool: *"What are the (most) related terms in the tool?"*.

The tool provides a list of all the related objectives or metrics (Table 4), whenever one metric or objective is selected. It can be used on different levels, since there are options to select an objective factor, objective characteristic, metric factor and metric characteristic. The objective factors are the general terms for the performance optimisation of the OR. The objective characteristic is a specification on the objective factor, similar with the metrics. So, the characteristic actually elaborates on the topic wherein the objective term applies. It is important to realise that selecting a more specific term leads to more specific relations that are provided by the tool. Whenever the user has a broad term of interest, there will be found a high variety in relations, which does not counsel with creating the target performance. The tool can be used on all the levels, by selecting the right terms. After deciding the level of input, objective or metric, and the term, the HCP can select the term in the drop-down.

Table 4: The terms that can be chosen for the tool, as is required to select in box 3.

Performance	Terms
Objective factor	Accessibility, Care outcomes, Finance, Management, Patient (health) condition, Quality-of-care, Resources, Safety, Satisfaction, Service, Staff (health) condition, Surgical performance, Team
Objective characteristic	Adequacy, Care outcomes, Decision-making, Environment, Operational performance, Patient satisfaction, Safety, Staff performance, Staff satisfaction, Surgical performance, Teamwork, Technology, Value-based healthcare, Workload
Metric factor	Accessibility, Accreditation, Accuracy, Audit performance, Authority, Bed utilisation, Behaviour, Care outcomes, Communication, Complexity, Complication, Cost, Culture, Decision-making, Diagnose, Discharge, Distribution equipment, Disturbance, Education, Environment, Equipment type, Equipment utilisation, Equity, Ergonomics, Expertise, Hospital capacity, Hygiene, Idle time, Inventory, Investment, Length of stay, Maintenance, Operational performance, OR block, OR design, OR time, OR utilisation, Patient (health) condition, Patient flow, Patient satisfaction, Pharmaceuticals, Policy, Profit, Readmission, Responsiveness, Revenue, Safety, Savings, Schedule, Shift, Skill, Staff (health) condition, Staff performance, Staff satisfaction, Start time, Stressors, Surgery duration, Surgery efficiency, Surgery volume, Surgical performance, Survival, Team structure, Teamwork, Technology, Treatment type, Trust, Waiting list, Workforce, Workload
Metric characteristic	Accuracy, Anatomy, Anxiety, Authority, Bed utilisation, Behaviour, Cancellation, Communication, Complexity, Complication, Delay, Distribution equipment, Disturbance, Energy, Equipment, Equipment inventory, Equity, Ergonomics, Expertise, Hospital capacity, Length of stay, Maintenance, Morbidity, Mortality, Nutrition, OR block, OR break, OR design, OR over time, OR time, OR utilisation, Patient satisfaction, Physical work, Psychological condition, Responsiveness, Robustness, Sensory factors, Shift, Skill, Sleep, Staff satisfaction, Start time, Stressors, Surgery efficiency, Surgery volume, Task, Technology, Transparency, Treatment, Turnover, Workforce

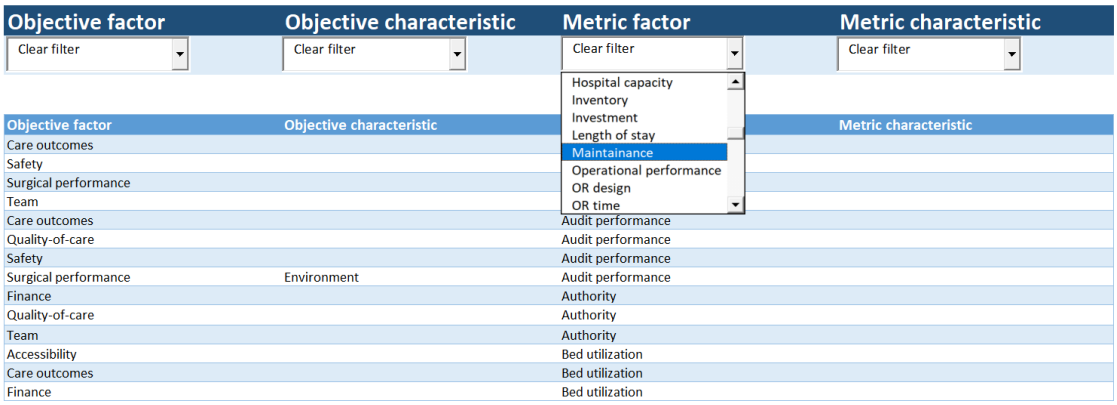


Figure 20: The relation list of the tool with the drop-down box that provides an interactive system to select the desired codes.

9.3.1.4 Step 4: List of related metrics or objectives

Within step four (box 4), the question "*What are the relations of those terms?*" is answered and an overview of the relations to the selected terms is created. Whenever a metric is selected, a list of related objectives and causalities to this metric will be provided. These causalities describe the impact of adjusting a metric by for example an innovation. When an objective is selected, the tool will provide a list of related metrics. With the list of related metrics, the causalities to the metrics can also be provided, when the metrics are selected. Next to that, the tool can work reversible, since it can provide related metrics when the objective is selected, or related objectives when the metric is selected.

9.3.1.5 Step 5: Defining target performance

The fifth step is to analyse these relations and define the target performance (box 5): *"What was the goal of this problem/innovation? Does this agree with the given relations?"*. The suggestion is to notice the overlapping objectives and metrics, and to discuss the results with other professionals. With this analysis and the conversation, the targeted performance, which is similar to the desired objective of the performance optimisation of this specific OR, or metrics should be determined, including the related influences.

9.3.1.6 Step 6: Information for decision-making

As last step, including on all this information, it is the moment of creating a holistic view (box 6): "*Should we invest more time or money in researching this innovation?*". The tool provides information and insight in the impact of an optimisation on the OR performance. Based on the outcomes of the tool and critical thinking, the HCP can evaluate these results. This research is required to determine if the innovation is at the end worth to purchase or develop.

9.3.1.7 Timeline

This decision-making process normally takes a while and many stakeholders are involved. A global timeline can be seen at Figure 21, with in blue the current situation and in green including the tool. The suggestion is to make one person responsible for gathering the information; however, boxes 2, 3 and 5 should be discussed with multiple stakeholders. For boxes 2 and 3 is stated that there should be at least three HCPs, to gather multiple perspectives. For box 5, all the involved HCPs are required, since the aim of the OR and the decision is discussed.

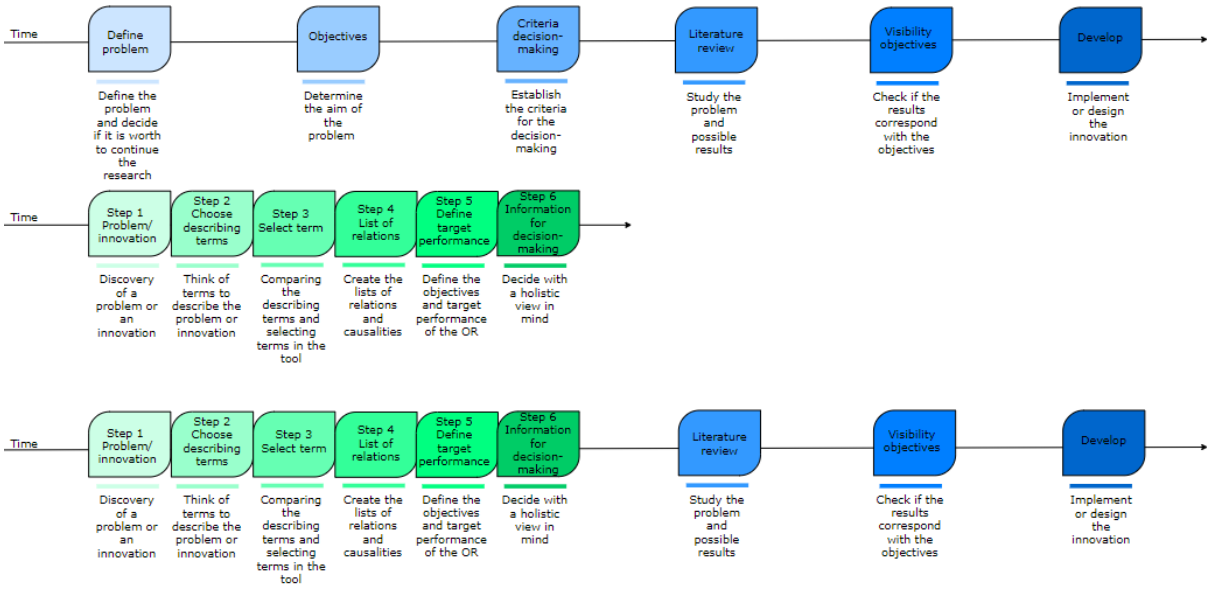


Figure 21: The timeline of the decision-making process (blue) and the timeline of the tool (green). As last the timeline is sketched when the tool is used in the decision-making process instead of the steps "Define problem", "Objectives" and "Criteria decision-making" of the (blue) decision-making process.

9.4 PORC-tool

The tool is called the Performance Operating Room Counselling (PORC-)tool (Figure 22) and aims to cover-up the blind spots of the HCPs. It provides the information of the relations between the performance objectives and metrics. The PORC-tool consists of three components: an Excel file, a brochure and a manual, as can be seen in Figure 23. The Excel file provides the information from the OR performance. The brochure provides a short but global impression of the function of the tool and the step-by-step-plan. Whenever more details are desired by the user, the HCP is referred to the manual. Here will be given a short overview of all the elements of the tool. These three components will be discussed below.

Figure 22: The logo of PORC-tool.

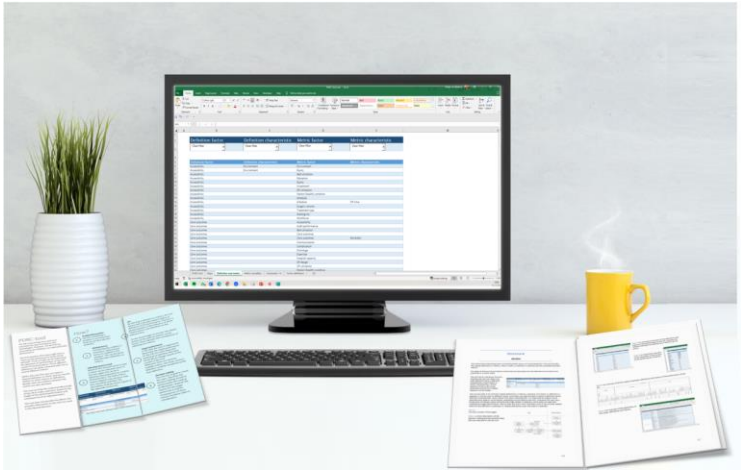


Figure 23: The PORC-tool, including the Excel file, brochure and the manual on the desk.

9.4.1 Excel file

The PORC-tool consists of six pages in the Excel file (Microsoft, 2021): the first page is an introduction page, the second page provides the flowchart (Figure 19) and a global timeline (Figure 21). The next two pages provide the interactive list of objectives and metrics (Figure 24), and the interactive list of the causalities between the metrics (Figure 25). The lists of relations and causalities are interactive, since the user can select their own interest, by use of a combo box in Excel (Microsoft, 2021), which is a drop-down list wherein an item can be selected (Figure 20). The selectable items are the codes for the objective and metric combinations, also provided in Table 4. The combo-box requires that the Excel file is saved as an Excel Macro-Enables Workbook (*.xlsm). Within step four (box 4), the question "*What are the relations of those terms?*" is answered and an overview of the relations to the selected terms is created (Figure 24). Whenever a metric is selected, a list of related objectives and causalities to this metric will be provided. These causalities (Figure 25) describe the impact of adjusting a metric by for example an optimisation. When an objective is selected, the tool will provide a list of related metrics. With the list of related metrics, the causalities to the metrics can also be provided, when the metrics are selected on page four. Next to that, the tool can work reversible, since it can provide related metrics whenever the objective is selected, or related objectives whenever the metric is selected.

Objective factor	Objective characteristic	Metric factor	Metric characteristic
Clear filter	Clear filter	Clear filter	Clear filter
Care outcomes		Accessibility	
Safety		Accuracy	
Surgical performance		Accuracy	
Team		Accuracy	
Care outcomes		Audit performance	
Quality-of-care		Audit performance	
Safety		Audit performance	
Surgical performance	Environment	Audit performance	
Finance		Authority	
Quality-of-care		Authority	
Team		Authority	
Accessibility		Bed utilization	
Care outcomes		Bed utilization	
Finance		Bed utilization	
Patient (health) condition		Bed utilization	
Service		Bed utilization	
Safety		Behaviour	
Team		Behaviour	
Care outcomes		Care outcomes	
Care outcomes		Care outcomes	Morbidity
Finance		Care outcomes	

Figure 24: The third page of the PORC-tool with some of the relations between the objectives and the metrics.

Cause-metric	Result-metric
Clear filter	Clear filter
OR block	Bed utilization
Patient flow	Bed utilization
Policy	Bed utilization
Responsiveness	Bed utilization
Schedule	Bed utilization
Surgery duration	Bed utilization
Surgery volume	Bed utilization
Treatment type	Bed utilization
Bed utilization	Cancellation
Patient flow	Cancellation
Policy	Cancellation
Responsiveness	Cancellation
Schedule	Cancellation
Start time	Cancellation
Bed utilization	Cost
Distribution Equipment	Cost
Equipment type	Cost
Equipment utilization	Cost
Idle time	Cost
Inventory	Cost
Length of stay	Cost
Operational performance	Cost
OR opening hours	Cost

Figure 25: The fourth page of the PORC-tool with the causalities.

The other two pages are focused on providing more information for the user about the relations. The fifth page shows an overview of all the relations in a horizontal manner (Figure 26 and Appendix K). The last page provides an overview of all the codes (Table 4) and the definitions of those codes (Appendix B).

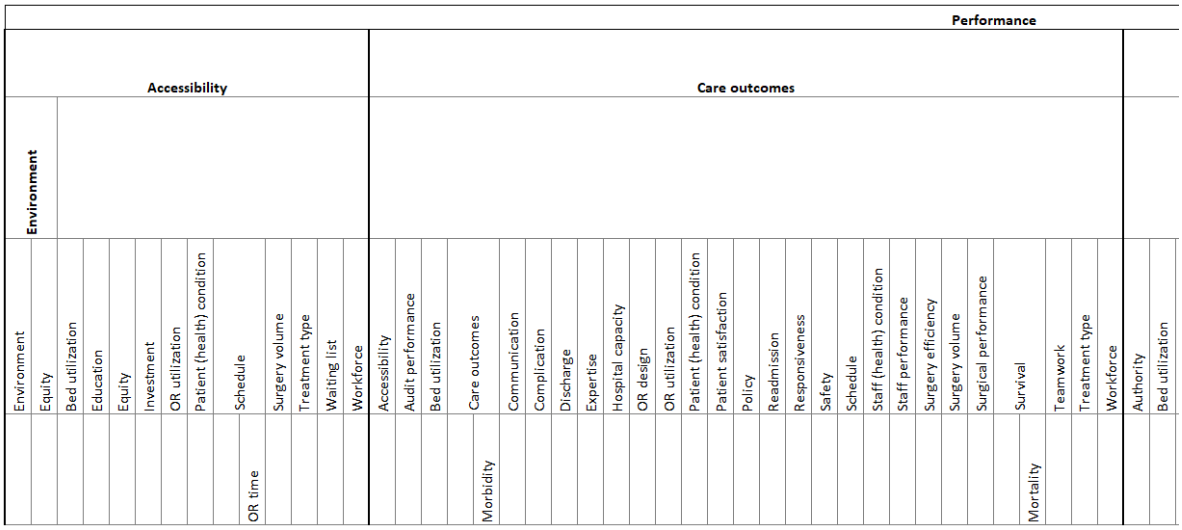


Figure 26: A part of the overview of all the relations between the objective and the metrics in a horizontal manner, provided on the fifth page of the PORC-tool. This is just a part of the overview due to the size of this overview. In Appendix K, the whole overview is shown.

9.4.2 Manual

The manual describes all the PORC-tool in a more detailed manner and guides the users in their process. In Figure 27 and Appendix I, the manual can be found. The manual covers the purpose of the tool and the addressable questions, it provides an overview of the structure of the PORC-tool, including a description of the design and the supporting materials (the brochure and this study). In the manual-chapter Practice, the target audience, the quick guide and the timeline are discussed. There is an elaborated step-by-step plan for the application of the tool, including figures of each step (Figure 28) and for updating the tool. For each step to create a holistic view, the aim of the step, the required participants and the essentials are noted down.

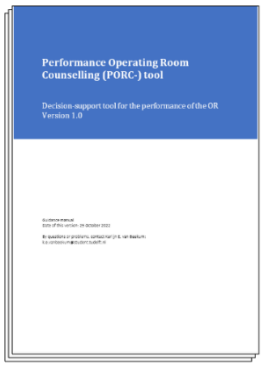


Figure 27: The manual of the PORC-tool.

STEP 4

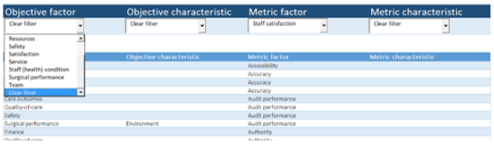
LIST OF RELATIONS

AIM: CREATING A LIST OF THE RELATIONS AND CAUSALITIES FROM THE SELECTED TERMS
PARTICIPANTS: HEALTHCARE PROFESSIONAL WHO IS PROFICIENT WITH EXCEL
ESSENTIALS: PORC-TOOL, PAPER, PENCIL

1) Create the list of relations by selecting the terms in the drop-down.
   a. *"What are the relations of those terms?"*.

2) Copy the list of relations.
   a. This can by hand, photograph or on the computer.

3) Clear the list by putting all the drop-downs on "Clear filter"
   a. If this does not work, clear the list with ALT+D+F+S



4) In case of a selected objective in step 3, identify the most related metric and perform step 3.5

5) In case of multiple chosen words, perform step 3.4 and 3.5 again.

Figure 28: A step (step 4 of the step-by-step-plan) from the PORC-tool manual.

9.4.3 Brochure

Besides the tool and the manual, there will be given a brochure to the users, which helps to start using the tool and contains a short explanation of the tool. This brochure is made on a trifold template, therefore is easy to carry and distribute. It includes a short, but clear, overview of all the functionalities of the tool and the steps that should be taken for usage. The goal of this brochure is to provide a short explanation, remind the HCPs about the PORC-tool and acquaint with potential users by sharing the brochure. This brochure is stated in Figure 29 and in Appendix K presents the same brochure but readable.

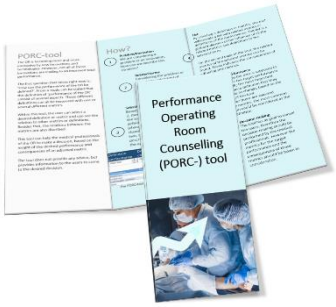


Figure 29: The trifold brochure for the PORC-tool.

9.5 Validation

To validate the PORC-tool, there are performed two steps. First of all, the tool is compared to the design criteria of Chapter 8 and to the critical node and design goal. The second step to validate the tool, was by studying a case of the LUMC, presented below.

This critical node is defined as: "*The HCPs do not have a complete vision of the performance of the OR and impact of optimisation, due to the lack of information of the impact of optimisation on the performance of the OR".* By gathering information, a holistic view can be created, this aligns with the design goal, which is *"Designing a support tool that enables and standardised the decision-making process of HCPs on optimisation for the OR by providing a holistic view of the performance objective and its metrics".* The tool provides the holistic view by a clear overview of all the related metrics and objectives.

Besides that, there were stated 11 design criteria in the Harris Profile (including the weights): Alignment, Consistency decision-making, Environment, Transparency (weight 3), Accessibility, Functional, Simple (weight 2), Accuracy and precision, Aesthetic, Cheap, Elimination (weight 1). The tool provides a clear overview in an understandable structure in a common programme, which fulfils the criteria Accessibility, Alignment, Cheap, Functional and Simple. This tool provides consistent information for the decision-making and the hospital can consider their own strategy; however, it does not decide itself. Therefore, the Consistency decision-making and Environment criteria are not fully covered, but the tool provides a structure for consistency. The Transparency will be covered, since the manner of information gathering is clearer. The Aesthetic is work-in-progress, still the tool functions properly, which is the main goal for a decision-support tool. Last but not least, the criterion Elimination should make sure that the non-relevant values would have been removed. This is not the case, since the tool does not provide any Accuracy and precision in the relations, because this requires more research. If the Harris profile is applied to the PORC-tool, instead of the concepts, the number of points would be:

- Weight 3: Alignment (2), Consistency decision-making (1), Environment (0), Transparency (1)
- Weight 2: Accessibility (2), Functional (2), Simple (2)
- Weight 1: Accuracy and precision (-1), Aesthetic (0), Cheap (2), Elimination (0)

With a total score of 25 points. This is lower than the possible number of points stated in Chapter 8 (36 points), which indicates that there is protentional for further developments (which is further discussed in the next chapter).

9.5.1 Case: step-by-step-plan

The case is about the workflow within the ORs of the LUMC, the Netherlands, related to the PhD of Schouten (2021-2025). The focus of this study is improving the functioning of the OR by improving the well-being of the operative nurses (Schouten, 2021). The steps described in this case are related to the step-by-step-plan and the steps in Figure 19.

9.5.1.1 Step 1: Problem

The operative nurses are crucial for the performance of the OR, they perform serval actions for the patients, the surgery, the medical team or for the instrumentation (WHO, 2021c). The operating nurse performs the comprehensive care, assistance and pain management during the surgery, but is also providing the handover (WHO, 2021c), as can be seen in Appendix A. There is predicted a great shortage of operative nurses in the OR, especially since the operative nurses are tended to switch profession quickly (Schouten, 2021). Besides the shortage in number of operative nurses, this is also leading to a lack of experienced operative nurses (Schouten, 2021). To create an understanding in the causes of the drop-out of operative nurses, the working experience and work pressure should be investigated.

9.5.1.2 Step 2: Corresponding terms

The focus of this problem is about the many steps that are required within the OR and how the nurses experience this work. Both of those terms, experience and workload, will be visioned from the view of the operating staff. Terms that are related to the topic work experience are appreciation, enjoyment, knowledge, participation and satisfaction; to the topic workload are constraint, demand, stress and, work pressure.

9.5.1.3 Step 3: Selecting terms

Within step three (box 3), the question "*What are the (most) related terms in the tool?*" is answered. The list of the possible terms is given in Table 4. For this case, the working experience and work pressure will be analysed, therefore this is an assessing criterion. This indicates that a metric has to be studied, which most likely will be a metric factor. For this problem, the term that is most corresponding to the metric work experience is "Staff satisfaction", which indicates the satisfaction of the medical staff and to the metric work load is "Workload", which indicates all the work that the staff needs to perform in the OR.

9.5.1.4 Step 4: Relations

The question "*What are the relations of those terms?*" is answered and an overview of the relations to the selected terms is created. These two metric-terms are selected in the PORC-tool, the third page is shown in Figure 30, to provide the relations between the objectives and the metrics of the performance optimisation of the OR, with the upper table presenting the relations to Staff satisfaction and the lower table the relations to Workload. The metric Staff satisfaction is related to the performance objectives Satisfaction (as factor and with Workforce as characteristic), Staff (health) condition and Team. For the metric Workload, the related objectives are Quality-of-care, Safety, Staff (health) condition and Surgical performance (as factor and with Staff performance as characteristic).

The metric-terms have also been selected on the fourth page in Figure 31 to provide a list of the causalities. There were no related metrics found to the metric factor Staff satisfaction. Adjusting the metric factor Workload leads to impact on three metrics: Care outcomes, Staff (health) condition and Surgical performance. The metrics however can be influenced by other metrics (being a result-metric). For Staff satisfaction, this are seven cause-metrics: Distribution equipment, Idle time, OR block, Policy, Shift, Staff (health) condition and Team structure. The metric Workload is the result of 11 cause-metrics: Distribution equipment, Equipment type,

Idle time, Inventory, OR time, Policy, Schedule, Shift, Surgery duration, Surgery volume and Teamwork.

Objective factor	Objective characteristic	Metric factor	Metric characteristic
Clear filter	Clear filter	Staff performance	Clear filter

Objective factor	Objective characteristic	Metric factor	Metric characteristic
Satisfaction		Staff satisfaction	
Satisfaction		Staff satisfaction	Workforce
Staff (health) condition		Staff satisfaction	
Team		Staff satisfaction	

Objective factor	Objective characteristic	Metric factor	Metric characteristic
Clear filter	Clear filter	Workload	Clear filter

Objective factor	Objective characteristic	Metric factor	Metric characteristic
Quality-of-care		Workload	
Safety		Workload	
Staff (health) condition		Workload	
Surgical performance	Staff performance	Workload	
Surgical performance		Workload	

Figure 30: The related objectives to the selected metrics, above with metric factor Staff satisfaction, below with metric factor Workload.

Cause-metric	Result-metric
Workload	Clear filter

Cause-metric	Result-metric
Workload	Care outcomes
Workload	Staff (health) condition
Workload	Surgery performance

Figure 31: The causalities of the metrics to the selected metrics, solely of the metric factor Workload, since for the staff satisfaction were no specific links

9.5.1.5 Step 5: Targeted performance

The goal is to increase the number of operative nurses by improving their work experience and workload. Hereby can be focussed on Staff satisfaction and Workload. The overlapping objective of the performance optimisation of the OR, that is related to the both metrics, is Staff (health) condition. Therefore, there can be stated that the focus of the new innovation should be on this topic. Besides that, optimising the metrics Staff satisfaction and Workload has influence on three different metrics: Care outcomes, Staff (health) condition and Surgical performance.

9.5.1.6 Step 6: Decision-making

This tool does not provide a decision itself, but it focusses more on gathering a holistic view for a specific innovation/problem. In Figure 32, the steps for this case study are presented. The decision-making can be based on an advice, that is related to the outcomes of the tool. In this case, the main performance seems to be Staff (health) condition and therefore the solution for the shortage of operative nurses should focus on this performance objective. With working on a solution, the professionals acknowledge the impact for the Care outcomes and Surgical performance, since they can directly be influenced by the cause-metric Workload.

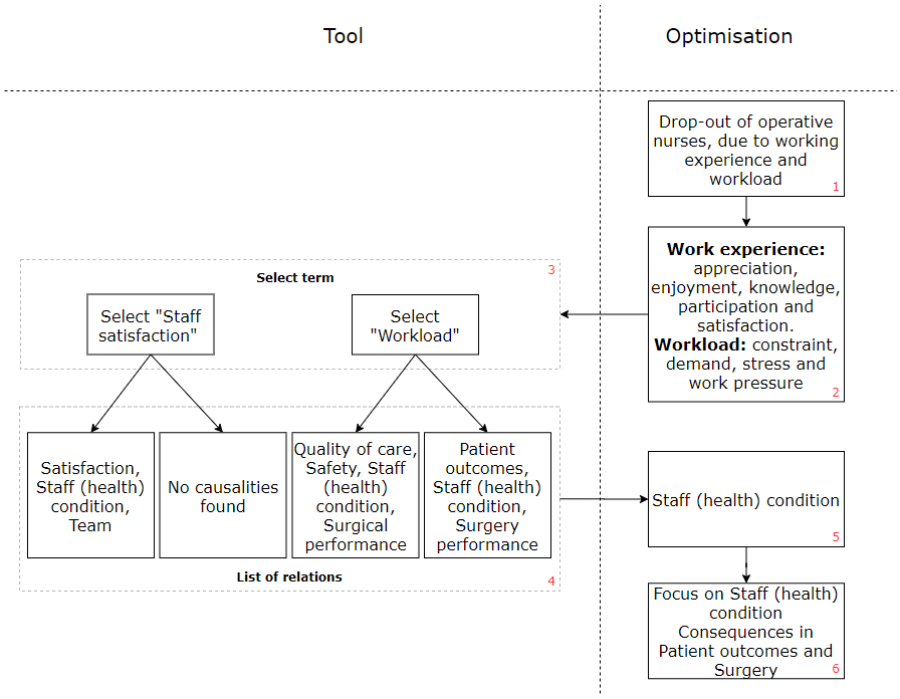


Figure 32: The steps of the case study presented in the flowchart Figure 19.

The result of the PORC-tool has been discussed with the case-owner. The HCP mentioned that the structure in decision-making for a research topic is satisfying. The result, Staff (health) condition, is a focus that the HCP herself also thought of after informing herself with literature research and her own intuition. Besides that, it is relevant to understand the impact of an optimisation on the objectives and other metrics of the OR performance. It is good that the PORC-tool provides an advice and evidence for the decision-making, but it still requires many actions and a critical mind of the HCP and requires more validation. Therefore, the tool does not provide enough evidence or information only rely on for the decision-making, but it is a competent help for decision-making.

9.6 Discussion

This tool had as aim: *"Designing a support tool that enables and standardised the decision-making process of HCPs on optimisation for the OR by providing a holistic view of the performance objective and its metrics"* and a tool should support a mutual vision (Littlejohn et al., 2017) and should be based on evidence (Turner et al., 2017). The tool provides a holistic view (of the optimisation) of the performance of the OR, a view that normally should be constructed with the help of many HCP perspectives to create a holistic view. This holistic view is created by stating the objectives and the assessment criteria for performance optimisation of the OR and the optimisation impact. This tool can help to gather information more easily, provides multiple perspectives on the OR performance and supports to gather more insight into the OR organisation and goals before the decision-making of the HCP. Since the tool provides this view already, less HCPs are necessary at the moment of decision-making. The PORC-tool accelerate and standardise the process, by providing structure and information about the decision-making process to the HCPs.

The PORC-tool supports to think about HCP's own perspectives and to start a conversation on the perspectives on the objectives and metrics of the OR performance optimisation, creating a holistic view of the OR performance and providing evidence for decision-making. By the decision-making process the HCPs are supported to take a collective decision, therefore a

mutual vision on these objectives is required (Littlejohn et al., 2017). Objective tasks (clarity in the problem), group task (how the group behaves) and group structure (cohesiveness) can influence the decision-making process (Littlejohn et al., 2017). Therefore, sharing the personal perspectives can be a start in creating a mutual vision (Guo, 2020), since it clarifies the objectives and aim for a better cohesiveness. After agreeing on the purpose of optimisation, the assessing criteria (metrics) for the optimisation should be optimised. Therefore, the tool provides information about the performance optimisation of the OR and the impacts of optimisations, but can also help creating a mutual vision on the performance of the OR and creates a simple opportunity for multidisciplinary learning.

Since the HCPs are already provided evidence by the information of the relations, there is more time left for a conversation about the objectives and optimisation. This time can be used to create a mutual vision, and the tool can provide evidence and a big scale of perspectives to the discussion. The tool itself covers a lot of information; however, it does not cover all the information. Therefore, the user should still think rationally and critically to make sure to pick the correct terms (suggesting to perform this in a group) and to analyse the relations. After selecting the terms in the PORC-tool, a list of related metrics (if an objective is selected) or related objectives (if a metric is selected) will be shown, which could lead to the target performance. Again, the user has to come up with the target performance itself, since this varies for all organisations (Liberatore & Nydick, 2008; Nassiri et al., 2020; Pennington & DeRienzo, 2013). With the PORC-tool, it is advised to consider the overlapping metric or objective as the target performance; however, this does not always have to be the case. Therefore, the user should think critically and analyse the results and advised is to discuss this with multiple stakeholders (to stick to the mutual vision). This tool is an addition to the conversation for the decision-making, and cannot be seen as a replacement.

The PORC-tool is a tool that does not require an expert, but can be used by all HCPs. The assumption is that the frequency of using the tool will be greater by independent usage. The HCPs have to can think of related describing terms, determined by the user itself, to minimise the bias of the tool on the user. 14 objective factors, 19 objective characteristics, 70 metric factors and 42 metric characteristics can be selected in the tool, therefore, the user has to come up with a connection between the self-invented describing terms and the tools terms. Someone present that already used the PORC-tool would be helpful in this step. This person already went to the process at least once and hopefully in able to counsel the group in the process. Still the bias of this person can then be projected on the terms. All HCPs can use the PORC-tool without needlessly time- and money-consuming by an expert.

Since the structure for the decision-making process is already established in the PORC-tool, presented in Figure 21, this could be time-saving for the HCPs. The first three steps of the process without tool, “Define problem”, “Objectives” and “Criteria decision-making”, are steps that are often passed up or are minimised. However, these steps are important to ensure the fit of an optimisation to the objectives and the OR performance. The tool is replacing the three steps by six steps. Even though the number of steps is increased, the steps are smaller and require less work, since the structure and goals are already determined. Besides that, all the information should still have been gathered and studied without the tool. Assumable is that using the tool would be time-saving for the user, since the tool provides the steps, the information is already gathered and studied and a singular person can perform most of the steps individually. However, the quantification should be validated by comparing the processes with and without the tool.

The tool does not require a baseline measurement; however, adding this could lead to interesting information. First, this baseline measurement can help you (re)evaluate the data

after implementation and indicate the improvements or consequences of the optimisation. Therefore, the impact of the optimisation can be detected more systematism. Secondly, this measurement could be a first step of stating the goal and the desired results for the HCPs. Discussing the performance and goals can already help with specifying the demand of the optimisation. Therefore, adding a baseline measurement is recommended for those two reasons. This tool provides insight, but does not provide any indication of the accuracy and precision in the relations. The users should indicate the amount of impact of an optimisation on the OR performance. The PORC-tool cannot replace a critical mind and view on the investment in innovations, since the tool does not consider the gravity of the problem and does not quantify the impact of an optimisation.

The tool provides the HCPs with the requested information; however, the tool could increase its performance, in relation to the aesthetics and the functionality. The full potential within the tool is not reached yet in a short design process, since the validation score is less than the concepts scores in the Harris profile (25 vs. 34). Two improvements in functionality and one in aesthetics will be discussed. First of all, the tool could ease the guidance in the tool. At the moment, the user has to open two programmes; Microsoft Word for the manual and Excel for the tool. The same ineffectively step applies for the definitions of the terms mentioned in the tool. To check these definitions, the user has to check the sixth page and therefore has to switch between pages. Whenever the steps of the tool or the objectives of the terms would be explained at the correct page in the Excel file (possibly via a pop-up), the user can easily check the information. Secondly, to improve the functionality, it could help the user to get more guidance in defining the target performance. Therefore, in the future it would be pleasant that the HCP can select multiple terms at the same time, and that the tool itself selects the overlapping terms. This could save-time and effort for the HCPs; however, it can also cancel out some personal bias. For the aesthetics, the tool currently provides a list of relations; however, most people are visually oriented, therefore it could help to create figures with all the relations. When highlighting the relations, Figures 11 and 12 could be an example for this figure. As said, there is room for improvement; however, the tool functions properly at this moment.

In the future, the PORC-tool should be tested in practice to validate the accuracy, the functionality and the reliability, by testing on more practical cases and comparing the results of the case to the current situation, to see how the decision-making process and the results differ. The information in the tool should be examined in practice, to apply the practical knowledge as well. Further on, for the future, it is required that the tool is discussed with the stakeholders and decision-makers, mainly because of the appearance and the user-friendliness. The PORC-tool is also designed in a manner that the tool can be adjusted easily, the stakeholders can adjust the tool easy during the practice or improvements.

In this chapter, MRQ ("*How can a decision-support tool for optimisation in the operating room help a healthcare professional to select the objectives and the assessment criteria for performance optimisation of the operating room and the optimisation impact?")* is answered by elaborating the concepts flowchart, matrix table and Excel. The matrix table provides an overview of several aspects of (the optimisation of) the OR performance, the flowchart guides the HCPs through the steps and Excel is the programme that it is running in. The PORC-tool supports starting the conversation on the perspectives on the objectives and metrics of the OR performance optimisation, creating a holistic view of the OR performance and providing evidence for decision-making, and helps to accelerate the decision-making process, by providing structure and information to the HCPs.

10 Discussion

In this chapter, this study will be analysed and discussed. First of all, the decision-making process will be discussed in the paragraph Decision-making. The paragraph Codes will discuss the results from Chapter 4, 5 and 6 and the corresponding research questions with other researches. The method of this study will be discussed in paragraph Methodology. The technique, functionality and impact of the tool are analysed in the paragraph PORC-tool and the further developments will be stated in the paragraph Recommendations. The conclusion will be stated in the next chapter. At the end of this chapter, a reflection of process, from the perspective of the author, will be given.

10.1 Decision-making

The HCPs are influenced by their own experience, attitudes, perception and the social network (Iacopino, 2018). The decisions are particularly influenced by the interpersonal relations (Iacopino, 2018), even though it should be based on evidence (Turner et al., 2017). Since the OR is a complex organisation with many designs, responsibilities, phases and a multidisciplinary team (Van Beekum, 2022), these decisions affect the OR on many levels and aspects (Britt et al., 2021). The HCPs should consider the OR as a whole system while deciding about an optimisation and anticipate on the impact of the decisions on (the optimisation of) the OR performance. Therefore, the aim of this study was: *"To develop a decision-support tool for healthcare professionals that guides the selection of objectives and assessment criteria for performance optimisation of the OR and accounts for the impact of an optimisation on the total system"*.

The decision-making on the optimisation of the OR performance can be at different levels, for example solving a problem, researching the current situation or inventing a new technique. However, similar in all studies was the stated importance of the clearness of the goals and ability to measure this (Guo, 2020; Leinonen et al., 2008; Nassiri et al., 2020; TU Delft Library, 2022). Therefore, this study focusses on providing insight in (the optimisation of) the performance of the OR and its metrics, which is assumable useful for all the decision-making for the OR, though to varying degrees. To help HCPs to decide on an optimisation by stating objectives and assessment criteria of the performance optimisation of the OR, which resulted in the following research question (MRQ): "*How can a decision-support tool for optimisation in the operating room help a healthcare professional to select the objectives and the assessment criteria for performance optimisation of the operating room and the optimisation impact?".* To answer this question, there are drafted three sub questions, which will be discussed below.

10.2 Codes

The question *"What is the definition of the performance of the operating room according to the healthcare professionals to identify the objectives of optimising the performance of the operating room?"* (SRQ1), resulted in a high variety of the perspectives on the objectives (165 combinations), which corresponds with the hypothesis, that the objectives cannot be stated in a singular definition. One of the objectives of hospitals is that they have to find a balance between the quality and efficiency of their services (Zhang et al., 2020; Zhang et al., 2021), which corresponds with the objective factors Quality-of-care (65% of the articles) and Surgical performance (64%). Burdett & Kozan (2018) also mentioned the cost vs. service relation as a balance, which corresponds with the objective factors Finance and Service, respectively 43% and 29%. This indicates that the findings of this study are more relatable to the balance between quality and efficiency of the service than to cost vs. service; however, it is found that other aspects are also important, such as Care outcomes (46%) and Safety (46%). Britt et al. (2021) stated that capacity, balancing, utilization, throughput, timeliness, and financial are the categories of the objective functions for optimisation in the OR. In this study, 14 objective

factors have been found, from which the most can be subdivided under these objective functions of Britt et al. (2021); however, Care outcomes (46%) and Quality-of-care (65%) are not mentioned in those objective functions. An explanation for this could be that the performance of the OR is more related to service, results and patients, than the optimisation of the OR, indicating that performance is more focussed on the actual healthcare or due to the scope. Nassiri et al. (2020) said that the purchase in hospitals should be made based on an analysis of patient-centred value. This value is defined as health outcomes achieved per dollar spent, which is related to Care outcomes and Finance. Therefore, both objectives should be mentioned in an article to state this value. This is in this study only done in 18 articles (21%), and since more aspects are important in the OR, it makes sense to look into more objectives for the determination of a purchase. Concluding from the high variety in perspectives on the objectives, there are many aspects that can be focussed on for the optimisation.

The objectives can be assessed in 133 metric combinations including 70 metric factors and 42 metric characteristics, which is the answer to *"What are the assessment criteria to quantify the performance optimisation of the operating room?"* (SRQ2). The answer to SRQ2a (*"How are the assessment criteria and the objectives of the operating room related to each other?")* indicates that the most common metrics are not directly leading to the most common objectives, suggesting that the methods are often not measuring the desired performance. In Van Beekum (2022) is mentioned that 68% of the study has the expenditures of the OR as the method for optimisation. In this study is found that only 13 articles (15%) mentioned Cost as a metrics for the OR performance. However, 36 articles (38%) mentioned Finance as an objective for the OR optimisation. This indicates that the expenditures are less important for the optimisation of the OR performance, as found in Van Beekum (2022). This can again be explained by the focus of the study (innovations vs. OR performance) and by the methods (focussing on the main message or every phrase individually). The same applies for the differences in number of studies focussing on Schedule, 30% vs. 66% of the articles (Van Beekum, 2022). However, Schedule has been mentioned in 45% of all the phrases, so as soon as an author mentioned Schedule, it was in a high frequency. For the units were found a high occurrence of cost (43%) and time (48%; Van Beekum, 2022), which correlates with the high amount of mentioned unit Money ($, €; 276 (38)) and Time: OR time (hours; 117 (32)), respectively 45% and 38%. As can be seen, authors, researchers or organisation have different perspectives on the OR performance, which emphasises the complexity of the OR and the struggle in finding a mutual vision.

In the SRQ2b (*"How are the assessment criteria of the operating room performance optimisation affecting on each other?"*), the causalities between metrics have been studied to understand the impact of optimisations on the OR performance. There have been found 253 causalities, which corresponds with the hypothesis, it is assumable that the metrics would influence each other. Cost has been mentioned as the most common optimisation result-metric (948 (64)), which is not surprising since this was also mentioned as a main reason to optimise in Zhang et al. (2020) and Zhang et al. (2021). The causalities and the differences in amount of impact show that the OR is a complex system and therefore, the decisions on optimisations on the OR performance should be taken well-informed.

10.3 Methodology

For this study, a literature study is performed based on the search terms: as first term '*impact* AND *innovation* AND *"operating room"* AND *hospital'* and as second term '*("operation room" OR "operating room" OR "operating theater" OR "operating theatre") AND (optimization OR optimize OR optimisation) AND (hospital OR healthcare)'*. The first term is used to define the objectives and assessment criteria, and the second term is applied to confirm the found metric

factors and to find the causalities. The first search term is focused on the impact of an innovation, although this study is mainly about objectives of optimisation of the OR performance, therefore these search terms do partially ascribe this study. Eventually, the term "*impact*" could have been exchanged for "optimisation" or "development", or fully removed. However, the benefit of these terms is that it focusses on existing innovations and all stated still an objective. Therefore, the second search term can be used to confirm the results of the first search terms. It is also notable that for the second search terms the synonyms of the term were searched as well, for the first it did not. At the end, it did not limit the number of articles.

Due to the scope, exclusively the ORs are considered, therefore many innovations have been excluded. Among others, innovations that improve the OR in relation to other departments (as ICU and PACU), even though these innovations could increase the efficiency of the OR (Debats et al., 2021; Kheiri et al., 2021). Besides that, due to the scope, exclusively the medical vision is included, indicating that the digital or ethical view is excluded. This is also partly due to the search term "*innovation*". Due to the focus on ORs from prosperous countries and the exclusion of ORs for one specific procedure or including specialised instrumentation, the focus of this study was quite narrow. This resulted in a focus on "cost vs. effects optimisation" (Van Beekum, 2022), which could affect the frequency of the objectives greatly; however, this does not have influence on the design of the tool.

In every article, the objectives and metrics, and factors and characteristics, and units were identified. All the phrases in the articles that mentioned at least one of those five terms have been selected, as long as the combination of all terms was not identified earlier in the same article. However, if a phrase had two metric factors included with one objective, this objective was analysed twice. Therefore, the frequencies could be influenced. Sometimes there was an overlap in the description of the objective and assessment criteria mentioned in a phrase, this has been selected as an objective as long as no unit was mentioned. To ensure there would be no (or at least less) ambiguous phrases or codes, the objectives and metrics of (the optimisation of) the OR performance should have been defined more specifically in the beginning. There is also an inaccuracy in the frequency and number of articles by the causalities, due to the intermediate links that are based on other studies and the personal knowledge of the author. This is minimised to let the frequency of the causalities be the basis of the links. This could influence the reliability of the PORC-tool or the information in the tool.

The codes have been derived from inductive coding/open coding for the objectives and the assessment criteria. These codes have eventually been used in closed coding for the causalities. However, there was some overlap in the definitions of the codes, therefore sometimes the clustering was ambiguous. This has been done according to the definition of the codes (Appendix B), but could still include some overlap in the terms. However, it has been useful to use these codes for the causalities, to minimise the interpretation bias. To reduce the personal bias, the identified code has been checked at least three times by the author for validation and the objective and metric combination that occurred only in one article (# (1)) have been removed. Even though, these steps have been performed, there was still a probability that the personal bias influenced the results. The personal bias has been the most in stating the intermediate links, since these are based on the highest frequency of the found causalities, but also on the authors knowledge. To validate these intermediate links, the results should have been discussed with professionals or been validated in practice.

The high heterogeneity in the objectives and metrics for the performance optimisation of the OR indicates multifaceted perspective on the objectives and multiple optimisation metrics. To reach the aim of this study, the HCPs should get rid of their lack of information of (the impact of) optimisation on the OR performance (critical node). The critical node of this study is based

on the literature on decision-making and the experience of the author. However, this should have been validated by HCPs or should have been analysed in practice. Therefore, the design goal was defined as: *"Designing a support tool that enables and standardised the decision-making process of HCPs on optimisation for the OR by providing a holistic view of the performance objective and its metrics"*. In this study, the holistic view is based on the objectives of and the metrics of performance optimisation in the OR. However, a holistic view includes more than those two aspects of the scope of this study. For example, the relation with other departments within the hospital or the impact on the society. Therefore, the HCPs should think critically about their own OR and if the whole situation is covered. Besides that, this holistic view is fully focussed on the OR in prosperous countries; however, expending this for other (less prosperous) countries could provide a more holistic view as well. The consideration of the objectives and metrics are a good start; however, more research to the holistic view could be helpful to create a more complete holistic view. To ensure the application of the tool, three design categories are stated: Availability, Insight in impact and User-friendly.

Due to (personal) circumstances, stakeholders have not been involved in this study. Therefore, the concepts and the tool are all brought up by the author, without co-creation with the stakeholders and therefore personal bias can be included. Leinonen et al. (2008), Reay et al. (2017) and Sanders (2008) stated that co-creation/co-design is a better way to design tools, since it could help the designer focus on the users' needs (Leinonen et al., 2008; Sanders, 2008) and on the solution of the actual problem (Leinonen et al., 2008). The co-creation can also help to create a holistic view of and a mutual vision on the problem/solution (Leinonen et al., 2008). At the same time, designing with stakeholders creates more knowledge about a problem and design (Leinonen et al., 2008), and involving several stakeholders could improve the satisfaction and acceptance of an innovation (Wilson et al., 2020). Therefore, co-designs will be accepted faster than an enforced design (Boyd et al., 2012). In this study, this topic only has been discussed with three medical scientists. Therefore, it is not sure how the HCPs in hospitals look at this tool. Therefore, one of the limitations in this study is that the stakeholders were not involved and therefore could not improve the satisfaction and acceptance of an innovation (Wilson et al., 2020). Besides that, the diversity of teams can indicate a range of perspectives and mental models (Leinonen et al., 2008), which can lead to new insights.

Due to that the PORC-tool is not designed and tested in practice, but developed with literature. There is a need to apply the PORC-tool in practice, to validate and improve the tool. This tool can be a first step to an improved decision-making process on the OR performance and creating a mutual vision on the objective of the performance optimisation of the OR. With use of the mutual vision and to apply the knowledge and experience of HCPs, there will be more support for the optimisation (Littlejohn et al., 2017). This tool can accommodate the HCPs to better align the process and outcomes with the values, needs and expectations, to accelerate the constructive decision-making and creates a simple opportunity for multidisciplinary learning. The tool has been validated by comparing the tool to the design criteria and by applying the tool on a case. However, this does not fully prove the accuracy, the functionality and the reliability of the tool yet. The same applies for the manual, that has been checked by scientists; however, there HCP had advanced knowledge of Excel and knew the functionality of the tool.

10.4 PORC-tool

The PORC-tool consists of three components; an Excel file, a manual and a brochure. By answering SRQ3 (*"What means can be developed to support decision-making on an optimisation of the performance of the operating room?")*, the Excel file consists of two parts; a flowchart that describes a process and counsels the decision-making process, due to covering multiple steps and the matrix table is more focused on providing an overview in the information base. The HCPs can be supported in their decision-making for optimisation in the OR by creating a holistic view of the objectives and the assessment criteria for performance optimisation of the OR and the optimisation impact. This holistic view can support starting a conversation with the HCPs about their objectives according (the optimisation of) the performance of the OR. A mutual vision on these objectives should be determined, which can be done by effective and respectful communication, equal participation, consensus-based decision-making (Littlejohn et al., 2017). Therefore, all the information should be gathered, and the decisions should be taken in a well-informed and evidence-based manner (Guo, 2020). After agreeing on the objectives, the methods to achieve these objectives can be determined, by stating the metrics. Based on all the information in the PORC-tool and on the mutual vision on the performance optimisation of the OR can lead to a well-informed decision, which corresponds to aim of this study: *"To develop a decision-support tool for healthcare professionals that guides the selection of goals and assessment criteria for performance optimisation of the OR and accounts for the impact of an optimisation on the total system"*.

The complexity of the OR is well-known by the HCPs (Van Beekum, 2022), due to the number and types of surgeries that are performed and due to the many aspects, that the OR includes. The types of HCPs all have a personal external reality within their mind, also called a mental model (Fox et al., 2014), based on their knowledge and experience in the field. The differences in mental models carry different knowledge, skills and abilities (Fay et al., 2006), but can also lead to different goals or priorities in the OR. It is important to have mutual perspectives on a situation while decision-making (Leinonen et al., 2008; Littlejohn et al., 2017), therefore these mutual perspectives should be combined into a singular view. This view is the holistic view in this study. This tool combines multiples visions and perspectives on the objectives and the assessment criteria of the OR performance optimisation. Combining all this information helps the HCPs create a holistic view of the OR and create new knowledge (Turner et al., 2017), since the tool enhances to share perspectives and opens up the conversation about the OR performance optimisation, which could lead to a mutual vision (Littlejohn et al., 2017). If there are already many perspectives involved, the holistic view could already be made by the perspectives of the stakeholders; however, when this is not the case a holistic view is required. This tool provides the user already with different per perspectives, due to the explicitly this can support exchanging mental models. Therefore, this tool can help to gather information more easily, since it provides multiple perspectives on the OR performance and supports to gather more insight into the OR organisation and goals before the decision-making of the HCP. Besides that, the tool can help the HCPs to explain their decisions, since the method can be presented schematical and the objectives and impact can be verified. Therefore, the answer to the main research question is that the HCPs should be facilitated to consider the whole complex system in their decision-making process and create a mutual vision on the objectives and assessment criteria.

It counsels getting insight into the evidence; the relations and causality between the objectives and metrics of the performance optimisation of the OR. Due to this, the users can indicate the influence of a certain optimisation without implementing it. The metrics can function as a relation to the objectives, as a measurement option and as an understanding of a problem. This tool can also be used during an implementation or a design process, to validate if the

project is still on the desired track or if the HCPs are still on the same page. The user still has to be critical themselves, by defining the target performance. To come to the target performance, the user is advised to find the overlapping objectives and metrics of the OR performance optimisation. This function could be built into the tool, which decreases the number of tasks of the HCPs; however, it probably also leads to less critical thinking of the user, since it is partly done by the tool. But could also contain more personal bias.

The PORC-tool is developed with the assumption that HCPs are open to get support in their decision-making process. However, this is not validated by the HCPs itself. According to Turner et al. (2017), there is still a power dynamic present in the decision-making, the highest in hierarchy are the ones deciding. However, evidence is a crucial part of the decision-making and the persuading of the decision-makers (Turner et al., 2017), and therefore is important within a decision-support tool. The PORC-tool consists of scientifical information that can be seen as evidence. Per group, organisation and person, it differs how the decision-making is performed and who is involved in the decision-making process. Therefore, the number of influences and perspectives differs per time. But since the step-by-step-plan for the decision-process is mentioned already, this tool can accommodate the HCPs to better align and standardise the process and outcomes with the values, needs and expectations, to accelerate the constructive decision-making

Due the comprehensive healthcare agreement 2022 of the Netherlands (Dutch: *Integraal Zorgakkoord 2022*), described in Chapter 2, there has been organised a symposium by the Dutch Health Leaders Foundation themed "*Determine the value of your healthcare innovation*" (Dutch: *"Bepaal de waarde van je zorginnovatie"*; Dutch Health Hub, 2022). The PORC-tool can support determining the added value of an optimisation decision for the OR performance, since it provides a clear insight in the impact of implementing an innovation. Therefore, this tool is aligned with the comprehensive healthcare agreement 2022 and therefore supports the Dutch government, umbrella organisations of hospitals, mental healthcare and care for the elderly.

There have been developed a tool in 2020 that helps decision-making for surgical value-based purchasing (Nassiri et al., 2020). This tool focussed on the weighting the patient and clinical care factors, surgeon and care team factors and the hospital factors (finance and sourcing) (Nassiri et al., 2020). Based on a literature study, a list of questions is made to determine about the purchasing. The tool of Nassiri et al. (2020) differs from the PORC-tool, since the PORC-tool provides information about the impact of the optimisation on the OR performance. PORC-tool provides a holistic view of (the optimisation of) the OR performance by use of a clear, structural overview, to support a conversation about the perspectives on objectives and the metrics and stimulate a clarification of the objectives for the optimisation and what methods could help the HCPs to reach this goal.

10.5 Recommendations

This tool focusses on ORs in public hospitals exclusively, only in prosperous countries. Therefore, this tool can be used for all general ORs in this area, but is not perfectly suitable for ORs that are specialised or have specialised equipment, such as imaging equipment. The PORC-tool can be used for these ORs as well; however, more factors are involved. The user can add information or should think critically about the input and output of the tool. Besides that, the innovations related to other departments in the hospital are not considered. However, with critical thinking, it is assumable that the tool can be used for other departments within the hospital as well, since it provides an impression of the objectives and metrics. Also, it provides

a structure to create a holistic view before the decision-making or start up a conversation between the HCPs about the objectives of the optimisation.

The PORC-tool is based on an extensive literature study to the objectives and assessment criteria of the OR performance optimisation. Therefore, this tool cannot be implemented in other (scientific) fields since it does not contain the relevant information; however, the method and template could be applied in these sectors. The literature study is time-consuming and a great deal of work, and therefore probably not visible for professionals to perform. Another method to gather information is by going into conversation with professionals about the objectives and assessment criteria in their (scientific) field. This should be listed and mapped, to discover relations. To validate this, the information should be validated by literature. Assumable this conversation would already give insight in the objectives and can create a mutual vision, required for a sustainable decision (Littlejohn et al., 2017). Although, by implementing the gathered information in the template, the tool, and therefore the information, can be applied more times, which is time-efficient and can become a standard method of decision-making. The PORC-tool can after gathering the correct and relevant information be generalised for other sectors to create a holistic view about the optimisation.

To validate the tool, it is recommended to test the PORC-tool with more cases and to optimise the tool with stakeholders and potential users. It is appreciated that the tool is discussed with the stakeholders and decision-makers, mainly because of their expertise on the OR and the objectives of the OR performance. They are pre-eminently the ones with the knowledge and experience on the OR performance and OR optimisations. Therefore, they could further refine the content of the tool. Besides that, the results of cases can be compared to the results/impact of introducing an optimisation to the OR performance, to indicate the effects of the tool. All the information is gathered by one person, even though the personal bias is tried to minimalised, there could be bias in the objectives, metrics and causalities of the metrics. Therefore, the information should be verified in practice and with stakeholders. One of the improvements could be adding a more specific timeline, in order that the HCPs can check at what moment the tool could be useful. But also, for the appearance and the user-friendliness, the input of stakeholders could help. The tool is also designed in a manner that the tool can be easily adjusted, the stakeholders can adjust the tool during the optimisation.

The PORC-tool can provide insight in the impact and consequences of an optimisation; however, it does not quantify this. Therefore, another recommendation is to add any indication of the accuracy and precision in the metric causalities, which also can be done by literature and practice. The tool also does not elaborate on the units of the metrics; however, these can be found in Appendix F. For the future, it would be recommended to implement these on another sheet in the PORC-tool. To elaborate the tool even further, the data can be gathered for private or specialist hospitals as well and more information about disease-specific surgeries can be added. It would also be interesting to add information or adjust the tool for underdeveloped countries, since assumable they cannot use the PORC-tool due to other objectives and decision-making processes. Other interesting topics to research could be evaluating the impact after implementation, and the kind of situations where the tool could be used, for example implementing the costs/service delivery (Naderi et al., 2021), which is pressured in the hospitals (Xiao & Yoogalingam, 2021).

10.6 Reflection

The master CDI focusses on the communication in innovation processes, often in multidisciplinary environments to improve understanding of problems or create ingenious innovations for complex situations. BME is a combination of at least two research fields,

namely engineering and healthcare and could therefore be seen as a multidisciplinary field. In this study, BME vision covers mainly the understanding of the complexity of the OR by use of a literature study. This understanding is not only important to explain the research, but also to create support for the innovation or the application (Littlejohn et al., 2017). The complexity of the OR is amplified by the many visions and mental models of the involved disciplines. For CDI, the focus was mainly on the decision-making between multidisciplinary fields and come to a collective decision by sharing different visions. This could help biomedical engineers with determining the goals of an innovations or the direction of a solution. By combining the two fields, there is created an understanding of the complexity of the OR and its decision-making, which lead to the PORC-tool, that acknowledges the desires and requirements from the both fields. Concluded can be that technical knowledge and understanding of multidisciplinary collaboration is essential for developing this tool, since it combines several perspectives and creates a holistic view.

The healthcare system in prosperous countries is already good; however, BME focusses on everything that could/should be improved. To improve the healthcare and its decision-making, there should be performed more research, in my opinion especially in the combination of BME and CDI. However, other disciplines could be involved as well to create a better understanding in the decision-making on healthcare. To understand the complexity of situations better, collaboration between several research fields is required (Fay et al. 2006), including HCPs, engineers and financial expertise for the OR. In my opinion, it could help to set priorities is goals and limits for the optimisation of the OR, to consider innovations. Hereford, the politics could take a leading position; however, the decision-making system in the hospitals should be changed as well, thinking about releasing the hierarchy while creating a holistic view.

A requirement for optimisation is multidisciplinary collaboration, in my opinion. Due to these collaborations, sustainable decisions can be made in/for the designing processes and innovations can optimise the healthcare, support implementation and the acceptance of the innovation by the laymen and HCPs (Fay et al. 2006). In the last paragraphs, there is reflected on this study and the masters BME and CDI and the added value of combining those. It includes my personal vision on the studies, and the current scientifical fields and research. Therefore, no scientifical rights can be derived from this.

The PORC-tool provides a holistic view of (the optimisation of) the OR performance, including the high heterogeneity in the perspectives on the objectives and metrics for the optimisation of the performance of the OR. This holistic view is created in the PORC-tool, however, the information for the tool and the design of the tool is gathered by one person, even though co-design would be better for the result. The PORC-tool provides insight for the users and stakeholders by creating a holistic view with a clear and structural overview. This tool can accommodate the HCPs to better align the process and outcomes with the values, needs and expectations, to accelerate the constructive decision-making and creates a simple opportunity for multidisciplinary learning, by sharing perspectives and starting a conversation. This tool provides a lot of information and does not require an expert; however, the HCPs should still think critically about their input and results. For the future, the tool should be validated in practice and be test on the functionality.

11 Conclusion

Last decades, the OR is pressured to improve the quality of care (Britt et al., 2021), reduce the expenditure (Britt et al., 2021), manage the high need for services (Bovim et al., 2020; Kheiri et al., 2021) and enhance the safety (WHO Europe, 2021; WHO, 2021c). For optimisation in the OR, the objectives and assessment criteria for the OR should be known or defined per situation. This is hard, since the OR is a complex organisation with multidisciplinary teams (WHO, 2021c), a constant evolution in design (Chasseigne et al., 2020), high time-pressure (Xiao & Yoogalingam, 2021) and the high responsibility for lives (Burdett & Kozan, 2018). Currently, HCPs often take the decisions based on experience, attitudes and society pressure (Iacopino, 2018), even though decision-making requires a mutual vision (Littlejohn et al., 2017) and should be based on evidence (Turner et al., 2017). The ignorance of HCPs about (the optimisation of) the performance of the OR, leads to different situations as wrong purchasing, no specific goal and research. Therefore, the MRQ is defined as: "*How can a decision-support tool for optimisation in the operating room help a healthcare professional to select the objectives and the assessment criteria for performance optimisation of the operating room and the optimisation impact?".*

This question is partly answered by gathering evidence for the decision-making, respectively stating the objectives of the performance optimisation of the OR by an extensive literature study (SRQ1: *"What is the definition of the performance of the operating room according to the healthcare professionals to identify the objectives of optimising the performance of the operating room?"*). A big variety in the objectives have been found, in total, there are found 14 objective factors with a general focus on the performance optimisation of the OR and 19 objective characteristics. Metrics and units are identified as an answer on SRQ: *"What are the assessment criteria to quantify the performance optimisation of the operating room?"*. According to the clustered phrases from 84 articles in factors and characteristics of the metrics, there are identified 70 metric factors, 42 metric characteristics and 29 units. By asking *"How are the assessment criteria and the objectives of the operating room related to each other?"* (SRQ2a), there have been found a high number of relations between objectives and metrics (namely 223 in number). The most common objective does not correspond with the most common metric and can be stated that the methods are therefore often not measuring the desired performance optimisation. For comparing ORs, Schedule could be a good method, since this is the most common metric and occurs in 50% of the objectives. By analysing 56 other articles SRQ2b (*"How are the assessment criteria of the operating room performance optimisation affecting on each other?"*) can be answered, the metrics have been verified and causalities between the metrics are indicated. There are found 253 causalities between 42 metrics, which confirms the complexity of the OR.

The OR is a multifaceted and complex organisation; therefore, the decision-making process requires evidence (Turner et al., 2017) and a mutual vision (Littlejohn et al., 2017) on the OR performance. A holistic view of the (the optimisation of) performance of the OR can help to create a mutual vision, therefore supports a well-informed decision-making. This led to designing the Performance Operating Room Counselling (PORC-)tool that enables and standardised the decision-making on performance optimisation for the HCPs in the OR by counselling in considering a holistic view of the performance objective and its metrics. The tool consists of three parts: an Excel file, a manual and a brochure. The manual provides guidance for the tool-user and brochure is a short version of the manual and can remind the potential user to use and share the tool. The Excel file provides an overview of the relations between the objectives and metrics and of the causalities of the metrics. The Excel file is based on a flowchart that describes a process and helps deciding due to covering multiple steps and a matrix table that focusses more on providing an overview in the information base, as the

answer to *"What means can be developed to support decision-making on an optimisation of the performance of the operating room?"* (SRQ3).

Creating a holistic view, causing HCPs to think about their objectives for the OR, how this could be achieved, sharing (different) perspectives on the objectives or assessing criteria and creating a mutual vision contributes to a well-informed decision on the OR performance. The PORC-tool provides a clear and structural overview, that provides evidence about the objectives, the assessing criteria, relations and causalities of the OR and facilitates to consider the whole complex system in their decision-making process. The PORC-tool accelerate and standardise the process, by providing structure and information about the decision-making process to the HCPs. In the future, this tool can help to gather information more easily and therefore more insight into the OR organisation and goals before the decision-making of the HCP. However, more validation and upgrading of the tool is desired to adopt the PORC-tool in practice. After validating this tool and analysing the result, the tool could be applied in other (health) departments or sectors if desired.

The PORC-tool is designed to create a holistic view that enables and standardised the decision-making process of HCPs on optimisation for the OR performance. This tool supports the HCPs to clarify what their objectives are for the OR performance and what method could help them to reach this goal. This tool opens up the perspectives and the conversations about the OR performance optimisation, to create a mutual vision under the HCPs. The PORC-tool could support the HCP to take decisions whereby the whole complex system is considered in a standardise process. This is the answer to the MRQ: "*How can a decision-support tool for optimisation in the operating room help a healthcare professional to select the objectives and the assessment criteria for performance optimisation of the operating room and the optimisation impact?".* However, for the factual support, the tool should be validated in practice.

“A good decision is based on the holistic view of the knowledge and a mutual vision, and not only on numbers”

K.E. van Beekum

Adaptations to a quote of Plato: "A good decision is based on knowledge and not on numbers"

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Appendix

Table of tables

Appendix A Operating room

Design

The requirements for an OR included among others: a minimum size of 37 squared meter (Burlingame, 2014), personal protective equipment (Adams et al., 2016; WHO, 2021c), listed below, high-level of disinfected or sterile instruments (Langlands, 2021), filters for air pressure (WHO, 2021c), low temperature (WHO, 2021c) and environmental controls (Langlands, 2021) to prevent infections (Clemons, 2000). The OR need to be well lighted, have a present air-ventilation, dedicated equipment for procedure and to monitor patients and drugs for routine and emergencies (WHO, 2021c). Besides the interior design of the OR, there are also some requirements outside the OR (WHO, 2021c): washing, changing, preparation and recover room, storage, central sterile service department and cleaning facilities.

Personal protective equipment helps to prevent bacteria from infecting the surgical incision and to prevent exposure of the surgical team to blood or other fluids from the patients (WHO, 2021c). The following attires are part of this set of equipment: an attire of clean, nonsterile hospital-laundered clothes (Adams et al., 2016), also called a sterile surgical robe (WHO, 2021c), masks that cover the mouth and nose (Adams et al., 2016; WHO, 2021c), hair-coverings (Adams et al., 2016; WHO, 2021c) and sterile surgical robes (Adams et al., 2016; WHO, 2021c). The attire listed above is the basic attire for a surgery, sometimes the surgery requires some extra equipment as glasses of protective covers for shoes (WHO, 2021c).

To perform the surgery, the surgical team requires some equipment, some other equipment is necessary in case of an unexpected issue. According to WHO (2021b), the following facilities should be present in a standard OR:

- Anaesthetic machine
- Caesarean section set
- Defibrillator
- Electrocardiogram Monitor
- Electrosurgical unit
- General set of instruments
- Instrument cabinet
- Instrument table (MAYO)
- Instrument trolleys, incl. medication/equipment
- Laryngoscope
- Myomectomy
- Operating theatre lamp, ceiling mounted
- Operating theatre mobile lamp
- Operating theatre table
- Oxygen regulator
- Patient trolley
- Pulse oximeter
- Refrigerator
- Resuscitation bag
- Spot light
- Suction electric machine
- Surgeon foot step
- Surgeon’s stool
- Vital Signs Monitor

Phases

The process of a surgery in the OR can be divided in four phases and tasks for the team; scheduling, preoperative, operative and postoperative phase (LUMC, 2021; WHO, 2021c). In the scheduling phase, the administrative staff determine the location, timeslot and medical professionals (WHO, 2021c). Within the preoperative phase, the medical team prepares for the surgery by putting on the personal protective equipment and checking the OR and instrumentation (WHO, 2021c). In this phase, the surgeon also has a conversation with the patient (LUMC, 2021), to prepare the patient for its surgery (WHO, 2021c) and the operating nurse does a routine examination (LUMC, 2021) to check the patient's physical condition (WHO, 2021c).

Afterwards, the patient will be brought to the OR (WHO, 2021c), be positioned (WHO, 2021c) and the personal information, such as name, medical problem and date, will be checked (LUMC, 2021; WHO, 2021c). In this operative phase, the anaesthetist or CRNA performs the anaesthesia safety check, connects the pulse oximeter (WHO, 2021c) and gives the anaesthetics (LUMC, 2021; WHO, 2021c). The whole team discusses the surgical and medical potential issues (WHO, 2021c). The operating nurse prepares, cleans, disinfects and drapes the patient with sterile paper (WHO, 2021c). At this point, the surgery can start and at the end, the specimens are labelled, the number of instruments is checked and the operating nurse tidies up the surgical field (WHO, 2021c).

In the postoperative phase, the patient will be brought back to the recovery ward (LUMC, 2021; WHO, 2021c) and the surgeon and anaesthetist provide the patient handover to the recovery practitioner (WHO, 2021c). The instrumentation should be brought away for sterilisation and the cleaning personnel cleans the whole OR (WHO, 2021c). In the meantime, the surgical team de-scrubs themselves of the personal protective equipment and start handwashing (WHO, 2021c). A more elaborated overview is provided in Table Appendix 1.

Table Appendix 1: The process of a surgery in the OR, divided in the tasks of the surgical team and the process for the patient. In case that "whole team" is stated, this includes surgeons, anaesthetist, CRNA and operating nurse.

Phase	Task team	Goal	Process patient
Scheduling	Administrative staff: determine location, timeslot and practitioners (WHO, 2021c)		
Pre-operative	Whole team: scrubbing hands and putting on the personal protective equipment (WHO, 2021c)	Minimizing chance on infections (WHO, 2021c)	Be on an empty stomach (LUMC, 2021)
	Whole team: check if OR is uncontaminated and dust free, cleaning need to be done by water with detergent and disinfection (WHO, 2021c). From now on, the doors should be closed as much as possible (WHO, 2021c)	Minimizing chance on infections (WHO, 2021c)	Check-in at the nursing department (LUMC, 2021)
	Operative nurse: check if all surgical instruments and administering medication is present (WHO, 2021c)		Changing clothes and placing in the bed (LUMC, 2021)
	Surgeon: conversation with patient (LUMC, 2021)	Prepare the patient for its surgery (WHO, 2021c)	Conversation with the surgeon (LUMC, 2021; WHO, 2021c)
	Anaesthetist or CRNA: conversation with patient (LUMC, 2021)	Pre-operative screening (LUMC, 2021; WHO, 2021c)	Conversation with the anaesthetist (LUMC, 2021; WHO, 2021c)
	Operating nurse: Routine examination (LUMC, 2021)	Check on the physical condition, to secure a good probability of recovery (WHO, 2021c)	Routine examination by a nurse (LUMC, 2021)
	Operative nurse: locate the equipment and facilities, as table, lights and materials, on the right place (WHO, 2021c)		Waiting room (LUMC, 2021)

Phase	Task team	Goal	Process patient
	Operative nurse: make ready the MAYO table with instruments and count the surgical instruments (WHO, 2021c)		Towards the OR (LUMC, 2021)
Operative	Operative nurse: bring patient in, keep the doors closed and minimum amount of people in the OR as much as possible (WHO, 2021c)	Minimizing chance on infections (WHO, 2021c)	Arriving in the OR (WHO, 2021c)
	Operating nurse: positioning of the patient (including blankets) and operating table (WHO, 2021c)		Right position on the operating table (warm blankets; LUMC, 2021)
	Surgeon: check of personal information (LUMC, 2021; WHO, 2021c); identity, side of surgery; consent with operation (WHO, 2021c), consult the surgery (LUMC, 2021)	To secure the right treatment/surgery (WHO, 2021c)	Check of personal information (LUMC, 2021; WHO, 2021c), consent with operation (WHO, 2021c), consult the surgery (LUMC, 2021)
	Anaesthetist or CRNA: perform the anaesthesia safety check, pulse oximeter (WHO, 2021c)	Check on the physical condition, to secure a good probability of recovery (WHO, 2021c)	Infusion of Anaesthesia (LUMC, 2021)
	Anaesthetist and CRNA: taking care of anaesthesia (LUMC, 2021; WHO, 2021c)		Anaesthesia start working (LUMC, 2021; WHO, 2021c)
	Whole team: discuss issue potential (WHO, 2021c)	Check on the physical condition, to secure a good probability of recovery (WHO, 2021c)	Surgery (LUMC, 2021; WHO, 2021c)
	Anaesthetist and CRNA: taking care of holding the stability of the bodily functions (LUMC, 2021)	Intra-operative monitoring for safety (WHO, 2021c)	

Phase	Task team	Goal	Process patient
	Operating nurse: preparation, cleaning, sterilising, possibly shaving and draping, with sterile paper, of patient (WHO, 2021c)	Minimizing chance on infections (WHO, 2021c) and to keep the incision location free of other materials (LUMC, 2021; WHO, 2021c)	
	Surgeon and operating nurse: check the number of instruments (WHO, 2021c)	To prevent left overs in the body of the patient (WHO, 2021c)	
	Whole team: surgery (WHO, 2021c)		
	Surgeon or operating nurse: Closing wound (WHO, 2021c)		
	Surgeon or operating nurse: checking the labelling of the specimens, any issues to address to post-operative recovery and possible anticipated critical events (WHO, 2021c)	To prevent issues in the recovery (WHO, 2021c)	
	Surgeon and operating nurse: check the number of instruments (WHO, 2021c)	To prevent left overs in the body of the patient (WHO, 2021c)	
	Operating nurse: cleaning up the surgical field (WHO, 2021c)	Minimizing chance on infections for the team and next patients (WHO, 2021c)	
	Operating nurse: calling contact person about the outcome of the surgery (LUMC, 2021)		
Past-operative	Operating nurse: place the patient back in the bed and move it to the recovery ward (LUMC, 2021; WHO, 2021c)		Towards the recovery ward (LUMC, 2021; WHO, 2021c)

Phase	Task team	Goal	Process patient
	Surgeon and anaesthetist: Patient handover to recovery practitioner (WHO, 2021c)	To progress a good recovery care for the patient (WHO, 2021c)	Waking up (LUMC, 2021)
	Operating nurse: place instruments in autoclave baskets and bring it to the sterilisation department for sterilisation (WHO, 2021c)	To sterilise the instruments, to purged microorganisms and spores (WHO, 2021c)	Update by nurse about the outcome of the surgery (LUMC, 2021)
	Nurse/cleaning personnel: cleaning the surgical area, disinfection of the surfaces and placing the materials in the right bin, biological, contaminated, bio-hazardous and sharp materials (WHO, 2021c)	Recovery of the first day(s) after surgeries with a large impact on the bodily condition (LUMC, 2021)	Towards the ICU/PACU/nurse department (LUMC, 2021)
	Whole team: de-scrub of the personal protective equipment and handwashing (WHO, 2021c)	Minimizing chance on infections for the team and next patients (WHO, 2021c)	Recovery at home
	Surgeon: finish documentation and the operation note and check the final checklist (WHO, 2021c)	To progress a good recovery care for the patient (WHO, 2021c)	
	Back to the pre-operative phase or at the end of the day: clean the whole OR by starting at the top and continue to the floor, including all furniture, overhead equipment and lights, using a liquid disinfectant at a dilution recommended by the manufacturer (WHO, 2021c)	Minimizing chance on infections for the team and next patients (WHO, 2021c)	

Appendix B The codes definitions

Table Appendix 2: The definitions of all the codes used in this thesis, organised on alphabetical order and in the second column is the term level (objective factor, objective characteristic, metric factor, metric characteristic and unit) described.

Code	Terms	Definition
Accessibility	Objective factor, metric factor	The ability to obtaining or using healthcare at the OR, this includes services (range of diagnose, number of resources and safety) and geographical, financial accessibility.
Accreditation	Metric factor, unit	The number of certifications of being officially recognised, accepted, or approved of performing a certain act, expressed in number or quality.
Accuracy	Metric factor, metric characteristic	The degree of precision to which the treatment is performed without making mistakes and being exact.
Adequacy	Objective characteristic	The fact that the services in the OR can performed till the desired sufficiency.
Affordability	Metric factor	The state of being (in)expensive enough for people to be able to buy.
Alcohol (mL/kg)	Unit	The amount of alcohol in the body.
Anatomy	Metric characteristic	The status of the physical structure of the patient.
Anticoagulation	Metric characteristic	The amount of medicine to prevent blood clothing.
Anxiety	Metric characteristic	The degree of worrying and tension of the staff for performing their act.
Audit performance	Metric factor	The number of evaluations of the OR performance in a certain time-period; device audit, laboratory evaluation, clinical evaluation.
Authority	Objective characteristic, metric factor, metric characteristic	The degree of leadership during a treatment and who is in control and makes the decisions, mostly the surgeon.
Bed utilisation	Metric factor, metric characteristic	The degree to which the ward-beds are used in an effective way.
Beds (#)	Unit	The number of beds in the hospital.
Behaviour	Metric factor, metric characteristic	The way the medical staff is treating or acting in the OR and the effects on the other stakeholders.
Caffeine (mL/kg)	Unit	The amount of caffeine in the body.
Cancellation	Metric characteristic, unit	The number of surgeries that are cancelled, expressed in number.
Care outcomes	Objective factor, objective characteristic, metric factor	The effect of the treatment on the patient and therefore the patient's health condition over time.

Code	Terms	Definition
Coaching	Metric characteristic, unit	The feedback and coaching based on videos and audio, expressed in number of frequencies by the HCP to other staff.
Communication	Metric factor, metric characteristic	The amount and the quality of information transmission between stakeholders.
Complexity	Metric factor, metric characteristic	The degree of complicatedness of the treatment for the medical staff.
Complication	Metric factor, metric characteristic	The number and degree of extra medical problems, that makes it more difficult to treat the illness or to recover from the surgery.
Complications (#)	Unit	The number of complications occurring during and after the surgery.
Cost	Metric factor	The cost in/of the hospital.
Culture	Metric factor	The organisational environment of the hospital, including the general norms and values of a group.
Deaths (#)	Unit	The number of deaths during or after the surgery.
Decision-making	Objective characteristic, metric factor, metric characteristic	The processing of deciding during the surgery about the treatment and the after-care in number and quality.
Delay	Metric characteristic	The time period that the surgery starts later than planned in the OR schedule.
Development innovations (#)	Unit	The number of developed innovations.
Diagnose	Metric factor	The correctness of diagnosing the patient.
Diagnosis range (#)	Unit	The number of diagnosed range that the hospital can treat.
Discharge	Metric factor, unit	The number of patients that can leave the hospital (ward) according to the medical professional, expressed in number of discharges.
Disposables (#)	Unit	The number of disposables during or after the surgery.
Distribution equipment	Metric factor, metric characteristic	The number of resources deliveries to the OR.
Distribution velocity	Metric characteristic, unit	The velocity of the resource's deliveries to the OR, expressed in number of equipment transferred in a time period.
Disturbance	Metric factor, metric characteristic	The number and length of interruptions during a surgery and its effects on the surgical performance.

Code	Terms	Definition
Education	Metric factor, metric characteristic	The quality and content of the education of the medical staff.
Education & knowledge	Objective characteristic	The (extra) instructions and the development of knowledge (improvement) of and for the medical staff.
Emergency cases (#)	Unit	The number of emergency cases.
Emission (CO2)	Unit	The amount of CO2 emission.
Emission (CO2/GHG)	Unit	The amount of CO2/GHG emission.
Emission (GHG)	Unit	The amount of GHG emission.
Energy	Metric characteristic	The amount of generated power and electricity used during the surgery.
Environment	Objective characteristic, metric factor, metric characteristic	The effects (of sustainable development) on the nature, climate and climate change.
Equipment	Metric characteristic	The number of (set of) tools for the surgery in the OR.
Equipment inventory	Metric characteristic	The amount of equipment in stock and available to use.
Equipment type	Metric factor	The number of (set of) tools for the surgery in the OR.
Equipment utilisation	Metric factor, metric characteristic	The degree to which the equipment is used in an effective way.
Equity	Metric factor, metric characteristic	The degree to which the stakeholders can access and obtain the same type or number of treatments.
Ergonomics	Metric factor, metric characteristic	The degree to which the staff can work in an appropriate posture or the posture of the staff during the surgery.
Error (#)	Unit	The number of errors during or after the surgery.
Experience (years)	Unit	The number of years in experience of the professional in its expertise.
Expertise	Metric factor, metric characteristic	The degree of expertise and knowledge of the medical staff that performs the surgery.
Finance	Objective factor	The management of money, the business and investments.
Flow (#)	Unit	The frequency of communication.

Code	Terms	Definition
FTE (#)	Unit	The number of full-time employments at the hospital.
Haptic feedback	Unit	The feeling of the haptic feedback.
Hygiene	Metric factor	The degree to which people keep themselves or their environment clean, to prevent disease.
Idle time	Metric factor	The period of time that the medical staff or the OR is not being used, despite the fact that it is available.
Interruptions (#)	Unit	The number of interruptions during the surgery.
Inventory	Metric factor	The amount of equipment and resources in stock and available to use.
Investment	Metric factor	The amount of money that is put in resources, equipment and other parts of the hospital to achieve an improvement of the performance.
Length of stay	Metric factor, metric characteristic, unit	The days that the patient had to stay in the hospital for their treatment and recovery, expressed in number of days.
Lighting	Metric characteristic, unit	The amount of lightning in the OR, expressed in lumen.
Maintenance	Metric factor, metric characteristic	The amount of work that need to be performed to keep the OR and its equipment/resources in good condition.
Management	Objective factor	The control of the organisation, including the administration, board and its policies.
Management satisfaction	Objective characteristic	The fulfilling/achieving the need or desire of the act for the management/board of the hospital.
Misidentification	Metric characteristic	The number of misidentifications of patients.
Money ($; €)	Unit	The amount of money that a certain action or material costs.
Morbidity	Metric characteristic	The degree of the patient's condition of chronic (long-term) and age-related diseases.
Mortality	Metric characteristic	The number of deaths caused by an event or illness over a specific period of time.
Noise (dB)	Unit	The amount of dB of noise during the surgery.
Nutrition	Metric characteristic	The quality of the food that is consumed by a person.
Opening hours OR	Metric factor	The hours that the OR is available for surgery.
Operational performance	Objective characteristic, metric factor	The arrangements and tasks required to control the operation of a plan or organisation.
OR block	Metric factor, metric characteristic	The amount of time that is blocked in the OR schedule for a certain treatment, expressed in number of blocks.

Code	Terms	Definition
OR block; double booking (#)	Unit	The number of OR blocks double booked in a schedule.
OR block; gaps (#)	Unit	The number of OR blocks unfilled in the schedule.
OR break	Metric characteristic	The period of time that is used for an interruption in working for the medical staff.
OR design	Metric factor, metric characteristic	The quality of the state and the furniture of the OR.
OR overtime	Metric characteristic	The period of time that the medical staff or the OR is being used, despite the fact that it should be available to be used for the next surgery.
OR size (m2)	Unit	The size of the OR.
OR time	Metric characteristic, unit	The time period that the OR is in use, expressed in percentage.
OR utilisation	Metric factor, metric characteristic	The degree to which the opening hours of the ORs are used in an effective way.
ORs (#)	Unit	The number of ORs that are available in a hospital.
PACU over time	Metric characteristic	The period of time that the PACU is being used, despite the fact that it should be available to be used for the next patient.
Patient (#)	Unit	The number of patients that require surgery.
Patient (health) condition	Objective factor, metric factor, metric characteristic	The quality of the physical condition and fitness of the patient, including sickness and the life(style) circumstances of the patients.
Patient flow	Objective factor, metric factor	The transfers of patients through the hospital; from the ward to the OR to the ward.
Patient health: Blood loss (mL)	Unit	The amount of blood loss from the patient during the surgery.
Patient health: Blood pressure (mmHg)	Unit	The blood pressure of the patient during the surgery.
Patient health: Cardiac output (L/min)	Unit	The amount of cardiac output of the patient during the surgery.
Patient health: Catecholamine (mg/kg)	Unit	The amount of catecholamine in the body of the patient during the surgery.

Code	Terms	Definition
Patient health: Compression (depth; rate)	Unit	The depth of the compression and the rate of the compression of the patient's body during the surgery.
Patient health: Glucose control (mg/dL)	Unit	The amount of glucose in the body of the patient during the surgery.
Patient health: Haemoglobin A1c (%)	Unit	The amount of haemoglobin A1c in the body of the patient during the surgery.
Patient health: Haemorrhage incidence (#)	Unit	The amount of haemorrhage incidents that the patients endure during surgery.
Patient health: Heart rate (bpm)	Unit	The heart rate of the patient during the surgery.
Patient health: Hypoglycaemia (mmol/L)	Unit	The amount of hypoglycaemia in the body of the patient during the surgery.
Patient health: Ischemic stroke (%)	Unit	The percentage of occurring ischemic stroke of the patient during a surgery.
Patient health: Stroke volume (L)	Unit	The stroke volume of the patient during the surgery.
Patient priority	Metric characteristic	The arrangement of patients in emergency for the OR planning.
Patient satisfaction	Objective characteristic, metric factor, metric characteristic	The fulfilling/achieving the need or desire of the act for the patients of the hospital.
Perspiration	Metric characteristic	The amount of sweat from the staff during the act.
Pharmaceutical inventory	Metric characteristic	The number of pharmaceuticals in stock and available to use.
Pharmaceuticals	Metric factor, unit	The number of medicines that are necessary for the patients, expressed in number of pharmaceuticals.

Code	Terms	Definition
Pharmaceuticals; B-blockers (#)	Unit	The number of B-blockers medication the patient has to take.
Physical work	Metric characteristic	The amount and load of muscles work for the staff.
Policy	Metric factor, metric characteristic	The number and the quality of the guidelines for the treatment and the degree that these guidelines are followed up.
Profit	Metric factor	The amount of money that is earned in trade or business after paying the costs of producing and selling goods and services.
Psychological condition	Metric characteristic	The quality of the psychological condition and mental fitness of the staff.
QALY	Unit	The level of quality of life per year stated by the patient.
Quality of care	Objective factor, objective characteristic	The value of health services for individuals and populations to increase the likelihood of desired health outcomes.
Quality of life	Metric factor	The level of satisfaction and comfort that the patient values its life.
Quality per price	Unit	The quality of the treatment in relation to the price of the treatment.
Readmission	Metric factor, metric characteristic	The number of patients that are readmitted to the hospital after a discharge, expressed in number of readmissions.
Resources	Objective factor	The equipment, means and materials for the treatment and after-care.
Responsiveness	Metric factor, metric characteristic	The time period and quality of the reaction to an emergency case and the degree of alertness of the situation.
Revenue	Metric factor	The amount of income that a company receives regularly.
Robustness	Metric characteristic, unit	The level of quality to be likely to happen in a schedule, expressed in percentage.
Safety	Objective factor, objective characteristic, metric factor	Health services for individuals and populations providing a safe and risk-free healthcare, with the intention of the best outcomes for the patient and staff.
Satisfaction	Objective factor	The fulfilling/achieving the need or desire of the act for a certain stakeholder.
Satisfaction patient	Unit	The level of satisfaction and comfort that the patient values its treatment.
Satisfaction staff	Unit	The level of satisfaction and comfort that the staff values its work.
Satisfaction Staff/Patient	Unit	The level of satisfaction and comfort that the staff values its work and the patient values its treatment.
Savings	Metric factor	The amount of money that is not spend/invested and therefore is kept on the bank account.
Schedule	Metric factor	The quality of the OR schedule.

Code	Terms	Definition
Sensory factors	Metric characteristic	The amount of physical sense of touch, smell, taste, hearing and sight.
Service	Objective factor	All provided types of activities within the hospital and OR, except the task surgery.
Service capacity	Metric factor, metric characteristic	The total amount of services, except from surgery, that can be delivered in the hospital/OR.
Shift	Metric factor, metric characteristic	The number, duration and type of period of time working (hours) during the day or night, expressed in number of shifts.
Skill	Metric factor, metric characteristic	The level of ability to perform or practised a treatment, this includes cognitive, nontechnical and technical skills.
Sleep	Metric characteristic	The amount of sleep for a person.
Staff (# Nurses)	Unit	The number of nurses at the surgery.
Staff (# RNs)	Unit	The number of registered nurses (RNs) at the surgery.
Staff (#)	Unit	The number of staff at the surgery.
Staff (health) condition	Objective factor, metric factor	The quality of the physical condition and fitness of the staff, including sickness and the life(style) circumstances of the staff.
Staff health: Absences (#)	Unit	The number of staff absences caused by (a lack of) staff health.
Staff health: Circadian rhythm	Unit	The circadian rhythm of staff caused by (a lack of) staff health.
Staff health: Muscular load	Unit	The muscular loas of staff caused by (a lack of) staff health.
Staff health: Respiration rate	Unit	The respiration rate of staff caused by (a lack of) staff health.
Staff health: Tremor (#)	Unit	The number of tremors of the staff caused by (a lack of) staff health.
Staff performance	Objective characteristic, metric factor	The performance of the individuals of the medical staff during the surgery or after-care.
Staff satisfaction	Objective characteristic, metric factor, metric characteristic	The fulfilling/achieving the need or desire of the act for the medical staff of the hospital.
Start time	Metric factor, metric characteristic	The accuracy in that the actual time of beginning is the planned start time according to the schedule.

Code	Terms	Definition
Stressors	Metric factor, metric characteristic	The amount of stress that is caused at the surgery.
Supply	Objective characteristic	The contribution of resources and equipment to the OR and the stock of all those resources.
Surgery (#)	Unit	The number of surgeries performed in a set time period.
Surgery duration	Metric factor	The time period to perform a surgery.
Surgery efficiency	Metric factor, metric characteristic	The level of time and staff is used in a good way (without any waste) during a surgery.
Surgery volume	Metric factor	The number of surgeries performed in a time period.
Surgical performance	Objective factor, objective characteristic, metric factor	The results of accomplishment and its quality of the surgery completes by the medical staff.
Survival	Metric factor, metric characteristic	The number of patients that survive from the surgery.
Task	Metric characteristic, unit	The tasks performed by the staff, expressed in number.
Team	Objective factor	The group of medical professionals that perform care in the OR.
Team structure	Metric factor, metric characteristic	The type of medical professionals that are involved with the team during a treatment.
Teamwork	Objective characteristic, metric factor, metric characteristic	The collaboration of the group of medical professionals that perform care in the OR.
Technology	Objective characteristic, metric factor, metric characteristic	The development of new technology and its effects on the healthcare.
Temperature (°C; F)	Unit	The temperature in the OR.
Time (days)	Unit	The number of days.
Time (hours)	Unit	The number of hours.
Time (months)	Unit	The number of months.
Time: Delay (#)	Unit	The number of delayed surgeries.
Time: Delay (%)	Unit	The percentage of delayed surgeries.
Time: Delay (hours)	Unit	The period of time that is spend to delay (later start as planned on beforehand).
Time: Idle time (hours)	Unit	The period of time that is spend to idle time (time that the staff is not performing an acts).

Code	Terms	Definition
Time: OR block time (hours)	Unit	The period of time that is reserved as a OR block in the OR schedule.
Time: OR opening hours (hours)	Unit	The period of time that the OR is open.
Time: OR over time (hours)	Unit	The period of time that is spend longer in the OR as planned on beforehand.
Time: OR time (hours)	Unit	The period of time that is spend in the OR.
Time: PACU over time (hours)	Unit	The period of time that is spend longer in the PACU as planned on beforehand.
Time: Waiting time (days)	Unit	The days spend that the patient spend on waiting for a surgery or on the waiting list.
Time: Waiting time (hours)	Unit	The hours spend that the patient spend on waiting for a surgery.
Time: Waiting time (hours; days)	Unit	The hours/days spend that the patient spend on waiting for a surgery or on the waiting list.
Transfers (#)	Unit	The number of patient transfers through the hospital.
Transparency	Metric characteristic	The quality of openness in what is performed.
Treatment	Metric characteristic	The types of surgeries that are performed.
Treatment type	Metric factor	The types of surgeries that are performed.
Trust	Metric factor, metric characteristic	The believe in capability and truth in the team or medical staff.
Turnover	Metric characteristic	The number of tasks that can be perform in a certain time period in OR.
Usability	Metric characteristic	The easiness of obtaining or using equipment and resources at the OR.
Usage (#)	Unit	The frequency of utilisation of resources during the whole treatment.
Value-based healthcare	Objective characteristic	The aim to improve patient outcomes while optimising the use of hospitals' resources among medical personnel, administrations and support services through an evidence-based, collaborative approach.
Ventilation	Metric characteristic	The amount of ventilation in the OR.

Code	Terms	Definition
Waiting list	Metric factor, unit	The number of people, who desire care, that are put on list since there is no care available yet, expressed in number of patients on the list.
Waiting time	Metric factor	The period of time that the patient has to wait before or after entering the OR.
Waste	Metric factor, metric characteristic, unit	The number of materials that is ditched or the amount of unnecessary or wrong used materials, expressed in kilogram.
Waste Reuse (#)	Unit	The amount of waste after surgery that could be reused.
Wires (#)	Unit	The number of wires in the OR.
Workforce	Metric factor, metric characteristic, unit	The number of medical staff who work in the hospital or department, expressed in number of staff per patient to provide work.
Working hours (#)	Unit	The number of working hours.
Workload	Objective characteristic, metric factor, metric characteristic	The work and the number of tasks that needs to be performed by the medical staff.

Appendix C The objective of the performance optimisation of the OR

Table Appendix 3: The objectives of the performance optimisation of the OR, including the objective factors and characteristics, together with the corresponding number of studies and references. Between the brackets, the frequency of phrases within the articles are stated. All the objectives that occurred only once (n=1) in all articles or only occur in one article has been removed.

Objective factor	Objective characteristic	Frequency (# phrases (# articles))	References (# phrases)
Accessibility		37 (12)	Aringhieri et al. (2022) (13); Collins et al. (2017) (1); Crocitto et al. (2021) (1); Ferreira & Marques (2019) (12); Kubala et al. (2021) (3); Marques & Captivo (2017) (6); Moons et al. (2019) (1); Moreira et al. (2017) (2); Mundt et al. (2020) (2); Pradere et al. (2022) (1); Rodríguez et al. (2021) (2); Saporito et al. (2021) (3)
Care outcomes	Operational performance	2 (2)	Adams et al. (2021) (1); Chrouser et al. (2018) (1)
	Quality of care	3 (3)	Adams et al. (2021) (1); Bottani et al. (2022) (1); Chrouser et al. (2018) (1)
	Safety	6 (5)	Adams et al. (2022) (1); Bath et al. (2019) (1); Chrouser et al. (2018) (2); Emond et al. (2022) (1); Nicholson et al. (2020) (1)
		153 (35)	Adams et al. (2021) (9); Adams et al. (2022) (17); Aringhieri et al. (2022) (7); Auerbach et al. (2018) (8); Bath et al. (2019) (3); Bayramzadeh et al. (2021) (15); Belykh et al. (2018) (2); Bilgic et al. (2020) (1); Birkhoff et al. (2021) (1); Bretonnier et al. (2020) (1); Chrouser et al. (2018) (12); Collins et al. (2017) (1); Crocitto et al. (2021) (3); Ferreira & Marques (2019) (1); Glaser et al. (2019) (4); Glennie et al. (2019) (1); Ibrahim et al. (2022) (6); Kleiner (2019) (7); Lear et al. (2017) (5); Levin & Lee (2019) (4); Lichtenberg (2015) (1); MacNeil et al. (2019) (1); Monnickendam & de Asmundis (2018) (4); Moreira et al. (2017) (3); Olmsted et al. (2022) (11); Sateri et al. (2017) (1); Scali et al. (2020) (2); Shehadeh & Padman (2022) (3); Sotto et al. (2021) (11); Thomsen et al. (2017) (1); Trosman et al. (2017) (1); Turkelson & Keiser (2017) (1); Volk (2017) (1); Zingiryan et al. (2017) (4)
Finance	Operational performance	3 (3)	Beaulieu & Bentahar (2021) (1); Childers & Maggard-Gibbons (2018) (1); Chrouser et al. (2018) (1)
	Value-based healthcare	2 (2)	Cossio-Gil et al. (2022) (1); Moons et al. (2019) (1)

Objective factor	Objective characteristic	Frequency (# phrases (# articles))	References (# phrases)
		222 (34)	Alban et al. (2019) (10); Aringhieri et al. (2022) (8); Auerbach et al. (2018) (6); Beaulieu & Bentahar (2021) (5); Bottani et al. (2022) (3); Breuer et al. (2020) (5); Brüngger et al. (2021) (12); Childers & Maggard-Gibbons (2018) (16); Collins et al. (2017) (1); Crocitto et al. (2021) (10); Egeland et al. (2017) (14); Erhard et al. (2018) (4); Ferreira & Marques (2019) (5); Gelb et al. (2018) (2); Glaser et al. (2019) (2); Glennie et al. (2019) (26); Hadaya et al. (2021) (4); Ibrahim et al. (2022) (2); Kleiner (2019) (1); Koppka et al. (2018) (4); Kuritzkes et al. (2019) (1); Lai et al. (2022) (1); Levin & Lee (2019) (4); MacNeil et al. (2019) (1); Marques & Captivo (2017) (2); Monnickendam & de Asmundis (2018) (12); Moons et al. (2019) (5); Moreira et al. (2017) (4); Patel et al. (2022) (20); Pattni et al. (2019) (2); Pradere et al. (2022) (1); Saporito et al. (2021) (14); Seelen et al. (2018) (3); Shehadeh & Padman (2022) (12)
Management	Decision-making	3 (3)	Adams et al. (2022) (1); Cossio-Gil et al. (2022) (1); Levin & Lee (2019) (1)
	Operational performance	12 (5)	Birkhoff et al. (2021) (2); Chrouser et al. (2018) (1); Lai et al. (2022) (5); Levin & Lee (2019) (2); Nicholson et al. (2020) (2)
		142 (18)	Adams et al. (2022) (1); Aringhieri et al. (2022) (1); Beaulieu & Bentahar (2021) (2); Birkhoff et al. (2021) (5); Breuer et al. (2020) (27); Chrouser et al. (2018) (1); Collins et al. (2017) (2); Di Sivo (2017) (8); Erhard et al. (2018) (23); Koppka et al. (2018) (17); Lai et al. (2022) (8); Marques & Captivo (2017) (1); Monnickendam & de Asmundis (2018) (11); Moons et al. (2019) (7); Moreira et al. (2017) (4); Nilsson et al. (2018) (1); Seelen et al. (2018) (5); Shehadeh & Padman (2022) (18)
Patient (health) condition		6 (3)	Lai et al. (2022) (1); Rodríguez et al. (2021) (4); Saporito et al. (2021) (1)
Patient flow		21 (6)	Beaulieu & Bentahar (2021) (3); Bottani et al. (2022) (3); Erhard et al. (2018) (3); Koppka et al. (2018) (4); Kubala et al. (2021) (3); Shehadeh & Padman (2022) (5)
Quality of care	Adequacy	13 (6)	Adams et al. (2021) (1); Aringhieri et al. (2022) (1); Auerbach et al. (2018) (8); Breuer et al. (2020) (1); Freundlich et al. (2020) (1); Ibrahim et al. (2022) (1)

Objective factor	Objective characteristic	Frequency (# phrases (# articles))	References (# phrases)
	Care outcomes	13 (6)	Adams et al. (2021) (3); Adams et al. (2022) (4); Di Sivo (2017) (2); Ferreira & Marques (2019) (2); Olmsted et al. (2022) (1); Patel et al. (2022 (1)
	Education & knowledge	3 (3)	Auerbach et al. (2018) (1); Bilgic et al. (2020) (1); Levin & Lee (2019) (1)
	Operational performance	7 (4)	Adams et al. (2021) (3); Newsweek (2022) (2); Olmsted et al. (2022) (1); Volk (2017) (1)
	Safety	3 (2)	Di Sivo (2017) (2); Olmsted et al. (2022) (1)
	Surgical performance	12 (7)	Adams et al. (2021) (3); Bottani et al. (2022) (1); Freundlich et al. (2020) (1); Lichtenberg (2015) (2); Newsweek (2022) (2); Olmsted et al. (2022) (2); Patel et al. (2022) (1)
	Value-based healthcare	5 (4)	Auerbach et al. (2018) (1); Freundlich et al. (2020) (2); Hadaya et al. (2021) (1); Ibrahim et al. (2022) (1)
		294 (54)	Adams et al. (2021) (9); Adams et al. (2022) (7); Alban et al. (2019) (7); Aringhieri et al. (2022) (2); Auerbach et al. (2018) (5); Beaulieu & Bentahar (2021) (2); Bilgic et al. (2020) (3); Bottani et al. (2022) (10); Bretonnier et al. (2020) (4); Breuer et al. (2020) (1); Brun et al. (2021) (3); Chrouser et al. (2018) (3); Cohen et al. (2021) (1); Collins et al. (2017) (4); Cossio-Gil et al. (2022) (3); Crocitto et al. (2021) 11); Di Sivo (2017) (4); Egeland et al. (2017) (2); El Boghdady & Tang (2022) (1); Emond et al. (2022) (1); Erhard et al. (2018) (9); Ferreira & Marques (2019) (29); Freundlich et al. (2020) (4); Glaser et al. (2019) (32); Gui et al. (2021) (2); Hadaya et al. (2021) (13); Ibrahim et al. (2022) (14); Kava et al. (2017) (1); Kleiner (2019) (6); Koppka et al. (2018) (4); Kubala et al. (2021) (4); Kuritzkes et al. (2019) (1); Lai et al. (2022) (3); Lear et al. (2017) (4); Lichtenberg (2015) (8); MacNeil et al. (2019) (1); Marques & Captivo (2017) (2); Moons et al. (2019) (7); Moreira et al. (2017) (9); Mundt et al. (2020) (1); Newsweek (2022) (5); Olmsted et al. (2022) (16); Patel et al. (2022) (1); Rodríguez et al. (2021) (5); Saporito et al. (2021) (1); Seelen et al. (2018) (10); Shortell et al. (2018) (2); Trosman et al. (2017) (1); Truong et al. (2021) (8); Turkelson & Keiser (2017) (1); Ukegjini et al. (2020) (1); Volk (2017) (3); Wang et al. (2021) (1); Zweifel (2021) (2)
Resources	Education & knowledge	2 (2)	Levin & Lee (2019) (1); Moreira et al. (2017) (1)

Objective factor	Objective characteristic	Frequency (# phrases (# articles))	References (# phrases)
	Supply	2 (2)	Collins et al. (2017) (1); Moons et al. (2019) (1)
	Technology	18 (4)	Auerbach et al. (2018) (2); Moreira et al. (2017) (5); Scholte et al. (2021) (10); Trosman et al. (2017) (1)
		61 (19)	Adams et al. (2022) (4);Bayramzadeh et al. (2021) (3); Beaulieu & Bentahar (2021) (7); Bottani et al. (2022) (3); Breuer et al. (2020) (3); Brun et al. (2021) (1); Chrouser et al. (2018) (3); Cohen et al. (2021) (1); Collins et al. (2017) (1); Cossio-Gil et al. (2022) (3); Di Sivo (2017) (4); Ferreira & Marques (2019) (11); Gelb et al. (2018) (10); Levin & Lee (2019) (1); Lichtenberg (2015) (1); Marques & Captivo (2017) (1); Monnickendam & de Asmundis (2018) (1); Moons et al. (2019) (11); Seelen et al. (2018) (1)
Safety	Surgical performance	4 (3)	Alban et al. (2019) (1); Chrouser et al. (2018) (2); Nicholson et al. (2020) (1)
		186 (39)	Alban et al. (2019) (14); Bath et al. (2019) (3); Beaulieu & Bentahar (2021) (1); Belykh et al. (2018) (1); Bottani et al. (2022) (2); Bretonnier et al. (2020) (3); Breuer et al. (2020) (1); Brun et al. (2021) (1); Chrouser et al. (2018) (14); Collins et al. (2017) (1); Crocitto et al. (2021) (2); El Boghdady & Tang (2022) (2); Emond et al. (2022) (19); Ferreira & Marques (2019) (5); Frasier et al. (2019) (3); Gelb et al. (2018) (2); Gui et al. (2021) (4); Ibrahim et al. (2022) (12); Kava et al. (2017) (1); Kim et al. (2019) (3); Kubala et al. (2021) (1); Kuritzkes et al. (2019) (3); Lear et al. (2017) (5); Leuridan (2020) (6); MacNeil et al. (2019) (1); McMullan et al. (2020) (3); Moons et al. (2019) (2); Mundt et al. (2020) (1); Nicholson et al. (2020) (5); Nilsson et al. (2018) (8); Pattni et al. (2019) (10); Pradere et al. (2022) (1); Saporito et al. (2021) (1); Scali et al. (2020) (2); Sotto et al. (2021) (13); Thomsen et al. (2017) (5); Truong et al. (2021) (15); Turkelson & Keiser (2017) (8); Volk (2017) (2)
Satisfaction	Care outcomes	2 (2)	Moons et al. (2019) (1); Newsweek (2022) (1)
	Management satisfaction	3 (3)	Koppka et al. (2018) (1); Marques & Captivo (2017) (1); Moons et al. (2019) (1)
	Patient satisfaction	8 (8)	Bayramzadeh et al. (2021) (1); Cohen et al. (2021) (1); Freundlich et al. (2020) (1); Kava et al. (2017) (1); MacNeil et al. (2019) (1); Marques & Captivo (2017) (1); Moons et al. (2019) (1); Pattni et al. (2019) (1)

Objective factor	Objective characteristic	Frequency (# phrases (# articles))	References (# phrases)
	Staff satisfaction	9 (6)	Bayramzadeh et al. (2021) (1); Breuer et al. (2020) (3); Brun et al. (2021) (1); Erhard et al. (2018) (2); Koppka et al. (2018) (1); Moons et al. (2019) (1)
		31 (16)	Aringhieri et al. (2022) (5); Auerbach et al. (2018) (1); Beaulieu & Bentahar (2021) (1); Bottani et al. (2022) (1); Breuer et al. (2020) (4); Chrouser et al. (2018) (1); Cohen et al. (2021) (2); Erhard et al. (2018) (2); Koppka et al. (2018) (2); Kubala et al. (2021) (1); MacNeil et al. (2019) (3); Marques & Captivo (2017) (2); Moons et al. (2019) (1); Moreira et al. (2017) (1); Newsweek (2022) (2); Olmsted et al. (2022) (2)
Service	Environment	12 (3)	Beaulieu & Bentahar (2021) (1); Pradere et al. (2022) (5); Rodríguez et al. (2021) (6)
	Operational performance	12 (4)	Marques & Captivo (2017) (1); Moreira et al. (2017) (1); Olmsted et al. (2022) (1); Shehadeh & Padman (2022) (9)
		108 (23)	Adams et al. (2022) (8); Aringhieri et al. (2022) (5); Beaulieu & Bentahar (2021) (2); Bottani et al. (2022) (2); Breuer et al. (2020) (18); Erhard et al. (2018) (2); Ferreira & Marques (2019) (4); Koppka et al. (2018) (1); Kubala et al. (2021) (4); MacNeil et al. (2019) (1); Marques & Captivo (2017) (7); Monnickendam & de Asmundis (2018) (24); Moons et al. (2019) (3); Moreira et al. (2017) (5); Newsweek (2022) (8); Olmsted et al. (2022) (1); Rodríguez et al. (2021) (1); Seelen et al. (2018) (1); Shehadeh & Padman (2022) (3); Sotto et al. (2021) (1); Trosman et al. (2017) (4); Turkelson & Keiser (2017) (1); Wang et al. (2021) (2)
Staff (health) condition		66 (16)	Adams et al. (2022) (1);Alban et al. (2019) (4); Bayramzadeh et al. (2021) (2); Belykh et al. (2018) (16); Bilgic et al. (2020) (3); Bretonnier et al. (2020) (3); Breuer et al. (2020) (2); Chrouser et al. (2018) (17); Crocitto et al. (2021) (5); Di Sivo (2017) (1); Erhard et al. (2018) (1); Ferreira & Marques (2019) (3); Ibrahim et al. (2022) (3); Nicholson et al. (2020) (1); Nilsson et al. (2018) (1); Ukegjini et al. (2020) (3)
Surgical performance	Adequacy	6 (3)	Gui et al. (2021) (1); Marques & Captivo (2017) (4); Pradere et al. (2022) (1)
	Authority	2 (2)	Alban et al. (2019) (1); Cossio-Gil et al. (2022) (1)
	Care outcomes	2 (2)	Belykh et al. (2018) (1); Bilgic et al. (2020) (1)

Objective factor	Objective characteristic	Frequency (# phrases (# articles))	References (# phrases)
	Decision-making	5 (4)	Bilgic et al. (2020) (1); Collins et al. (2017) (1); Cossio-Gil et al. (2022) (2); Olmsted et al. (2022) (1)
	Education & knowledge	2 (2)	Lai et al. (2022) (1); Levin & Lee (2019) (1)
	Environment	20 (3)	Ferreira & Marques (2019) (1); Pradere et al. (2022) (18); Saporito et al. (2021) (1)
	Operational performance	2 (2)	MacNeil et al. (2019) (1); Marques & Captivo (2017) (1)
	Staff performance	85 (23)	Adams et al. (2022) (1); Alban et al. (2019) (6); Bayramzadeh et al. (2021) (2); Beaulieu & Bentahar (2021) (2); Belykh et al. (2018) (24); Bilgic et al. (2020) (1); Bottani et al. (2022) (1); Bretonnier et al. (2020) (3); Breuer et al. (2020) (1); Chrouser et al. (2018) (21); Cohen et al. (2021) (1); Crocitto et al. (2021) (4); Di Sivo (2017) (1); Erhard et al. (2018) (4); Frasier et al. (2019) (1); Ibrahim et al. (2022) (1); Lear et al. (2017) (1); McMullan et al. (2020) (1); Moreira et al. (2017) (1); Thomsen et al. (2017) (3); Truong et al. (2021) (2); Ukegjini et al. (2020) (2); Volk (2017) (1)
	Teamwork	4 (2)	Bretonnier et al. (2020) (3); Cohen et al. (2021) (1)
	Technology	2 (2)	Alban et al. (2019) (1); Bilgic et al. (2020) (1)
		241 (52)	Adams et al. (2022) (10); Alban et al. (2019) (15); Aringhieri et al. (2022) (3); Bath et al. (2019) (4); Bayramzadeh et al. (2021) (8); Beaulieu & Bentahar (2021) (1); Belykh et al. (2018) (10); Bilgic et al. (2020) (5); Birkhoff et al. (2021) (1); Bottani et al. (2022) (6); Bretonnier et al. (2020) (5); Breuer et al. (2020) (2); Chrouser et al. (2018) (18); Cohen et al. (2021) (3); Collins et al. (2017) (4); Cossio-Gil et al. (2022) (2); Crocitto et al. (2021) (1); Di Sivo (2017) (1);El Boghdady & Tang (2022) (5); Ferreira & Marques (2019) (7); Glaser et al. (2019) (1); Glennie et al. (2019) (1); Gui et al. (2021) (11); Ibrahim et al. (2022) (3); Kleiner (2019) (3); Koppka et al. (2018) (1); Kubala et al. (2021) (6); Lai et al. (2022) (3); Lear et al. (2017) (1); Levin & Lee (2019) (2); Lichtenberg (2015) (1); Marques & Captivo (2017) (5); McMullan et al. (2020) (4); Moons et al. (2019) (18); Moreira et al. (2017) (1); Mundt et al. (2020) (7); Nilsson et al. (2018) (2); Olmsted et al. (2022) (1); Pradere et al. (2022) (9); Rodríguez et al. (2021) (1); Sateri et al. (2017) (1); Seelen et al. (2018) (2); Shehadeh &

Objective factor	Objective characteristic	Frequency (# phrases (# articles))	References (# phrases)
			Padman (2022) (1); Shortell et al. (2018) (5); Sotto et al. (2021) (9); Thomsen et al. (2017) (3); Truong et al. (2021) (3); Turkelson & Keiser (2017) (9); Ukegjini et al. (2020) (10); Volk (2017) (2); Wang et al. (2021) (2); Zingiryan et al. (2017) (2)
Team	Care outcomes	3 (3)	Frasier et al. (2019) (1); Pattni et al. (2019) (1); Truong et al. (2021) (1)
	Decision-making	4 (2)	Breuer et al. (2020) (1); McMullan et al. (2020) (3)
	Operational performance	7 (4)	Ibrahim et al. (2022) (1); McMullan et al. (2020) (3); Pattni et al. (2019) (2); Volk (2017) (1)
	Safety	3 (2)	Frasier et al. (2019) (1); Freundlich et al. (2020) (2)
	Workload	3 (3)	MacNeil et al. (2019) (1); McMullan et al. (2020) (1); Newsweek (2022) (1)
		131 (22)	Belykh et al. (2018) (1); Bretonnier et al. (2020) (2); Chrouser et al. (2018) (16); Collins et al. (2017) (1); Crocitto et al. (2021) (2); Frasier et al. (2019) (11); Gui et al. (2021) (3); Ibrahim et al. (2022) (4); Kubala et al. (2021) (4); Lear et al. (2017) (4); Leuridan (2020) (1); MacNeil et al. (2019) (6); McMullan et al. (2020) (10); Monnickendam & de Asmundis (2018) (1); Mundt et al. (2020) (4); Nicholson et al. (2020) (1); Nilsson et al. (2018) (2); Pattni et al. (2019) (10); Sotto et al. (2021) (4); Truong et al. (2021) (11); Volk (2017) (30); Zingiryan et al. (2017) (3)

Appendix D The metric combination of the performance optimisation of the OR

Table Appendix 4: The metric combination of the performance optimisation of the OR from the 84 selected articles, together with the corresponding number of studies and references. Between the brackets, the frequency of phrases within the articles are stated. All the metrics that occurred only once (n=1) in all articles or only occurred in one article has been removed.

Metric factor	Metric characteristic	Frequency	References
Accessibility		14 (11)	Aringhieri et al. (2022) (4); Bath et al. (2019) (1); Bottani et al. (2022) (1); Collins et al. (2017) (1); Ferreira & Marques (2019) (1); Glennie et al. (2019) (1); Levin & Lee (2019) (1); Marques & Captivo (2017) (1); Newsweek (2022) (1); Olmsted et al. (2022) (1); Sotto et al. (2021) (1)
Accreditation		3 (3)	Adams et al. (2021) (1); Bilgic et al. (2020) (1); Brun et al. (2021) (1)
Accuracy		14 (11)	Alban et al. (2019) (1); Aringhieri et al. (2022) (1); Belykh et al. (2018) (1); Bilgic et al. (2020) (2); Chrouser et al. (2018) (2); El Boghdady & Tang (2022) (2); Freundlich et al. (2020) (1); Gui et al. (2021) (1); Ibrahim et al. (2022) (1); Turkelson & Keiser (2017) (1); Volk (2017) (1)
Audit performance		13 (10)	Adams et al. (2021) (1); Brun et al. (2021) (1); Chrouser et al. (2018) (2); Glaser et al. (2019) (1); Kim et al. (2019) (1); Lai et al. (2022) (1); Nicholson et al. (2020) (1); Pradere et al. (2022) (3); Rodríguez et al. (2021) (1); Volk (2017) (1)
Authority		30 (16)	Auerbach et al. (2018) (1); Bretonnier et al. (2020) (1); Chrouser et al. (2018) (1); Collins et al. (2017) (3); Crocitto et al. (2021) (8); El Boghdady & Tang (2022) (1); Freundlich et al. (2020) (1); Hadaya et al. (2021) (1); Ibrahim et al. (2022) (2); Lear et al. (2017) (1); McMullan et al. (2020) (2); Pattni et al. (2019) (2); Pradere et al. (2022) (1); Sotto et al. (2021) (1); Ukegjini et al. (2020) (1); Volk (2017) (3)
Bed utilisation	Length of stay	2 (2)	Ferreira & Marques (2019) (1); Seelen et al. (2018) (1)
		17 (11)	Aringhieri et al. (2022) (4); Bottani et al. (2022) (2); Ferreira & Marques (2019) (2); Hadaya et al. (2021) (1); Ibrahim et al. (2022) (1); Kleiner (2019) (1); Koppka et al. (2018) (1); Lear et al. (2017) (2); Marques & Captivo (2017) (1); Moons et al. (2019) (1); Shehadeh & Padman (2022) (1)
Behaviour		17 (10)	Alban et al. (2019) (1); Chrouser et al. (2018) (5); Ibrahim et al. (2022) (1); Kava et al. (2017) (1); Lichtenberg (2015) (1); Leuridan (2020) (1); Pattni et al. (2019) (3); Pradere et al. (2022) (1); Truong et al. (2021) (1); Turkelson & Keiser (2017) (2)
Care outcomes	Complication	2 (2)	Emond et al. (2022) (1); Levin & Lee (2019) (1)

Metric factor	Metric characteristic	Frequency	References
	Morbidity	22 (14)	Adams et al. (2021) (1); Adams et al. (2022) (1); Cossio-Gil et al. (2022) (1); Bretonnier et al. (2020) (3); Glaser et al. (2019) (1); Ibrahim et al. (2022) (2); Kuritzkes et al. (2019) (1); Olmsted et al. (2022) (1); Pattni et al. (2019) (1); Sotto et al. (2021) (2); Truong et al. (2021) (2); Ukegjini et al. (2020) (3); Volk (2017) (2); Zingiryan et al. (2017) (1)
		46 (22)	Adams et al. (2021) (2); Adams et al. (2022) (2); Alban et al. (2019) (1); Aringhieri et al. (2022) (1); Auerbach et al. (2018) (3); Bayramzadeh et al. (2021) (2); Bottani et al. (2022) (1); Ferreira & Marques (2019) (5); Glaser et al. (2019) (3); Glennie et al. (2019) (1); Gui et al. (2021) (1); Hadaya et al. (2021) (1); Ibrahim et al. (2022) (3); Lear et al. (2017) (6); MacNeil et al. (2019) (2); McMullan et al. (2020) (2); Moons et al. (2019) (3); Moreira et al. (2017) (2); Newsweek (2022) (2); Rodríguez et al. (2021) (1); Seelen et al. (2018) (1); Shortell et al. (2018) (1)
Communication	Transparency	10 (8)	Adams et al. (2021) (1); Adams et al. (2022) (2); Beaulieu & Bentahar (2021) (1); Collins et al. (2017) (1); Glennie et al. (2019) (2); Ibrahim et al. (2022) (1); Moons et al. (2019) (1); Olmsted et al. (2022) (1)
		60 (28)	Alban et al. (2019) (1); Bayramzadeh et al. (2021) (1); Beaulieu & Bentahar (2021) (1); Belykh et al. (2018) (1); Bretonnier et al. (2020) (2); Chrouser et al. (2018) (3); Cohen et al. (2021) (2); Collins et al. (2017) (1); Cossio-Gil et al. (2022) (1); Crocitto et al. (2021) (1); Emond et al. (2022) (1); Frasier et al. (2019) (9); Gui et al. (2021) (1); Ibrahim et al. (2022) (1); Kava et al. (2017) (3); Lear et al. (2017) (3); Leuridan (2020) (1); Levin & Lee (2019) (5); MacNeil et al. (2019) (1); Moons et al. (2019) (1); Moreira et al. (2017) (1); Mundt et al. (2020) (1); Pattni et al. (2019) (5); Sotto et al. (2021) (2); Truong et al. (2021) (2); Turkelson & Keiser (2017) (1); Ukegjini et al. (2020) (2); Volk (2017) (6)
Complexity		6 (6)	Chrouser et al. (2018) (1); Ferreira & Marques (2019) (1); Gelb et al. (2018) (1); Ibrahim et al. (2022) (1); Kleiner (2019) (1); Ukegjini et al. (2020) (1)
Complication		59 (923)	Adams et al. (2021) (3); Adams et al. (2022) (2); Alban et al. (2019) (6); Bilgic et al. (2020) (1); Egeland et al. (2017) (1); Emond et al. (2022) (3); Gelb et al. (2018) (1); Glaser et al. (2019) (6); Glennie et al. (2019) (1); Kim et al. (2019) (1); Kuritzkes et al. (2019) (8); Lear et al. (2017) (1); Levin & Lee (2019) (1); Monnickendam & de Asmundis (2018) (1); Moreira et al. (2017) (1); Pattni et al. (2019) (3); Scali et al. (2020) (3); Sotto et al. (2021) (3); Thomsen et al. (2017) (2); Truong et al. (2021) (4); Turkelson & Keiser (2017) (1); Ukegjini et al. (2020) (3); Zingiryan et al. (2017) (3)

Metric factor	Metric characteristic	Frequency	References
Cost	Workforce	3 (2)	Childers & Maggard-Gibbons (2018) (2); Glennie et al. (2019) (1)
		23 (13)	Alban et al. (2019) (1); Aringhieri et al. (2022) (1); Brüngger et al. (2021) (2); Childers & Maggard-Gibbons (2018) (1); Erhard et al. (2018) (2); Ferreira & Marques (2019) (2); Glennie et al. (2019) (2); Monnickendam & de Asmundis (2018) (2); Moons et al. (2019) (1); Moreira et al. (2017) (1); Patel et al. (2022) (4); Scholte et al. (2021) (2); Trosman et al. (2017) (2)
Culture	Behaviour	2 (2)	Alban et al. (2019) (1); Leuridan (2020) (1)
		23 (16)	Chrouser et al. (2018) (3); Cohen et al. (2021) (1); Cossio-Gil et al. (2022) (1); Kuritzkes et al. (2019) (1); Lear et al. (2017) (2); Leuridan (2020) (1); MacNeil et al. (2019) (2); McMullan et al. (2020) (1); Mundt et al. (2020) (1); Nilsson et al. (2018) (1); Pattni et al. (2019) (2); Shortell et al. (2018) (2); Sotto et al. (2021) (1); Truong et al. (2021) (1); Volk (2017) (1); Zingiryan et al. (2017) (2)
Decision-making		7 (7)	Auerbach et al. (2018) (1); Freundlich et al. (2020) (1); Glennie et al. (2019) (1); McMullan et al. (2020) (1); Mundt et al. (2020) (1); Pradere et al. (2022) (1); Trosman et al. (2017) (1)
Diagnose		8 (6)	Lichtenberg (2015) (1); MacNeil et al. (2019) (1); McMullan et al. (2020) (1); Olmsted et al. (2022) (2); Scali et al. (2020) (1); Volk (2017) (2)
Discharge		10 (6)	Adams et al. (2021) (1); Adams et al. (2022) (3); Ferreira & Marques (2019) (2); Glennie et al. (2019) (1); Hadaya et al. (2021) (1); Olmsted et al. (2022) (2)
Distribution equipment		9 (3)	Birkhoff et al. (2021) (1); Childers & Maggard-Gibbons (2018) (2); Moons et al. (2019) (6)
Disturbance		26 (7)	Belykh et al. (2018) (1); Bretonnier et al. (2020) (2); Gui et al. (2021) (11); Levin & Lee (2019) (1); Pradere et al. (2022) (1); Ukegjini et al. (2020) (12)
Education		36 (20)	Auerbach et al. (2018) (1); Bath et al. (2019) (1); Belykh et al. (2018) (1); Brun et al. (2021) (1); Childers & Maggard-Gibbons (2018) (1); Cohen et al. (2021) (1); El Boghdady & Tang (2022) (1); Erhard et al. (2018) (1); Frasier et al. (2019) (1); Glaser et al. (2019) (3); Kava et al. (2017) (1); Lear et al. (2017) (2); Mundt et al. (2020) (1); Pattni et al. (2019) (1); Pradere et al. (2022) (1); Rodríguez et al. (2021) (1); Scholte et al. (2021) (2); Thomsen et al. (2017) (2); Truong et al. (2021) (8); Volk (2017) (5)
Environment	Energy	8 (3)	Bottani et al. (2022) (1); Pradere et al. (2022) (6); Rodríguez et al. (2021) (1)

Metric factor	Metric characteristic	Frequency	References
		8 (6)	Birkhoff et al. (2021) (1); Ibrahim et al. (2022) (1); Lai et al. (2022) (2); Pradere et al. (2022) (1); Rodríguez et al. (2021) (2); Saporito et al. (2021) (1)
Equipment type	Communication	2 (2)	Cohen et al. (2021) (1); El Boghdady & Tang (2022) (1)
	Equipment inventory	7 (4)	Beaulieu & Bentahar (2021) (3); Chrouser et al. (2018) (1); Lear et al. (2017) (1); Moons et al. (2019) (2)
	Maintenance	3 (3)	Brun et al. (2021) (1); Ferreira & Marques (2019) (1); Moons et al. (2019) (1)
	Staff satisfaction	2 (2)	Cohen et al. (2021) (1); Moons et al. (2019) (1)
		41 (30)	Adams et al. (2021) (1); Adams et al. (2022) (1); Aringhieri et al. (2022) (1); Auerbach et al. (2018) (3); Beaulieu & Bentahar (2021) (1); Birkhoff et al. (2021) (1); Bottani et al. (2022) (1); Brun et al. (2021) (2); Brüngger et al. (2021) (1); Childers & Maggard-Gibbons (2018) (1); Cohen et al. (2021) (1); Collins et al. (2017) (1); Crocitto et al. (2021) (1); Di Sivo (2017) (1); El Boghdady & Tang (2022) (1); Ferreira & Marques (2019) (2); Hadaya et al. (2021) (1); Lear et al. (2017) (2); MacNeil et al. (2019) (1); Marques & Captivo (2017) (2); McMullan et al. (2020) (1); Monnickendam & de Asmundis (2018) (1); Moons et al. (2019) (4); Olmsted et al. (2022) (1); Patel et al. (2022) (2); Scholte et al. (2021) (2); Seelen et al. (2018) (1); Shortell et al. (2018) (1); Sotto et al. (2021) (1); Volk (2017) (1)
Equipment utilisation		19 (12)	Beaulieu & Bentahar (2021) (1); Bottani et al. (2022) (2); Cohen et al. (2021) (1); Egeland et al. (2017) (1); Kubala et al. (2021) (1); Lear et al. (2017) (4); MacNeil et al. (2019) (1); Marques & Captivo (2017) (2); Monnickendam & de Asmundis (2018) (2); Moons et al. (2019) (2); Moreira et al. (2017) (1); Newsweek (2022) (1);
Equity		14 (6)	Crocitto et al. (2021) (1); Erhard et al. (2018) (1); Ferreira & Marques (2019) (2); Marques & Captivo (2017) (5); Rodríguez et al. (2021) (4); Saporito et al. (2021) (1)
Ergonomics		5 (4)	Belykh et al. (2018) (2); Di Sivo (2017) (1); El Boghdady & Tang (2022) (1); Erhard et al. (2018) (1)
Expertise		45 (24)	Adams et al. (2021) (1); Adams et al. (2022) (5); Bayramzadeh et al. (2021) (1); Belykh et al. (2018) (1); Bilgic et al. (2020) (1); Bretonnier et al. (2020) (1); Breuer et al. (2020) (1); Brun et al. (2021) (2); Chrouser et al. (2018) (3); Crocitto et al. (2021) (3); Di Sivo (2017) (1); El Boghdady & Tang (2022) (1); Gui et al. (2021) (1); Hadaya et al. (2021) (1); Ibrahim et al. (2022) (1); Kim et al. (2019) (1); Lai et al. (2022) (1); Mundt et al. (2020)

Metric factor	Metric characteristic	Frequency	References
			(1); Newsweek (2022) (2); Olmsted et al. (2022) (5); Sotto et al. (2021) (3); Thomsen et al. (2017) (1); Turkelson & Keiser (2017) (2); Volk (2017) (4); Wang et al. (2021) (1)
Hospital capacity		9 (4)	Kleiner (2019) (3); Koppka et al. (2018) (2); Kubala et al. (2021) (2); Seelen et al. (2018) (2)
Hygiene		3 (3)	Di Sivo (2017) (1); Kuritzkes et al. (2019) (1); Newsweek (2022) (1)
Idle time		4 (3)	Gui et al. (2021) (1); Monnickendam & de Asmundis (2018) (1); Shehadeh & Padman (2022) (2)
Inventory		14 (5)	Beaulieu & Bentahar (2021) (5); Childers & Maggard-Gibbons (2018) (1); Gelb et al. (2018) (1); Koppka et al. (2018) (1); Moons et al. (2019) (6)
Investment		6 (5)	Beaulieu & Bentahar (2021) (2); Childers & Maggard-Gibbons (2018) (1); Ferreira & Marques (2019) (1); Glennie et al. (2019) (1); Levin & Lee (2019) (1)
Length of stay		17 (12)	Adams et al. (2021) (1); Aringhieri et al. (2022) (1); Brüngger et al. (2021) (4); Emond et al. (2022) (1); Glaser et al. (2019) (2); Glennie et al. (2019) (1); Koppka et al. (2018) (1); Nicholson et al. (2020) (1); Olmsted et al. (2022) (2); Patel et al. (2022) (1); Saporito et al. (2021) (1); Wang et al. (2021) (1)
Maintenance		3 (2)	Ferreira & Marques (2019) (1); Scholte et al. (2021) (2)
Operational performance		14 (8)	Birkhoff et al. (2021) (1); Glennie et al. (2019) (2); Ibrahim et al. (2022) (3); Lear et al. (2017) (2); Moons et al. (2019) (2); Rodríguez et al. (2021) (1); Scholte et al. (2021) (2); Volk (2017) (1)
OR block		5 (4)	Ferreira & Marques (2019) (1); Moreira et al. (2017) (1); Newsweek (2022) (1); Shehadeh & Padman (2022) (2)
OR design		21 (12)	Alban et al. (2019) (1); Bayramzadeh et al. (2021) (7); Childers & Maggard-Gibbons (2018) (1); Collins et al. (2017) (1); Crocitto et al. (2021) (1); Di Sivo (2017) (2); Gui et al. (2021) (1); Kubala et al. (2021) (2); Kuritzkes et al. (2019) (2); Lai et al. (2022) (1); Seelen et al. (2018) (2); Turkelson & Keiser (2017) (1)
OR time	OR break	11 (3)	Belykh et al. (2018) (2); Bretonnier et al. (2020) (8); Glennie et al. (2019) (1)
	OR over time	7 (4)	Erhard et al. (2018) (2); Koppka et al. (2018) (2); Shehadeh & Padman (2022) (2); Wang et al. (2021) (1)

Metric factor	Metric characteristic	Frequency	References
OR utilisation		77 (20)	Aringhieri et al. (2022) (4); Bottani et al. (2022) (6); Bretonnier et al. (2020) (1); Breuer et al. (2020) (5); Childers & Maggard-Gibbons (2018) (1); Collins et al. (2017) (6); Erhard et al. (2018) (4); Ferreira & Marques (2019) (10); Glennie et al. (2019) (1); Koppka et al. (2018) (6); Kubala et al. (2021) (3); Marques & Captivo (2017) (3); Monnickendam & de Asmundis (2018) (7); Moons et al. (2019) (1); Patel et al. (2022) (6); Saporito et al. (2021) (6); Seelen et al. (2018) (3); Shehadeh & Padman (2022) (2); Wang et al. (2021) (1); Zingiryan et al. (2017) (1)
Patient (health) condition	Anatomy	3 (2)	Chrouser et al. (2018) (2); El Boghdady & Tang (2022) (1)
		30 (13)	Bayramzadeh et al. (2021) (2); Birkhoff et al. (2021) (2); Brüngger et al. (2021) (2); Chrouser et al. (2018) (4); Ferreira & Marques (2019) (4); Freundlich et al. (2020) (2); Glaser et al. (2019) (2); Ibrahim et al. (2022) (1); Olmsted et al. (2022) (1); Rodríguez et al. (2021) (2); Sotto et al. (2021) (1); Trosman et al. (2017) (1); Turkelson & Keiser (2017) (6)
Patient flow		7 (6)	Aringhieri et al. (2022) (1); Beaulieu & Bentahar (2021) (1); Bottani et al. (2022) (1); Glennie et al. (2019) (1); Kubala et al. (2021) (2); Moons et al. (2019) (1)
Patient satisfaction		45 (21)	Adams et al. (2021) (1); Adams et al. (2022) (5); Alban et al. (2019) (1); Aringhieri et al. (2022) (3); Bottani et al. (2022) (2); Brun et al. (2021) (1); Cohen et al. (2021) (2); Ferreira & Marques (2019) (1); Freundlich et al. (2020) (6); Glennie et al. (2019) (1); Koppka et al. (2018) (1); Kubala et al. (2021) (2); Lai et al. (2022) (1); MacNeil et al. (2019) (1); Marques & Captivo (2017) (1); McMullan et al. (2020) (2); Moreira et al. (2017) (3); Newsweek (2022) (5); Olmsted et al. (2022) (4); Trosman et al. (2017) (1); Zweifel (2021) (1)
Pharmaceuticals		13 (12)	Adams et al. (2022) (1); Beaulieu & Bentahar (2021) (1); Brüngger et al. (2021) (1); Crocitto et al. (2021) (1); El Boghdady & Tang (2022) (1); Emond et al. (2022) (1); Ferreira & Marques (2019) (1); Ibrahim et al. (2022) (1); Lichtenberg (2015) (2); Nicholson et al. (2020) (1); Olmsted et al. (2022) (1); Volk (2017) (1)
Policy	Accuracy	2 (2)	Alban et al. (2019) (1); McMullan et al. (2020) (1)

Metric factor	Metric characteristic	Frequency	References
		38 (26)	Adams et al. (2021) (1);Auerbach et al. (2018) (1); Birkhoff et al. (2021) (1); Brun et al. (2021) (2); Brüngger et al. (2021) (4); Chrouser et al. (2018) (1); Collins et al. (2017) (1); Cossio-Gil et al. (2022) (1); Crocitto et al. (2021) (1); Di Sivo (2017) (2); Emond et al. (2022) (1); Erhard et al. (2018) (1); Ferreira & Marques (2019) (2); Frasier et al. (2019) (1); Glaser et al. (2019) (2); Hadaya et al. (2021) (1); Lear et al. (2017) (2); Leuridan (2020) (1); MacNeil et al. (2019) (2); McMullan et al. (2020) (2); Moreira et al. (2017) (2); Patel et al. (2022) (2); Pattni et al. (2019) (1); Saporito et al. (2021) (1); Sotto et al. (2021) (1); Turkelson & Keiser (2017) (1)
Profit		8 (6)	Childers & Maggard-Gibbons (2018) (2); Crocitto et al. (2021) (1); Egeland et al. (2017) (1); Glennie et al. (2019) (1); Moreira et al. (2017) (2); Saporito et al. (2021) (1)
Readmission		15 (9)	Adams et al. (2021) (2); Adams et al. (2022) (1); Glaser et al. (2019) (1); Glennie et al. (2019) (3); Hadaya et al. (2021) (2); Kleiner (2019) (3); Koppka et al. (2018) (1); Moreira et al. (2017) (1); Newsweek (2022) (1)
Responsiveness		30 (17)	Alban et al. (2019) (2); Asch et al. (2022) (1); Auerbach et al. (2018) (1); Bretonnier et al. (2020) (2); Chrouser et al. (2018) (1); Ferreira & Marques (2019) (1); Ibrahim et al. (2022) (3); Lear et al. (2017) (1); MacNeil et al. (2019) (1); McMullan et al. (2020) (4); Moons et al. (2019) (1); Mundt et al. (2020) (1); Shortell et al. (2018) (1); Truong et al. (2021) (5); Turkelson & Keiser (2017) (1); Ukegjini et al. (2020) (3); Volk (2017) (1)
Revenue		5 (5)	Alban et al. (2019) (1); Aringhieri et al. (2022) (1); Egeland et al. (2017) (1); Koppka et al. (2018) (1); Marques & Captivo (2017) (1)
Safety		29 (24)	Adams et al. (2021) (1); Alban et al. (2019) (1); Belykh et al. (2018) (1); Birkhoff et al. (2021) (1); Chrouser et al. (2018) (2); Cohen et al. (2021) (1); Collins et al. (2017) (1); Ferreira & Marques (2019) (3); Kleiner (2019) (1); Kuritzkes et al. (2019) (1); Lai et al. (2022) (1); Lear et al. (2017) (2); McMullan et al. (2020) (1); Moreira et al. (2017) (1); Newsweek (2022) (1); Nilsson et al. (2018) (1); Olmsted et al. (2022) (1); Pattni et al. (2019) (1); Pradere et al. (2022) (1); Rodríguez et al. (2021) (1); Truong et al. (2021) (2); Turkelson & Keiser (2017) (1); Volk (2017) (1); Zingiryan et al. (2017) (1)
Savings		20 (12)	Alban et al. (2019) (2); Auerbach et al. (2018) (2); Crocitto et al. (2021) (1); Egeland et al. (2017) (3); Ferreira & Marques (2019) (1); Glennie et al. (2019) (3); Hadaya et al. (2021) (1); Kleiner (2019) (1); Marques & Captivo (2017) (1); Moons et al. (2019) (1); Moreira et al. (2017) (1); Patel et al. (2022) (3)

Metric factor	Metric characteristic	Frequency	References
Schedule	Authority	2 (2)	Monnickendam & de Asmundis (2018) (1); Moons et al. (2019) (1)
	Bed utilisation	6 (2)	Bottani et al. (2022) (1); Shehadeh & Padman (2022) (5)
	Cancellation	7 (5)	Bottani et al. (2022) (1); Breuer et al. (2020) (1); Koppka et al. (2018) (2); Monnickendam & de Asmundis (2018) (1); Shehadeh & Padman (2022) (1)
	Communication	2 (2)	Moons et al. (2019) (1); Seelen et al. (2018) (1)
	Delay	5 (3)	Monnickendam & de Asmundis (2018) (1); Seelen et al. (2018) (1); Shehadeh & Padman (2022) (3)
	Distribution equipment	3 (3)	Ibrahim et al. (2022) (1); Moons et al. (2019) (1); Shehadeh & Padman (2022) (1)
	Equipment	5 (3)	Di Sivo (2017) (1); Moons et al. (2019) (3); Shehadeh & Padman (2022) (1)
	Hospital capacity	4 (4)	Bottani et al. (2022) (1); Breuer et al. (2020) (1); Marques & Captivo (2017) (1); Shehadeh & Padman (2022) (1)
	Length of stay	2 (2)	Emond et al. (2022) (1); Shehadeh & Padman (2022) (1)
	OR block	18 (9)	Birkhoff et al. (2021) (1); Breuer et al. (2020) (1); Collins et al. (2017) (1); Koppka et al. (2018) (2); Kubala et al. (2021) (1); Marques & Captivo (2017) (1); Monnickendam & de Asmundis (2018) (4); Seelen et al. (2018) (2); Shehadeh & Padman (2022) (3)
	OR design	3 (3)	Di Sivo (2017) (1); Erhard et al. (2018) (1); Shehadeh & Padman (2022) (1)
	OR time	6 (3)	Aringhieri et al. (2022) (4); Monnickendam & de Asmundis (2018) (1); Saporito et al. (2021) (1)
	OR utilisation	20 (10)	Aringhieri et al. (2022) (1); Bottani et al. (2022) (3); Breuer et al. (2020) (3); Di Sivo (2017) (1); Erhard et al. (2018) (1); Koppka et al. (2018) (3); Marques & Captivo (2017) (1); Monnickendam & de Asmundis (2018) (4); Seelen et al. (2018) (2); Shehadeh & Padman (2022) (1)
	Patient satisfaction	6 (3)	Birkhoff et al. (2021) (1); Bottani et al. (2022) (4); Breuer et al. (2020) (1)
	Robustness	9 (3)	Bottani et al. (2022) (1); Breuer et al. (2020) (4); Marques & Captivo (2017) (4)
	Staff satisfaction	10 (2)	Breuer et al. (2020) (5); Erhard et al. (2018) (5)
	Start time	4 (2)	Breuer et al. (2020) (3); Moons et al. (2019) (1)
	Surgery efficiency	3 (2)	Aringhieri et al. (2022) (1); Marques & Captivo (2017) (2)
	Surgery volume	3 (3)	Breuer et al. (2020) (1); Marques & Captivo (2017) (1); Shehadeh & Padman (2022) (1)
	Treatment	5 (3)	Birkhoff et al. (2021) (1); Di Sivo (2017) (1); Shehadeh & Padman (2022) (3)
	Turnover	2 (2)	Marques & Captivo (2017) (1); Monnickendam & de Asmundis (2018) (1)

Metric factor	Metric characteristic	Frequency	References
	Workforce	4 (2)	Breuer et al. (2020) (1); Erhard et al. (2018) (3)
		155 (22)	Alban et al. (2019) (1); Aringhieri et al. (2022) (18); Beaulieu & Bentahar (2021) (1); Birkhoff et al. (2021) (1); Bottani et al. (2022) (10); Bretonnier et al. (2020) (1); Breuer et al. (2020) (19); Chrouser et al. (2018) (1); Collins et al. (2017) (9); Di Sivo (2017) (4); Erhard et al. (2018) (7); Ferreira & Marques (2019) (1); Frasier et al. (2019) (1); Koppka et al. (2018) (18); Lai et al. (2022) (1); Marques & Captivo (2017) (9); McMullan et al. (2020) (1); Monnickendam & de Asmundis (2018) (20); Moons et al. (2019) (3); Seelen et al. (2018) (3); Shehadeh & Padman (2022) (22); Wang et al. (2021) (4)
Shift	OR time	2 (2)	Breuer et al. (2020) (1); Erhard et al. (2018) (1)
		8 (2)	Breuer et al. (2020) (6); Erhard et al. (2018) (2)
Skill	Accuracy	3 (3)	Bilgic et al. (2020) (1); Chrouser et al. (2018) (1); McMullan et al. (2020) (1)
		32 (18)	Alban et al. (2019) (2); Bath et al. (2019) (4); Belykh et al. (2018) (1); Bilgic et al. (2020) (1); Bretonnier et al. (2020) (1); Breuer et al. (2020) (2); Chrouser et al. (2018) (6); Crocitto et al. (2021) (1); Gui et al. (2021) (2); Ibrahim et al. (2022) (1); Lai et al. (2022) (1); Marques & Captivo (2017) (1); McMullan et al. (2020) (1); Mundt et al. (2020) (1); Shortell et al. (2018) (1); Thomsen et al. (2017) (4); Turkelson & Keiser (2017) (1); Zweifel (2021) (1)
Staff (health) condition	Anxiety	3 (2)	Belykh et al. (2018) (2); Pattni et al. (2019) (1)
	Nutrition	10 (2)	Belykh et al. (2018) (9); Rodríguez et al. (2021) (1)
	Psychological condition	2 (2)	Belykh et al. (2018) (1); Chrouser et al. (2018) (1)
	Sleep	11 (3)	Bayramzadeh et al. (2021) (2); Belykh et al. (2018) (8); Lear et al. (2017) (1)
		23 (10)	Adams et al. (2021) (1); Adams et al. (2022) (2); Bayramzadeh et al. (2021) (2); Belykh et al. (2018) (6); Bretonnier et al. (2020) (1); Chrouser et al. (2018) (5); Erhard et al. (2018) (1); Leuridan (2020) (1); Nilsson et al. (2018) (3); Ukegjini et al. (2020) (1)
Staff performance	Physical work	3 (3)	Bayramzadeh et al. (2021) (1); Chrouser et al. (2018) (1); Lai et al. (2022) (1)
	Responsiveness	3 (2)	Chrouser et al. (2018) (1); Turkelson & Keiser (2017) (2)

Metric factor	Metric characteristic	Frequency	References
		43 (30)	Adams et al. (2022) (2); Alban et al. (2019) (1); Aringhieri et al. (2022) (1); Auerbach et al. (2018) (4); Bayramzadeh et al. (2021) (1); Belykh et al. (2018) (2); Childers & Maggard-Gibbons (2018) (1); Chrouser et al. (2018) (3); Collins et al. (2017) (1); Crocitto et al. (2021) (1); Di Sivo (2017) (1); Glaser et al. (2019) (1); Ibrahim et al. (2022) (1); Kava et al. (2017) (1); Kubala et al. (2021) (1); Kuritzkes et al. (2019) (1); Lai et al. (2022) (2); Lear et al. (2017) (2); Lichtenberg (2015) (1); MacNeil et al. (2019) (1); McMullan et al. (2020) (1); Mundt et al. (2020) (1); Nicholson et al. (2020) (1); Nilsson et al. (2018) (1); Pattni et al. (2019) (1); Saporito et al. (2021) (1); Shehadeh & Padman (2022) (1); Thomsen et al. (2017) (3); Ukegjini et al. (2020) (2); Zingiryan et al. (2017) (1)
Staff satisfaction		14 (10)	Belykh et al. (2018) (1); Breuer et al. (2020) (4); Chrouser et al. (2018) (1); Erhard et al. (2018) (1); Ibrahim et al. (2022) (1); Koppka et al. (2018) (1); McMullan et al. (2020) (2); Moons et al. (2019) (1); Mundt et al. (2020) (1); Nilsson et al. (2018) (1)
Start time	Cancellation	2 (2)	Aringhieri et al. (2022) (1); Wang et al. (2021) (1)
	Delay	5 (5)	Aringhieri et al. (2022) (1); Koppka et al. (2018) (1); Levin & Lee (2019) (1); Shehadeh & Padman (2022) (1); Truong et al. (2021) (1)
		3 (3)	Bottani et al. (2022) (1); Ferreira & Marques (2019) (1); Koppka et al. (2018) (1)
Stressors		18 (5)	Bretonnier et al. (2020) (2); Chrouser et al. (2018) (9); Ibrahim et al. (2022) (1); Nilsson et al. (2018) (2); Ukegjini et al. (2020) (4)
Surgery duration		23 (12)	Breuer et al. (2020) (2); Childers & Maggard-Gibbons (2018) (2); Collins et al. (2017) (1); Ferreira & Marques (2019) (1); Glaser et al. (2019) (3); Glennie et al. (2019) (2); Koppka et al. (2018) (4); Kubala et al. (2021) (1); Monnickendam & de Asmundis (2018) (3); Patel et al. (2022) (1); Saporito et al. (2021) (1); Wang et al. (2021) (2)
Surgery efficiency	Accuracy	3 (2)	Pradere et al. (2022) (1); Zweifel (2021) (2)
	Disturbance	2 (2)	Alban et al. (2019) (1); Gui et al. (2021) (1)
	Equipment	6 (4)	Alban et al. (2019) (1); Di Sivo (2017) (1); Lear et al. (2017) (1); Pradere et al. (2022) (3)
	OR design	3 (3)	Alban et al. (2019) (1); Di Sivo (2017) (1); Kubala et al. (2021) (1)
	OR utilisation	3 (2)	Erhard et al. (2018) (1); Seelen et al. (2018) (2)
	Skill	2 (2)	Erhard et al. (2018) (1); Turkelson & Keiser (2017) (1)
	Start time	2 (2)	Kubala et al. (2021) (1); Seelen et al. (2018) (1)

Metric factor	Metric characteristic	Frequency	References
		35 (19)	Alban et al. (2019) (1); Aringhieri et al. (2022) (1); Belykh et al. (2018) (1); Birkhoff et al. (2021) (1); Bottani et al. (2022) (3); Childers & Maggard-Gibbons (2018) (2); Chrouser et al. (2018) (1); Cohen et al. (2021) (1); Collins et al. (2017) (1); Ferreira & Marques (2019) (5); Kubala et al. (2021) (2); Levin & Lee (2019) (2); Marques & Captivo (2017) (1); Moons et al. (2019) (5); Moreira et al. (2017) (3); Patel et al. (2022) (1); Rodríguez et al. (2021) (2); Shehadeh & Padman (2022) (1); Sotto et al. (2021) (1)
Surgery volume	OR utilisation	4 (3)	Collins et al. (2017) (2); Erhard et al. (2018) (1); Ferreira & Marques (2019) (1)
	Surgery efficiency	18 (6)	Alban et al. (2019) (10); Collins et al. (2017) (2); Ferreira & Marques (2019) (3); Newsweek (2022) (1); Truong et al. (2021) (1); Volk (2017) (1)
	Task	2 (2)	Glaser et al. (2019) (1); Sotto et al. (2021) (1)
	Treatment	11 (4)	Brüngger et al. (2021) (8); Ferreira & Marques (2019) (1); Hadaya et al. (2021) (1); Wang et al. (2021) (1)
	Turnover	4 (4)	Erhard et al. (2018) (1); Kubala et al. (2021) (1); Monnickendam & de Asmundis (2018) (1); Saporito et al. (2021) (1)
		91 (39)	Adams et al. (2021) (1); Adams et al. (2022) (4); Aringhieri et al. (2022) (3); Auerbach et al. (2018) (3); Bath et al. (2019) (2); Bayramzadeh et al. (2021) (1); Beaulieu & Bentahar (2021) (2); Belykh et al. (2018) (2); Bilgic et al. (2020) (2); Bottani et al. (2022) (2); Breuer et al. (2020) (1); Brüngger et al. (2021) (1); Collins et al. (2017) (1); Egeland et al. (2017) (3); Emond et al. (2022) (1); Ferreira & Marques (2019) (8); Glaser et al. (2019) (16); Glennie et al. (2019) (1); Hadaya et al. (2021) (3); Ibrahim et al. (2022) (5); Kleiner (2019) (1); Koppka et al. (2018) (1); Kubala et al. (2021) (1); Lear et al. (2017) (2); Marques & Captivo (2017) (3); McMullan et al. (2020) (2); Monnickendam & de Asmundis (2018) (4); Moons et al. (2019) (1); Newsweek (2022) (1); Patel et al. (2022) (1); Saporito et al. (2021) (3); Sateri et al. (2017) (1); Scali et al. (2020) (1); Seelen et al. (2018) (1); Shehadeh & Padman (2022) (2); Sotto et al. (2021) (1); Thomsen et al. (2017) (1); Turkelson & Keiser (2017) (1); Wang et al. (2021) (1)
Surgical performance		18 (14)	Adams et al. (2021) (2); Bath et al. (2019) (1); Bilgic et al. (2020) (1); Bretonnier et al. (2020) (1); Breuer et al. (2020) (1); Brun et al. (2021) (2); Chrouser et al. (2018) (1); Collins et al. (2017) (1); El Boghdady & Tang (2022) (3); Ferreira & Marques (2019) (1); Glaser et al. (2019) (1); Hadaya et al. (2021) (1); Levin & Lee (2019) (1); Moons et al. (2019) (1)

Metric factor	Metric characteristic	Frequency	References
Survival	Mortality	47 (24)	Adams et al. (2021) (2); Adams et al. (2022) (1); Cossio-Gil et al. (2022) (1); Aringhieri et al. (2022) (1); Auerbach et al. (2018) (1); Bretonnier et al. (2020) (1); El Boghdady & Tang (2022) (1); Emond et al. (2022) (3); Glaser et al. (2019) (2); Hadaya et al. (2021) (1); Ibrahim et al. (2022) (3); Kleiner (2019) (2); Kuritzkes et al. (2019) (2); Lear et al. (2017) (1); Newsweek (2022) (1); Nilsson et al. (2018) (1); Olmsted et al. (2022) (7); Pattni et al. (2019) (1); Scali et al. (2020) (2); Sotto et al. (2021) (4); Truong et al. (2021) (2); Ukegjini et al. (2020) (2); Volk (2017) (3); Zingiryan et al. (2017) (2)
		12 (5)	Adams et al. (2022) (8); Auerbach et al. (2018) (1); Glaser et al. (2019) (1); Olmsted et al. (2022) (1); Turkelson & Keiser (2017) (1)
Team structure		5 (5)	Crocitto et al. (2021) (1); Frasier et al. (2019) (1); MacNeil et al. (2019) (1); Pattni et al. (2019) (1); Volk (2017) (1)
Teamwork		44 (21)	Bretonnier et al. (2020) (2); Chrouser et al. (2018) (4); Collins et al. (2017) (2); Crocitto et al. (2021) (1); Frasier et al. (2019) (1); Gui et al. (2021) (1); Ibrahim et al. (2022) (1); Kubala et al. (2021) (1); Lear et al. (2017) (4); Leuridan (2020) (1); MacNeil et al. (2019) (1); McMullan et al. (2020) (2); Mundt et al. (2020) (5); Nilsson et al. (2018) (3); Pattni et al. (2019) (3); Rodríguez et al. (2021) (1); Sotto et al. (2021) (1); Truong et al. (2021) (3); Turkelson & Keiser (2017) (1); Volk (2017) (5); Zingiryan et al. (2017) (1)
Technology		4 (4)	Adams et al. (2022) (1); Brun et al. (2021) (1); Di Sivo (2017) (1); Moreira et al. (2017) (2)
Treatment type	Bed utilisation	6 (4)	Ferreira & Marques (2019) (2); Moreira et al. (2017) (2); Patel et al. (2022) (1); Seelen et al. (2018) (1)
	Hospital capacity	5 (4)	Birkhoff et al. (2021) (1); Ferreira & Marques (2019) (2); Kleiner (2019) (1); Rodríguez et al. (2021) (1)
		86 (38)	Adams et al. (2021) (2); Adams et al. (2022) (6); Alban et al. (2019) (1); Aringhieri et al. (2022) (1); Auerbach et al. (2018) (6); Beaulieu & Bentahar (2021) (3); Bottani et al. (2022) (2); Breuer et al. (2020) (1); Brun et al. (2021) (1); Brüngger et al. (2021) (6); Childers & Maggard-Gibbons (2018) (2); Chrouser et al. (2018) (1); Cossio-Gil et al. (2022) (2); Crocitto et al. (2021) (3); Egeland et al. (2017) (1); Erhard et al. (2018) (1); Ferreira & Marques (2019) (3); Glaser et al. (2019) (4); Glennie et al. (2019) (3); Ibrahim et al. (2022) (1); Kleiner (2019) (2); Koppka et al. (2018) (1); Kuritzkes et al. (2019) (1); Lai et al. (2022) (2); Lear et al. (2017) (2); Lichtenberg (2015) (1); MacNeil et al. (2019) (2); Moons et al. (2019) (4); Moreira et al. (2017) (6); Mundt et al. (2020) (1);

Metric factor	Metric characteristic	Frequency	References
			Newsweek (2022) (2); Olmsted et al. (2022) (5); Patel et al. (2022) (1); Pattni et al. (2019) (1); Pradere et al. (2022) (1); Turkelson & Keiser (2017) (1); Wang et al. (2021) (1); Zingiryan et al. (2017) (1)
Trust		6 (6)	Beaulieu & Bentahar (2021) (1); Chrouser et al. (2018) (1); MacNeil et al. (2019) (1); McMullan et al. (2020) (1); Moons et al. (2019) (1); Rodríguez et al. (2021) (1)
Waiting list		18 (9)	Aringhieri et al. (2022) (2); Beaulieu & Bentahar (2021) (1); Bottani et al. (2022) (1); Erhard et al. (2018) (1); Ferreira & Marques (2019) (7); Marques & Captivo (2017) (2); Moreira et al. (2017) (1); Saporito et al. (2021) (1); Shehadeh & Padman (2022) (2)
Waste		17 (6)	Alban et al. (2019) (1); Beaulieu & Bentahar (2021) (1); Ferreira & Marques (2019) (1); Pradere et al. (2022) (10); Rodríguez et al. (2021) (2); Shortell et al. (2018) (1)
Workforce	Physical work	8 (5)	Alban et al. (2019) (2); Belykh et al. (2018) (1); Breuer et al. (2020) (1); Ferreira & Marques (2019) (3); Lai et al. (2022) (1)
		48 (23)	Adams et al. (2021) (1); Adams et al. (2022) (5); Alban et al. (2019) (2); Bayramzadeh et al. (2021) (1); Belykh et al. (2018) (1); Bottani et al. (2022) (4); Bretonnier et al. (2020) (1); Breuer et al. (2020) (2); Chrouser et al. (2018) (4); Cohen et al. (2021) (1); Cossio-Gil et al. (2022) (1); Crocitto et al. (2021) (4); Erhard et al. (2018) (4); Ferreira & Marques (2019) (2); Glennie et al. (2019) (1); Koppka et al. (2018) (2); MacNeil et al. (2019) (1); McMullan et al. (2020) (1); Mundt et al. (2020) (1); Olmsted et al. (2022) (2); Patel et al. (2022) (3); Rodríguez et al. (2021) (1); Volk (2017) (2); Zweifel (2021) (1)
Workload	Behaviour	2 (2)	Erhard et al. (2018) (1); McMullan et al. (2020) (1)
		23 (14)	Alban et al. (2019) (2); Aringhieri et al. (2022) (5); Beaulieu & Bentahar (2021) (1); Bilgic et al. (2020) (1); Birkhoff et al. (2021) (1); Bottani et al. (2022) (1); Bretonnier et al. (2020) (2); Breuer et al. (2020) (1); Erhard et al. (2018) (3); Lear et al. (2017) (1); Moons et al. (2019) (1); Nicholson et al. (2020) (1); Rodríguez et al. (2021) (1); Sotto et al. (2021) (2)

Appendix E The objective combination and its metric combination of the performance optimisation of the OR

Table Appendix 5: The objective combination and its metric combination of the performance optimisation of the OR, including the objective and metric characteristic, together with the corresponding number of studies and references. Between the brackets, the frequency of phrases within the articles are stated. All the metrics that occurred only once (n=1) in all articles or only occurred in one article have been removed.

Objective factor	Objective characteristic	Metric factor	Metric characteristic	Frequency (# phrases (# articles))	References (# phrases)
Accessibility		Bed utilisation		3 (2)	Aringhieri et al. (2022) (2); Ferreira & Marques (2019) (1)
		Equity		7 (3)	Marques & Captivo (2017) (4); Rodríguez et al. (2021) (2); Saporito et al. (2021) (1)
		OR utilisation		3 (3)	Kubala et al. (2021) (1); Marques & Captivo (2017) (1); Saporito et al. (2021) (1)
		Surgery volume		4 (3)	Ferreira & Marques (2019) (2); Moons et al. (2019) (1); Saporito et al. (2021) (1)
		Treatment type		2 (2)	Aringhieri et al. (2022) (1); Moreira et al. (2017) (1)
		Waiting list		3 (2)	Ferreira & Marques (2019) (2); Marques & Captivo (2017) (1)
		Workforce		2 (2)	Ferreira & Marques (2019) (1); Mundt et al. (2020) (1)
Care outcomes		Accessibility		2 (2)	Bath et al. (2019) (1); Levin & Lee (2019) (1)
		Care outcomes	Morbidity	3 (3)	Bretonnier et al. (2020) (1); Olmsted et al. (2022) (1); Sotto et al. (2021) (1)
				3 (2)	Bayramzadeh et al. (2021) (2); Glennie et al. (2019) (1)
		Communication		4 (3)	Bayramzadeh et al. (2021) (1); Levin & Lee (2019) (12); Turkelson & Keiser (2017) (1)
		Complication		7 (6)	Adams et al. (2021) (1); Adams et al. (2022) (1); Lear et al. (2017) (1); Monnickendam & de Asmundis (2018) (1); Sotto et al. (2021) (2); Zingiryan et al. (2017) (1)
		Discharge		5 (3)	Adams et al. (2021) (1); Adams et al. (2022) (3); Olmsted et al. (2022) (1)
		Expertise		2 (2)	Adams et al. (2022) (1); Sotto et al. (2021) (1)

Objective factor	Objective characteristic	Metric factor	Metric characteristic	Frequency (# phrases (# articles))	References (# phrases)
		OR utilisation		2 (2)	Monnickendam & de Asmundis (2018) (1); Shehadeh & Padman (2022) (1)
		Patient (health) condition		13 (6)	Birkhoff et al. (2021) (1); Bayramzadeh et al. (2021) (2); Chrouser et al. (2018) (3); Olmsted et al. (2022) (1); Sotto et al. (2021) (1); Turkelson & Keiser (2017) (5)
		Patient satisfaction		4 (4)	Adams et al. (2021) (1); Adams et al. (2022) (1); Moreira et al. (2017) (1); Olmsted et al. (2022) (1)
		Policy		3 (3)	Adams et al. (2021) (1); Crocitto et al. (2021) (1); Moreira et al. (2017) (1)
		Readmission		2 (2)	Adams et al. (2022) (1); Kleiner (2019) (1)
		Responsiveness		2 (2)	Auerbach et al. (2018) (1); Ibrahim et al. (2022) (1)
		Safety		2 (2)	Lear et al. (2017) (1); Zingiryan et al. (2017) (1)
		Schedule		8 (2)	Aringhieri et al. (2022) (7); Shehadeh & Padman (2022) (1)
		Staff (health) condition		2 (2)	Adams et al. (2021) (1); Belykh et al. (2018) (1)
		Staff performance		5 (5)	Adams et al. (2022) (1); Auerbach et al. (2018) (1); Belykh et al. (2018) (1); Shehadeh & Padman (2022) (1); Thomsen et al. (2017) (1);
		Surgery efficiency		2 (2)	Chrouser et al. (2018) (1); Levin & Lee (2019) (1)
		Surgery volume		9 (8)	Adams et al. (2021) (1); Bath et al. (2019) (1); Glaser et al. (2019) (2); Ibrahim et al. (2022) (1); Kleiner (2019) (1); Mundt et al. (2020) (1); Sateri et al. (2017) (1); Scali et al. (2020) (1)
		Surgical performance		2 (2)	Adams et al. (2021) (1); Bath et al. (2019) (1)
		Survival	Mortality	11 (6)	Adams et al. (2021) (1); Auerbach et al. (2018) (1); Kleiner (2019) (1); Olmsted et al. (2022) (6); Scali et al. (2020) (1); Sotto et al. (2021) (1)

Objective factor	Objective characteristic	Metric factor	Metric characteristic	Frequency (# phrases (# articles))	References (# phrases)
				10 (4)	Adams et al. (2022) (7); Auerbach et al. (2018) (1); Olmsted et al. (2022) (1); Turkelson & Keiser (2017) (1)
		Teamwork		2 (2)	Lear et al. (2017) (1); Volk (2017) (1)
		Treatment type		2 (2)	Adams et al. (2022) (1); Kleiner (2019) (1)
		Workforce		2 (2)	Adams et al. (2022) (1); Chrouser et al. (2018) (1)
Finance		Bed utilisation		2 (2)	Aringhieri et al. (2022) (1); Hadaya et al. (2021) (1)
		Care outcomes		2 (2)	Auerbach et al. (2018) (1); Seelen et al. (2018) (1)
		Communication	Transparency	4 (3)	Beaulieu & Bentahar (2021) (1); Glennie et al. (2019) (2); Ibrahim et al. (2022) (1)
		Complication		8 (5)	Alban et al. (2019) (3); Egeland et al. (2017) (1); Gelb et al. (2018) (1); Kuritzkes et al. (2019) (1); Pattni et al. (2019) (2)
		Cost	Workforce	3 (2)	Childers & Maggard-Gibbons (2018) (2); Glennie et al. (2019) (1)
				11 (6)	Alban et al. (2019) (1); Aringhieri et al. (2022) (1); Childers & Maggard-Gibbons (2018) (1); Glennie et al. (2019) (2); Monnickendam & de Asmundis (2018) (2); Patel et al. (2022) (4)
		Equipment type		6 (5)	Brüngger et al. (2021) (1); Ferreira & Marques (2019) (1); MacNeil et al. (2019) (1); Monnickendam & de Asmundis (2018) (1); Patel et al. (2022) (2)
		Inventory		2 (2)	Koppka et al. (2018) (1); Moons et al. (2019) (1)
		Investment		3 (3)	Beaulieu & Bentahar (2021) (1); Glennie et al. (2019) (1); Levin & Lee (2019) (1)
		Length of stay		3 (3)	Brüngger et al. (2021) (1); Gui et al. (2021) (1); Saporito et al. (2021) (1)
		OR time	OR over time	2 (2)	Koppka et al. (2018) (1); Shehadeh & Padman (2022) (1)
		OR utilisation		15 (9)	Aringhieri et al. (2022) (1); Breuer et al. (2020) (2); Erhard et al. (2018) (1); Koppka et al. (2018) (1); Monnickendam & de Asmundis (2018) (2); Patel et al. (2022) (3); Saporito et al.

Objective factor	Objective characteristic	Metric factor	Metric characteristic	Frequency (# phrases (# articles))	References (# phrases)
					(2021) (3); Seelen et al. (2018) (1); Shehadeh & Padman (2022) (1)
		Policy		3 (2)	Brüngger et al. (2021) (1); Patel et al. (2022) (2)
		Profit		5 (5)	Childers & Maggard-Gibbons (2018) (1); Crocitto et al. (2021) (1); Egeland et al. (2017) (1); Glennie et al. (2019) (1); Saporito et al. (2021) (1)
		Readmission		3 (2)	Glennie et al. (2019) (2); Moreira et al. (2017) (1)
		Revenue		5 (5)	Alban et al. (2019) (1); Aringhieri et al. (2022) (1); Egeland et al. (2017) (1); Koppka et al. (2018) (1); Marques & Captivo (2017) (1)
		Savings		19 (12)	Alban et al. (2019) (2); Auerbach et al. (2018) (1); Crocitto et al. (2021) (1); Egeland et al. (2017) (3); Ferreira & Marques (2019) (1); Glennie et al. (2019) (3); Hadaya et al. (2021) (1); Kleiner (2019) (1); Marques & Captivo (2017) (1); Moons et al. (2019) (1);Moreira et al. (2017) (1); Patel et al. (2022) (3)
		Schedule	OR time	2 (2)	Monnickendam & de Asmundis (2018) (1); Saporito et al. (2021) (1)
				5 (5)	Alban et al. (2019) (1); Ferreira & Marques (2019) (1); Monnickendam & de Asmundis (2018) (1); Moons et al. (2019) (1); Shehadeh & Padman (2022) (1)
		Staff performance		3 (3)	Auerbach et al. (2018) (1); Childers & Maggard-Gibbons (2018) (1); Saporito et al. (2021) (1)
		Surgery duration		9 (6)	Breuer et al. (2020) (2); Childers & Maggard-Gibbons (2018) (2); Collins et al. (2017) (1); Glennie et al. (2019) (2); Monnickendam & de Asmundis (2018) (1); Saporito et al. (2021) (1)
		Surgery volume		16 (12)	Aringhieri et al. (2022) (2); Bottani et al. (2022) (1); Breuer et al. (2020) (1); Brüngger et al. (2021) (1); Egeland et al. (2017) (3); Ferreira & Marques (2019) (1); Glaser et al. (2019) (1);

Objective factor	Objective characteristic	Metric factor	Metric characteristic	Frequency (# phrases (# articles))	References (# phrases)
					Glennie et al. (2019) (1); Hadaya et al. (2021) (2); Ibrahim et al. (2022) (1); Monnickendam & de Asmundis (2018) (1); Saporito et al. (2021) (2)
		Treatment type	Bed utilisation	2 (2)	Patel et al. (2022) (1); Seelen et al. (2018) (1)
				25 (14)	Alban et al. (2019) (1); Auerbach et al. (2018) (3); Beaulieu & Bentahar (2021) (1); Bottani et al. (2022) (2); Brüngger et al. (2021) (4); Childers & Maggard-Gibbons (2018) (2); Crocitto et al. (2021) (3); Erhard et al. (2018) (1); Ferreira & Marques (2019) (1); Glaser et al. (2019) (2); Glennie et al. (2019) (2); Lai et al. (2022) (1); Moons et al. (2019) (1); Moreira et al. (2017) (1)
		Waiting list		3 (3)	Aringhieri et al. (2022) (1); Saporito et al. (2021) (1); Shehadeh & Padman (2022) (1)
		Workforce		4 (2)	Glennie et al. (2019) (1); Patel et al. (2022) (3)
Management		OR utilisation		5 (2)	Breuer et al. (2020) (3); Koppka et al. (2018) (2)
		Schedule	Cancellation	4 (3)	Koppka et al. (2018) (2); Monnickendam & de Asmundis (2018) (1); Shehadeh & Padman (2022) (1)
			Communication	2 (2)	Moons et al. (2019) (1); Seelen et al. (2018) (1)
			Delay	2 (2)	Seelen et al. (2018) (1); Shehadeh & Padman (2022) (1)
			Distribution equipment	2 (2)	Moons et al. (2019) (1); Shehadeh & Padman (2022) (1)
			OR block	6 (5)	Birkhoff et al. (2021) (1); Breuer et al. (2020) (1); Monnickendam & de Asmundis (2018) (2); Seelen et al. (2018) (1); Shehadeh & Padman (2022) (1)
			OR design	2 (2)	Di Sivo (2017) (1); Erhard et al. (2018) (1)
			OR utilisation	6 (4)	Breuer et al. (2020) (3); Di Sivo (2017) (1); Erhard et al. (2018) (1); Monnickendam & de Asmundis (2018) (1)
			Staff satisfaction	8 (12)	Breuer et al. (2020) (3); Erhard et al. (2018) (5)

Objective factor	Objective characteristic	Metric factor	Metric characteristic	Frequency (# phrases (# articles))	References (# phrases)
			Workforce	3 (2)	Breuer et al. (2020) (1); Erhard et al. (2018) (2)
				54 (10)	Beaulieu & Bentahar (2021) (1); Breuer et al. (2020) (11); Di Sivo (2017) (4); Erhard et al. (2018) (5); Koppka et al. (2018) (13); Marques & Captivo (2017) (1); Monnickendam & de Asmundis (2018) (5); Moons et al. (2019) (1); Seelen et al. (2018) (2); Shehadeh & Padman (2022) (11)
		Treatment type		4 (2)	Lai et al. (2022) (1); Moreira et al. (2017) (3)
Patient flow		Bed utilisation		2 (2)	Koppka et al. (2018) (1); Shehadeh & Padman (2022) (1)
		OR utilisation		4 (2)	Erhard et al. (2018) (3); Koppka et al. (2018) (1)
		Schedule		3 (2)	Bottani et al. (2022) (1); Shehadeh & Padman (2022) (2)
Quality of care	Adequacy	Treatment type		2 (2)	Adams et al. (2021) (1); Auerbach et al. (2018) (1)
	Care outcomes	Technology		2 (2)	Adams et al. (2022) (1); Di Sivo (2017) (1)
		Audit performance		2 (2)	Glaser et al. (2019) (1); Rodríguez et al. (2021) (1)
		Authority		4 (2)	Crocitto et al. (2021) (3); Hadaya et al. (2021) (1)
		Care outcomes	Morbidity	3 (3)	Adams et al. (2021) (1); Bretonnier et al. (2020) (1); Ibrahim et al. (2022) (1)
				14 (9)	Adams et al. (2021) (2); Ferreira & Marques (2019) (3); Glaser et al. (2019) (2); Hadaya et al. (2021) (1); Ibrahim et al. (2022) (1); Lear et al. (2017) (2); Moreira et al. (2017) (1); Newsweek (2022) (1); Rodríguez et al. (2021) (1)
		Communication		3 (3)	Chrouser et al. (2018) (1); Ibrahim et al. (2022) (1); Kava et al. (2017) (1)
		Complication		5 (2)	Glaser et al. (2019) (4); Kuritzkes et al. (2019) (1)
		Cost		3 (2)	Erhard et al. (2018) (2); Ferreira & Marques (2019) (1)
		Diagnose		2 (2)	Lichtenberg (2015) (1); Olmsted et al. (2022) (1)
		Discharge		3 (2)	Ferreira & Marques (2019) (2); Hadaya et al. (2021) (1)
		Disturbance		3 (2)	Gui et al. (2021) (2); Ukegjini et al. (2020) (1)

Objective factor	Objective characteristic	Metric factor	Metric characteristic	Frequency (# phrases (# articles))	References (# phrases)
		Education		3 (2)	Glaser et al. (2019) (2); Truong et al. (2021) (1)
		Equipment type		7 (7)	Adams et al. (2021) (1); Bottani et al. (2022) (1); Collins et al. (2017) (1); Crocitto et al. (2021) (1); Di Sivo (2017) (1); Hadaya et al. (2021) (1); Seelen et al. (2018) (1)
		Expertise		9 (6)	Adams et al. (2021) (1); Adams et al. (2022) (1); Crocitto et al. (2021) (1); Hadaya et al. (2021) (1); Olmsted et al. (2022) (4); Turkelson & Keiser (2017) (1)
		Length of stay		3 (3)	Glaser et al. (2019) (1); Koppka et al. (2018) (1); Olmsted et al. (2022) (1)
		OR design		3 (2)	Lai et al. (2022) (1); Seelen et al. (2018) (2)
		Patient (health) condition		5 (3)	Ferreira & Marques (2019) (2); Freundlich et al. (2020) (2); Glaser et al. (2019) (1)
		Patient flow		2 (2)	Bottani et al. (2022) (1); Kubala et al. (2021) (1)
		Patient satisfaction		15 (10)	Adams et al. (2022) (2); Alban et al. (2019) (1); Bottani et al. (2022) (1); Brun et al. (2021) (1); Ferreira & Marques (2019) (1); Freundlich et al. (2020) (2); Kubala et al. (2021) (1); Moreira et al. (2017) (1); Newsweek (2022) (2); Olmsted et al. (2022) (3)
		Pharmaceuticals		3 (2)	Lichtenberg (2015) (2); Olmsted et al. (2022) (1)
		Policy		5 (5)	Auerbach et al. (2018) (1); Ferreira & Marques (2019) (1); Glaser et al. (2019) (1); Hadaya et al. (2021) (1); Saporito et al. (2021) (1)
		Readmission		5 (4)	Adams et al. (2021) (1); Hadaya et al. (2021) (2); Kleiner (2019) (1); Koppka et al. (2018) (1)
		Responsiveness		3 (2)	Ibrahim et al. (2022) (2); Truong et al. (2021) (1)
		Safety		4 (4)	Ferreira & Marques (2019) (1); Kleiner (2019) (1); Truong et al. (2021) (1); Volk (2017) (1)
		Schedule		3 (3)	Bottani et al. (2022) (1); Lai et al. (2022) (1); Moons et al. (2019) (1)

Objective factor	Objective characteristic	Metric factor	Metric characteristic	Frequency (# phrases (# articles))	References (# phrases)
		Staff performance		5 (5)	Crocitto et al. (2021) (1); Glaser et al. (2019) (1); Ibrahim et al. (2022) (1); Kubala et al. (2021) (1); Lichtenberg (2015) (1)
		Surgery duration		2 (2)	Ferreira & Marques (2019) (1); Glaser et al. (2019) (1)
		Surgery efficiency		9 (7)	Bottani et al. (2022) (1); Cohen et al. (2021) (1); Collins et al. (2017) (1); Ferreira & Marques (2019) (1); Moreira et al. (2017) (2); Patel et al. (2022) (1); Rodríguez et al. (2021) (1)
		Surgery volume		18 (5)	Adams et al. (2022) (1); Ferreira & Marques (2019) (4); Glaser et al. (2019) (11); Hadaya et al. (2021) (1); Seelen et al. (2018) (1)
		Surgical performance		8 (7)	Adams et al. (2021) (1); Bilgic et al. (2020) (1); Bretonnier et al. (2020) (1); Brun et al. (2021) (2); Chrouser et al. (2018) (1); Glaser et al. (2019) (1); Hadaya et al. (2021) (1)
		Survival	Mortality	5 (5)	Adams et al. (2021) (1); Glaser et al. (2019) (1); Hadaya et al. (2021) (1); Ibrahim et al. (2022) (1); Olmsted et al. (2022) (1)
		Teamwork		3 (3)	Mundt et al. (2020) (1); Truong et al. (2021) (1); Volk (2017) (1)
		Treatment type		15 (12)	Adams et al. (2022) (1); Breuer et al. (2020) (1); Ferreira & Marques (2019) (1); Glaser et al. (2019) (1); Ibrahim et al. (2022) (1); Kleiner (2019) (1); Lear et al. (2017) (1); Lichtenberg (2015) (1); Moons et al. (2019) (2); Moreira et al. (2017) (1); Newsweek (2022) (2); Olmsted et al. (2022) (2)
		Waiting list		3 (3)	Beaulieu & Bentahar (2021) (1); Erhard et al. (2018) (1); Ferreira & Marques (2019) (1)
		Waste		3 (3)	Ferreira & Marques (2019) (1); Seelen et al. (2018) (1); Shortell et al. (2018) (1)
		Workload		3 (2)	Aringhieri et al. (2022) (1); Erhard et al. (2018) (2)
Resources	Technology	Equipment type		3 (2)	Auerbach et al. (2018) (1); Scholte et al. (2021) (3)
		Equipment utilisation		3 (3)	Beaulieu & Bentahar (2021) (1); Bottani et al. (2022) (1); Marques & Captivo (2017) (1)

Objective factor	Objective characteristic	Metric factor	Metric characteristic	Frequency (# phrases (# articles))	References (# phrases)
		Inventory		5 (2)	Beaulieu & Bentahar (2021) (4); Gelb et al. (2018) (1)
		OR utilisation		3 (3)	Monnickendam & de Asmundis (2018) (1); Moons et al. (2019) (1); Seelen et al. (2018) (1)
		Schedule		4 (3)	Bottani et al. (2022) (1); Chrouser et al. (2018) (1); Collins et al. (2017) (1)
		Workforce		7 (6)	Adams et al. (2022) (2); Breuer et al. (2020) (1); Chrouser et al. (2018) (1); Cohen et al. (2021) (1); Cossio-Gil et al. (2022) (1); Ferreira & Marques (2019) (1)
Safety		Accuracy		2 (2)	Chrouser et al. (2018) (1); El Boghdady & Tang (2022) (1)
		Audit performance		2 (2)	Kim et al. (2019) (1); Nicholson et al. (2020) (1)
		Authority		3 (3)	Ibrahim et al. (2022) (1); Pattni et al. (2019) (1); Sotto et al. (2021) (1)
		Behaviour		2 (2)	Alban et al. (2019) (1); Chrouser et al. (2018) (1)
		Care outcomes	Morbidity	5 (5)	Bretonnier et al. (2020) (1); Ibrahim et al. (2022) (1); Pattni et al. (2019) (1); Sotto et al. (2021) (1); Truong et al. (2021) (1)
				3 (2)	Alban et al. (2019) (1); Lear et al. (2017) (2)
		Communication		10 (8)	Alban et al. (2019) (1); Chrouser et al. (2018) (1); Emond et al. (2022) (1); Frasier et al. (2019) (2); Kava et al. (2017) (1); Leuridan (2020) (1); Pattni et al. (2019) (2); Sotto et al. (2021) (1)
		Complexity		2 (2)	Chrouser et al. (2018) (1); Gelb et al. (2018) (1)
		Complication		17 (9)	Alban et al. (2019) (2); Emond et al. (2022) (3); Kim et al. (2019) (1); Kuritzkes et al. (2019) (2); Scali et al. (2020) (2); Sotto et al. (2021) (1); Thomsen et al. (2017) (2); Truong et al. (2021) (3); Turkelson & Keiser (2017) (1)
		Culture		4 (3)	Chrouser et al. (2018) (2); Leuridan (2020) (1); Sotto et al. (2021) (1)
		Education		4 (2)	Bath et al. (2019) (1); Truong et al. (2021) (3)

Objective factor	Objective characteristic	Metric factor	Metric characteristic	Frequency (# phrases (# articles))	References (# phrases)
		Equipment type		2 (2)	Beaulieu & Bentahar (2021) (1); Sotto et al. (2021) (1)
		Expertise		3 (3)	Kim et al. (2019) (1); Sotto et al. (2021) (1); Thomsen et al. (2017) (1)
		Length of stay		2 (2)	Emond et al. (2022) (1); Nicholson et al. (2020) (1);
		Operational performance		2 (2)	Ibrahim et al. (2022) (1); Lear et al. (2017) (1)
		OR time	OR break	2 (2)	Belykh et al. (2018) (1); Bretonnier et al. (2020) (1)
		Patient (health) condition		3 (3)	Chrouser et al. (2018) (1); Ibrahim et al. (2022) (1); Turkelson & Keiser (2017) (1)
		Pharmaceuticals		3 (3)	Emond et al. (2022) (1); Ibrahim et al. (2022) (1); Nicholson et al. (2020) (1)
		Policy		4 (4)	Emond et al. (2022) (1); Leuridan (2020) (1); McMullan et al. (2020) (1); Pattni et al. (2019) (1)
		Responsiveness		5 (2)	Alban et al. (2019) (2); Truong et al. (2021) (3)
		Safety		6 (6)	Alban et al. (2019) (1); Chrouser et al. (2018) (1); Kuritzkes et al. (2019) (1); Pattni et al. (2019) (1); Truong et al. (2021) (1); Turkelson & Keiser (2017) (1)
		Skill		4 (3)	Alban et al. (2019) (2); Bath et al. (2019) (1); Thomsen et al. (2017) (1)
		Staff (health) condition		3 (2)	Leuridan (2020) (1); Nilsson et al. (2018) (2)
		Staff performance		3 (3)	Nicholson et al. (2020) (1); Nilsson et al. (2018) (1); Thomsen et al. (2017) (1)
		Surgery volume		4 (4)	Emond et al. (2022) (1); Ibrahim et al. (2022) (1); Sotto et al. (2021) (1); Turkelson & Keiser (2017) (1)
		Survival	Mortality	11 (7)	El Boghdady & Tang (2022) (1); Emond et al. (2022) (3); Ibrahim et al. (2022) (2); Nilsson et al. (2018) (1); Pattni et al. (2019) (1); Sotto et al. (2021) (2); Truong et al. (2021) (1)

Objective factor	Objective characteristic	Metric factor	Metric characteristic	Frequency (# phrases (# articles))	References (# phrases)
		Teamwork		9 (7)	Gui et al. (2021) (1); Lear et al. (2017) (1); Leuridan (2020) (1); Nilsson et al. (2018) (2); Pattni et al. (2019) (2); Truong et al. (2021) (1); Volk (2017) (1)
		Treatment type		2 (2)	Chrouser et al. (2018) (1); Turkelson & Keiser (2017) (1)
		Workload		2 (2)	Alban et al. (2019) (1); Bretonnier et al. (2020) (1)
Satisfaction	Patient satisfaction	Communication		2 (2)	Cohen et al. (2021) (1); Kava et al. (2017) (1)
		Patient satisfaction		8 (7)	Aringhieri et al. (2022) (1); Cohen et al. (2021) (2); Koppka et al. (2018) (1); Kubala et al. (2021) (1); MacNeil et al. (2019) (1); Marques & Captivo (2017) (1); Newsweek (2022) (1)
		Staff satisfaction		4 (2)	Breuer et al. (2020) (3); Moons et al. (2019) (1)
		Workforce		5 (4)	Bottani et al. (2022) (1); Chrouser et al. (2018) (1); MacNeil et al. (2019) (1); Olmsted et al. (2022) (2)
Service		Bed utilisation		2 (2)	Ferreira & Marques (2019) (1); Moons et al. (2019) (1)
		Cost		3 (2)	Moreira et al. (2017) (1); Trosman et al. (2017) (2)
		Equipment type		2 (2)	Adams et al. (2022) (1); Olmsted et al. (2022) (1)
		Equipment utilisation		2 (2)	Bottani et al. (2022) (1); Newsweek (2022) (1);
		OR utilisation		2 (2)	Ferreira & Marques (2019) (1); Kubala et al. (2021) (1)
		Patient flow		2 (2)	Kubala et al. (2021) (1); Moons et al. (2019) (1)
		Patient satisfaction		4 (3)	Moreira et al. (2017) (1); Newsweek (2022) (2); Trosman et al. (2017) (1)
		Schedule	OR block	4 (2)	Monnickendam & de Asmundis (2018) (3); Shehadeh & Padman (2022) (1)
			OR utilisation	3 (2)	Aringhieri et al. (2022) (1); Monnickendam & de Asmundis (2018) (2)

Objective factor	Objective characteristic	Metric factor	Metric characteristic	Frequency (# phrases (# articles))	References (# phrases)
				31 (5)	Aringhieri et al. (2022) (3); Breuer et al. (2020) (8); Marques & Captivo (2017) (4); Monnickendam & de Asmundis (2018) (14); Wang et al. (2021) (2)
		Surgery efficiency	OR utilisation	2 (2)	Erhard et al. (2018) (1); Seelen et al. (2018) (1)
		Surgery volume	OR utilisation	2 (2)	Erhard et al. (2018) (1); Ferreira & Marques (2019) (1)
		Treatment type		5 (4)	Adams et al. (2022) (2); Beaulieu & Bentahar (2021) (1); Koppka et al. (2018) (1); MacNeil et al. (2019) (1)
Staff (health) condition		Ergonomics		3 (2)	Belykh et al. (2018) (2); Di Sivo (2017) (1)
		Expertise		2 (2)	Bilgic et al. (2020) (1); Ibrahim et al. (2022) (1)
		Staff (health) condition		3 (3)	Adams et al. (2022) (1); Bayramzadeh et al. (2021) (1); Belykh et al. (2018) (1)
		Staff satisfaction		2 (2)	Belykh et al. (2018) (1); Breuer et al. (2020) (1)
		Stressors		13 (5)	Bretonnier et al. (2020) (2); Chrouser et al. (2018) (6); Ibrahim et al. (2022) (1); Nilsson et al. (2018) (1); Ukegjini et al. (2020) (3)
		Workforce	Physical work	6 (3)	Alban et al. (2019) (2); Belykh et al. (2018) (1); Ferreira & Marques (2019) (3)
		Workload		3 (3)	Bilgic et al. (2020) (1); Bretonnier et al. (2020) (1); Breuer et al. (2020) (1)
Surgical performance	Staff performance	Education		6 (4)	Cohen et al. (2021) (1); Thomsen et al. (2017) (2); Truong et al. (2021) (2); Volk (2017) (1)
		Expertise		4 (3)	Belykh et al. (2018) (1); Chrouser et al. (2018) (1); Crocitto et al. (2021) (2)
		Skill		8 (6)	Belykh et al. (2018) (1); Bilgic et al. (2020) (1); Breuer et al. (2020) (1); Chrouser et al. (2018) (3); Crocitto et al. (2021) (1); Thomsen et al. (2017) (1)

Objective factor	Objective characteristic	Metric factor	Metric characteristic	Frequency (# phrases (# articles))	References (# phrases)
		Staff (health) condition	Psychological condition	2 (3)	Belykh et al. (2018) (1); Chrouser et al. (2018) (1); Crocitto et al. (2021) (2)
				9 (3)	Belykh et al. (2018) (3); Bretonnier et al. (2020) (1); Chrouser et al. (2018) (5)
		Staff performance		6 (4)	Alban et al. (2019) (1); Chrouser et al. (2018) (2); Di Sivo (2017) (1); Ukegjini et al. (2020) (2)
		Workforce		6 (5)	Alban et al. (2019) (2); Belykh et al. (2018) (1); Bottani et al. (2022) (1); Bretonnier et al. (2020) (1); McMullan et al. (2020) (1)
		Workload		3 (3)	Alban et al. (2019) (1); Beaulieu & Bentahar (2021) (1); Erhard et al. (2018) (1)
		Accuracy		8 (7)	Alban et al. (2019) (1); Belykh et al. (2018) (1); Bilgic et al. (2020) (2); El Boghdady & Tang (2022) (1); Gui et al. (2021) (1); Ibrahim et al. (2022) (1); Turkelson & Keiser (2017) (1)
		Care outcomes	Morbidity	2 (2)	Adams et al. (2022) (1); Ukegjini et al. (2020) (1)
				6 (5)	Aringhieri et al. (2022) (1); Gui et al. (2021) (1); Ibrahim et al. (2022) (1); Moons et al. (2019) (2); Shortell et al. (2018) (1)
		Communication		5 (5)	Cossio-Gil et al. (2022) (1); Levin & Lee (2019) (1); Cohen et al. (2021) (1); Mundt et al. (2020) (1); Truong et al. (2021) (1)
		Complication		3 (3)	Adams et al. (2022) (1); Alban et al. (2019) (1); Zingiryan et al. (2017) (1)
		Culture		3 (3)	Cohen et al. (2021) (1); Cossio-Gil et al. (2022) (1); Shortell et al. (2018) (1)
		Disturbance		11 (3)	Bretonnier et al. (2020) (1); Gui et al. (2021) (5); Ukegjini et al. (2020) (5)
		Equipment type		5 (5)	Aringhieri et al. (2022) (1); Cohen et al. (2021) (1); Ferreira & Marques (2019) (1); Moons et al. (2019) (1); Shortell et al. (2018) (1)
		Expertise		4 (4)	Bayramzadeh et al. (2021) (1); Lai et al. (2022) (1); Sotto et al. (2021) (1); Turkelson & Keiser (2017) (1)

Objective factor	Objective characteristic	Metric factor	Metric characteristic	Frequency (# phrases (# articles))	References (# phrases)
		OR design		5 (2)	Bayramzadeh et al. (2021) (4); Turkelson & Keiser (2017) (1)
		OR time	OR break	5 (2)	Belykh et al. (2018) (1); Bretonnier et al. (2020) (4)
		Patient satisfaction		4 (3)	Adams et al. (2022) (1); Bottani et al. (2022) (1); McMullan et al. (2020) (2)
		Policy		3 (3)	Di Sivo (2017) (1); Sotto et al. (2021) (1); Turkelson & Keiser (2017) (1)
		Responsiveness		4 (4)	Mundt et al. (2020) (1); Shortell et al. (2018) (1); Turkelson & Keiser (2017) (1); Ukegjini et al. (2020) (1)
		Safety		2 (2)	Belykh et al. (2018) (1); McMullan et al. (2020) (1)
		Skill		11 (8)	Bath et al. (2019) (3); Gui et al. (2021) (1); Lai et al. (2022) (1); McMullan et al. (2020) (1); Mundt et al. (2020) (1); Shortell et al. (2018) (1); Thomsen et al. (2017) (2); Turkelson & Keiser (2017) (1)
		Staff (health) condition		3 (3)	Belykh et al. (2018) (1); Nilsson et al. (2018) (1); Ukegjini et al. (2020) (1)
		Staff performance		3 (3)	Bayramzadeh et al. (2021) (1); Mundt et al. (2020) (1); Zingiryan et al. (2017) (1)
		Stressors		3 (2)	Chrouser et al. (2018) (2); Ukegjini et al. (2020) (1)
		Surgery efficiency	Equipment	5 (3)	Alban et al. (2019) (2); Lear et al. (2017) (1); Pradere et al. (2022) (2)
			Start time	2 (2)	Kubala et al. (2021) (1); Seelen et al. (2018) (1)
				19 (12)	Alban et al. (2019) (1); Aringhieri et al. (2022) (1); Belykh et al. (2018) (1); Birkhoff et al. (2021) (1); Bottani et al. (2022) (2); Ferreira & Marques (2019) (2); Kubala et al. (2021) (2); Levin & Lee (2019) (1); Marques & Captivo (2017) (1); Moons et al. (2019) (5); Shehadeh & Padman (2022) (1); Sotto et al. (2021) (1)
		Surgery volume	Surgery efficiency	10 (3)	Alban et al. (2019) (8); Collins et al. (2017) (1); Ferreira & Marques (2019) (1)

Objective factor	Objective characteristic	Metric factor	Metric characteristic	Frequency (# phrases (# articles))	References (# phrases)
Team				9 (7)	Adams et al. (2022) (1); Bayramzadeh et al. (2021) (1); Belykh et al. (2018) (2); Collins et al. (2017) (1); Ibrahim et al. (2022) (1); Marques & Captivo (2017) (1); Thomsen et al. (2017) (1)
		Surgical performance		3 (2)	El Boghdady & Tang (2022) (2); Moons et al. (2019) (1)
		Survival	Mortality	3 (3)	Adams et al. (2022) (1); Ukegjini et al. (2020) (1); Volk (2017) (1)
		Teamwork		7 (6)	Chrouser et al. (2018) (1); Kubala et al. (2021) (1); Mundt et al. (2020) (2); Truong et al. (2021) (1); Turkelson & Keiser (2017) (1); Volk (2017) (1)
		Workforce		2 (2)	Bayramzadeh et al. (2021) (1); Bottani et al. (2022) (1)
	Workload	Care outcomes		2 (2)	MacNeil et al. (2019) (1); Newsweek (2022) (1)
		Accuracy		2 (2)	Chrouser et al. (2018) (1); Volk (2017) (1)
		Authority		6 (5)	Chrouser et al. (2018) (1); Ibrahim et al. (2022) (1); Lear et al. (2017) (1); Pattni et al. (2019) (1); Volk (2017) (2)
		Behaviour		5 (4)	Chrouser et al. (2018) (2); Ibrahim et al. (2022) (1); Leuridan (2020) (1); Truong et al. (2021) (1)
		Care outcomes	Morbidity	3 (2)	Truong et al. (2021) (1); Volk (2017) (2)
				3 (3)	Ibrahim et al. (2022) (1); Lear et al. (2017) (1); McMullan et al. (2020) (1)
		Communication		15 (9)	Belykh et al. (2018) (1); Chrouser et al. (2018) (1); Frasier et al. (2019) (3); Gui et al. (2021) (1); MacNeil et al. (2019) (1); Pattni et al. (2019) (2); Sotto et al. (2021) (1); Truong et al. (2021) (1); Volk (2017) (4)
		Culture		7 (6)	MacNeil et al. (2019) (2); Mundt et al. (2020) (1); Pattni et al. (2019) (1); Truong et al. (2021) (1); Volk (2017) (1); Zingiryan et al. (2017) (1)
		Education		6 (4)	Frasier et al. (2019) (1); Pattni et al. (2019) (1); Truong et al. (2021) (2); Volk (2017) (2)

Objective factor	Objective characteristic	Metric factor	Metric characteristic	Frequency (# phrases (# articles))	References (# phrases)
		Responsiveness		3 (3)	Chrouser et al. (2018) (1); Lear et al. (2017) (1); Truong et al. (2021) (1)
		Staff performance		3 (3)	Chrouser et al. (2018) (1); McMullan et al. (2020) (1); Pattni et al. (2019) (1)
		Staff satisfaction		3 (2)	McMullan et al. (2020) (2); Mundt et al. (2020) (1)
		Surgery volume	Surgery efficiency	2 (2)	Truong et al. (2021) (1); Volk (2017) (1)
				2 (2)	Kubala et al. (2021) (1); Monnickendam & de Asmundis (2018) (1)
		Survival	Mortality	3 (2)	Truong et al. (2021) (1); Volk (2017) (2)
		Team structure		5 (5)	Crocitto et al. (2021) (1); Frasier et al. (2019) (1); MacNeil et al. (2019) (1); Pattni et al. (2019) (1); Volk (2017) (1)
		Teamwork		12 (11)	Bretonnier et al. (2020) (1); Chrouser et al. (2018) (3); Frasier et al. (2019) (1); Ibrahim et al. (2022) (1); Lear et al. (2017) (1); MacNeil et al. (2019) (1); McMullan et al. (2020) (1); Mundt et al. (2020) (1); Sotto et al. (2021) (1); Volk (2017) (1); Zingiryan et al. (2017) (1)
		Trust		2 (2)	MacNeil et al. (2019) (1); Chrouser et al. (2018) (1)

Appendix F The metric combination and the metric's unit of the performance optimisation of the OR

Table Appendix 6: The metric combination and the units of the performance optimisation of the OR from the 84 selected articles, together with the corresponding number of studies and references. Between the brackets, the frequency of phrases within the articles are stated. All the metrics that occurred only once (n=1) in all articles or only occurred in one article has been removed.

Metric factor	Metric characteristic	Unit	Frequency (# phrases (# articles))	References (# phrases)
Accessibility		Money ($; €)	2 (2)	Aringhieri et al. (2022) (1); Glennie et al. (2019) (1)
Bed utilisation	Length of stay	Time: stay (days)	2 (2)	Ferreira & Marques (2019) (1); Seelen et al. (2018) (1)
		Beds (#)	6 (5)	Aringhieri et al. (2022) (1); Bottani et al. (2022) (1); Ferreira & Marques (2019) (2); Koppka et al. (2018) (1); Lear et al. (2017) (1)
		Money ($; €)	2 (2)	Aringhieri et al. (2022) (1); Hadaya et al. (2021) (1)
Care outcomes	Morbidity	Error (#)	4 (2)	Bretonnier et al. (2020) (3); Volk (2017) (1)
		Money ($; €)	3 (3)	Auerbach et al. (2018) (1); Moons et al. (2019) (1); Seelen et al. (2018) (1)
Communication	Transparency	Money ($; €)	4 (3)	Beaulieu & Bentahar (2021) (1); Glennie et al. (2019) (2); Ibrahim et al. (2022) (1)
		Error (#)	7 (6)	Bretonnier et al. (2020) (1); Chrouser et al. (2018) (1); Frasier et al. (2019) (2); Ibrahim et al. (2022) (1); Levin & Lee (2019) (1); Pattni et al. (2019) (2)
Complication		Error (#)	12 (10)	Adams et al. (2021) (1); Alban et al. (2019) (2); Bilgic et al. (2020) (1); Kim et al. (2019)) (1); Lear et al. (2017) (1); Levin & Lee (2019) (1); Moreira et al. (2017) (1); Pattni et al. (2019) (2); Truong et al. (2021) (1); Ukegjini et al. (2020) (1)
		Money ($; €)	8 (5)	Alban et al. (2019) (2); Egeland et al. (2017) (1); Gelb et al. (2018) (1); Kuritzkes et al. (2019) (3); Pattni et al. (2019) (1)
		Time: OR time (hours)	3 (3)	Monnickendam & de Asmundis (2018) (1); Turkelson & Keiser (2017) (1); Zingiryan et al. (2017) (1)

Metric factor	Metric characteristic	Unit	Frequency (# phrases (# articles))	References (# phrases)
Cost	Workforce	Money ($; €)	3 (2)	Childers & Maggard-Gibbons (2018) (2); Glennie et al. (2019) (1)
		Money ($; €)	15 (9)	Alban et al. (2019) (1); Aringhieri et al. (2022) (1); Brüngger et al. (2021) (2); Childers & Maggard-Gibbons (2018) (1); Ferreira & Marques (2019) (1); Glennie et al. (2019) (2); Monnickendam & de Asmundis (2018) (2); Moons et al. (2019) (1); Patel et al. (2022) (4)
Distribution equipment		Money ($; €)	3 (2)	Childers & Maggard-Gibbons (2018) (1); Moons et al. (2019) (1)
Disturbance		Error (#)	4 (2)	Bretonnier et al. (2020) (1); Gui et al. (2021) (3)
		Interruptions (#)	2 (2)	Bretonnier et al. (2020) (1); Gui et al. (2021) (1)
Equipment type		Error (#)	3 (3)	El Boghdady & Tang (2022) (1); Moons et al. (2019) (1); Sotto et al. (2021) (1)
		Money ($; €)	10 (9)	Auerbach et al. (2018) (1); Brüngger et al. (2021) (1); Ferreira & Marques (2019) (1); Hadaya et al. (2021) (1); Lear et al. (2017) (1); MacNeil et al. (2019) (1); Monnickendam & de Asmundis (2018) (1); Moons et al. (2019) (1); Patel et al. (2022) (2)
Equipment utilisation		Usage (#)	8 (5)	Beaulieu & Bentahar (2021) (1); Kubala et al. (2021) (1); Lear et al. (2017) (4); Marques & Captivo (2017) (1); Moons et al. (2019) (1)
Idle time		Money ($; €)	2 (2)	Monnickendam & de Asmundis (2018) (1); Shehadeh & Padman (2022) (1)
Investment		Money ($; €)	4 (4)	Beaulieu & Bentahar (2021) (1); Ferreira & Marques (2019) (1); Glennie et al. (2019) (1); Levin & Lee (2019) (1)
Length of stay		Money ($; €)	3 (3)	Brüngger et al. (2021) (1); Glennie et al. (2019) (1); Saporito et al. (2021) (1)
		Time: stay (days)	2 (2)	Aringhieri et al. (2022) (1); Patel et al. (2022) (1)
Operational performance		Money ($; €)	3 (2)	Glennie et al. (2019) (2); Moons et al. (2019) (1)
OR time	OR overtime	Money ($; €)	2 (2)	Koppka et al. (2018) (1); Shehadeh & Padman (2022) (1)

Metric factor	Metric characteristic	Unit	Frequency (# phrases (# articles))	References (# phrases)
		Time: OR time (hours)	5 (4)	Erhard et al. (2018) (2); Koppka et al. (2018) (1); Shehadeh & Padman (2022) (1); Wang et al. (2021) (1)
OR utilisation		Money ($; €)	16 (11)	Aringhieri et al. (2022) (1); Breuer et al. (2020) (2); Childers & Maggard-Gibbons (2018) (1); Erhard et al. (2018) (1); Glennie et al. (2019) (1); Koppka et al. (2018) (1); Monnickendam & de Asmundis (2018) (2); Patel et al. (2022) (3); Saporito et al. (2021) (2); Seelen et al. (2018) (1); Shehadeh & Padman (2022) (1)
		Patient (#)	3 (2)	Ferreira & Marques (2019) (2); Marques & Captivo (2017) (1)
		Surgery (#)	3 (2)	Ferreira & Marques (2019) (2); Patel et al. (2022) (1)
		Time: Delay (hours)	3 (3)	Bottani et al. (2022) (1); Ferreira & Marques (2019) (1); Seelen et al. (2018) (1)
		Time: Idle time (hours)	2 (2)	Aringhieri et al. (2022) (1); Monnickendam & de Asmundis (2018) (1)
		Time: OR opening hours (hours)	3 (3)	Collins et al. (2017) (1); Koppka et al. (2018) (1); Patel et al. (2022) (1)
		Time: OR over time (hours)	2 (2)	Aringhieri et al. (2022) (1); Koppka et al. (2018) (1)
		Time: OR time (hours)	17 (9)	Bottani et al. (2022) (2); Bretonnier et al. (2020) (1); Breuer et al. (2020) (1); Ferreira & Marques (2019) (4); Koppka et al. (2018) (2); Monnickendam & de Asmundis (2018) (2); Moons et al. (2019) (1); Patel et al. (2022) (1); Saporito et al. (2021) (3)
		Usage (#)	4 (4)	Bottani et al. (2022) (1); Monnickendam & de Asmundis (2018) (1); Saporito et al. (2021) (1); Shehadeh & Padman (2022) (1)
Patient (health) condition		Patient health: Blood loss (mL)	3 (2)	Glaser et al. (2019) (2); Sotto et al. (2021) (1)
		Patient health: Blood pressure (mmHg)	3 (3)	Bayramzadeh et al. (2021) (1); Freundlich et al. (2020) (1); Turkelson & Keiser (2017) (1)

Metric factor	Metric characteristic	Unit	Frequency (# phrases (# articles))	References (# phrases)
		Patient health: Heart rate (bpm)	2 (2)	Bayramzadeh et al. (2021) (1); Turkelson & Keiser (2017) (1)
Policy		Money (; €)	3 (2)	Brüngger et al. (2021) (1); Patel et al. (2022) (2)
		Time: OR time (hours)	3 (3)	Collins et al. (2017) (1); Saporito et al. (2021) (1); Sotto et al. (2021) (1)
Profit		Money ($; €)	7 (6)	Childers & Maggard-Gibbons (2018) (1); Crocitto et al. (2021) (1); Egeland et al. (2017) (1); Glennie et al. (2019) (1); Moreira et al. (2017) (2); Saporito et al. (2021) (1)
Readmission		Money ($; €)	3 (2)	Glennie et al. (2019) (2); Moreira et al. (2017) (1)
Responsiveness		Time: Waiting list (hours)	2 (2)	Moons et al. (2019) (1); Truong et al. (2021) (1)
Revenue		Money ($; €)	5 (5)	Alban et al. (2019) (1); Aringhieri et al. (2022) (1); Egeland et al. (2017) (1); Koppka et al. (2018) (1); Marques & Captivo (2017) (1)
Safety		Error (#)	5 (5)	Chrouser et al. (2018) (1); Cohen et al. (2021) (1); Kuritzkes et al. (2019) (1); McMullan et al. (2020) (1); Volk (2017) (1)
Savings		Money ($; €)	18 (12)	Alban et al. (2019) (2); Auerbach et al. (2018) (1); Crocitto et al. (2021) (1); Egeland et al. (2017) (2); Ferreira & Marques (2019) (1); Glennie et al. (2019) (3); Hadaya et al. (2021) (1); Kleiner (2019) (1); Marques & Captivo (2017) (1); Moons et al. (2019) (1); Moreira et al. (2017) (1); Patel et al. (2022) (3)
Schedule	Bed utilisation	Beds (#)	4 (2)	Bottani et al. (2022) (1); Shehadeh & Padman (2022) (3)
	Cancellation	Cancellation (#)	7 (5)	Bottani et al. (2022) (1); Breuer et al. (2020) (2); Koppka et al. (2018) (2); Monnickendam & de Asmundis (2018) (1); Shehadeh & Padman (2022) (1)
	Length of stay	Time: stay (days)	6 (3)	Aringhieri et al. (2022) (3); Emond et al. (2022) (1); Shehadeh & Padman (2022) (2)
	OR time	Money ($; €)	3 (3)	Aringhieri et al. (2022) (1); Monnickendam & de Asmundis (2018) (1); Saporito et al. (2021) (1)

Metric factor	Metric characteristic	Unit	Frequency (# phrases (# articles))	References (# phrases)
	OR utilisation	Time: OR time (hours)	8 (4)	Bottani et al. (2022) (2); Breuer et al. (2020) (3); Koppka et al. (2018) (2); Monnickendam & de Asmundis (2018) (1)
	Start time	Time: Delay (hours)	4 (2)	Breuer et al. (2020) (3); Moons et al. (2019) (1)
	Turnover	Time: OR time (hours)	2 (2)	Marques & Captivo (2017) (1); Monnickendam & de Asmundis (2018) (1)
	Workforce	Staff (#)	3 (2)	Breuer et al. (2020) (1); Erhard et al. (2018) (2)
		Cancellation (#)	2 (2)	Koppka et al. (2018) (1); Shehadeh & Padman (2022) (1)
		Emergency cases (#)	2 (2)	Koppka et al. (2018) (1); Monnickendam & de Asmundis (2018) (1)
		Money ($; €)	12 (6)	Alban et al. (2019) (1); Ferreira & Marques (2019) (1); Marques & Captivo (2017) (2); Monnickendam & de Asmundis (2018) (5); Moons et al. (2019) (2); Shehadeh & Padman (2022) (1)
		ORs (#)	2 (2)	Di Sivo (2017) (1); Shehadeh & Padman (2022) (1)
		Patient (#)	9 (5)	Bottani et al. (2022) (1); Breuer et al. (2020) (5); Collins et al. (2017) (1); Koppka et al. (2018) (1); Monnickendam & de Asmundis (2018) (1)
		Staff (#)	3 (2)	Breuer et al. (2020) (2); Erhard et al. (2018) (1)
		Surgery (#)	9 (6)	Di Sivo (2017) (1); Aringhieri et al. (2022) (2); Breuer et al. (2020) (2); Collins et al. (2017) (1); Koppka et al. (2018) (1); Shehadeh & Padman (2022) (3)
		Time: Idle time (hours)	7 (3)	Koppka et al. (2018) (1); Monnickendam & de Asmundis (2018) (3); Shehadeh & Padman (2022) (3)
		Time: OR block time (hours)	16 (9)	Birkhoff et al. (2021) (1); Bottani et al. (2022) (1); Collins et al. (2017) (5); Erhard et al. (2018) (1); Koppka et al. (2018) (2); Marques & Captivo (2017) (1); Monnickendam & de Asmundis (2018) (1); Seelen et al. (2018) (1); Shehadeh & Padman (2022) (2)
		Time: OR opening hours (hours)	3 (2)	Bottani et al. (2022) (1); Koppka et al. (2018) (2)

Metric factor	Metric characteristic	Unit	Frequency (# phrases (# articles))	References (# phrases)
		Time: OR over time (hours)	18 (5)	Aringhieri et al. (2022) (1); Breuer et al. (2020) (5); Koppka et al. (2018) (5); Monnickendam & de Asmundis (2018) (3); Shehadeh & Padman (2022) (4)
		Time: OR time (hours)	19 (9)	Aringhieri et al. (2022) (2); Bottani et al. (2022) (2); Breuer et al. (2020) (3); Di Sivo (2017) (1); Erhard et al. (2018) (1); Koppka et al. (2018) (2); Marques & Captivo (2017) (1); Monnickendam & de Asmundis (2018) (4); Shehadeh & Padman (2022) (2)
		Time: Waiting list (days)	6 (5)	Beaulieu & Bentahar (2021) (1); Bottani et al. (2022) (1); Breuer et al. (2020) (2); Koppka et al. (2018) (1); Shehadeh & Padman (2022) (1)
		Transfers (#)	2 (2)	Aringhieri et al. (2022) (1); Erhard et al. (2018) (1)
		Waiting list (#)	4 (3)	Marques & Captivo (2017) (2); Monnickendam & de Asmundis (2018) (1); Shehadeh & Padman (2022) (1)
Shift	OR time	Money ($; €)	2 (2)	Breuer et al. (2020) (1); Erhard et al. (2018) (1)
		Working hours (#)	2 (2)	Breuer et al. (2020) (1); Erhard et al. (2018) (1)
Skill		Error (#)	3 (2)	Bath et al. (2019) (2); Bretonnier et al. (2020) (1)
Staff performance		Money ($; €)	3 (3)	Auerbach et al. (2018) (1); Childers & Maggard-Gibbons (2018) (1); Saporito et al. (2021) (1)
Staff satisfaction		Time: OR over time (hours)	2 (2)	Breuer et al. (2020) (1); Koppka et al. (2018) (1)
Start time	Cancellation	Cancellation (#)	2 (2)	Aringhieri et al. (2022) (1); Wang et al. (2021) (1)
Surgery duration		Money ($; €)	11 (6)	Childers & Maggard-Gibbons (2018) (2); Breuer et al. (2020) (2); Collins et al. (2017) (1); Glennie et al. (2019) (2); Monnickendam & de Asmundis (2018) (3); Saporito et al. (2021) (1)
		Time: OR time (hours)	12 (6)	Ferreira & Marques (2019) (1); Glaser et al. (2019) (3); Koppka et al. (2018) (4); Kubala et al. (2021) (1); Patel et al. (2022) (1); Wang et al. (2021) (2)
Surgery efficiency	Start time	Time: Delay (hours)	2 (2)	Kubala et al. (2021) (1); Seelen et al. (2018) (1)

Metric factor	Metric characteristic	Unit	Frequency (# phrases (# articles))	References (# phrases)
		Time: OR time (hours)	4 (4)	Aringhieri et al. (2022) (1); Bottani et al. (2022) (1); Childers & Maggard-Gibbons (2018) (1); Sotto et al. (2021) (1)
Surgery volume	Surgery efficiency	Time: OR time (hours)	6 (4)	Collins et al. (2017) (1); Ferreira & Marques (2019) (3); Newsweek (2022) (1); Volk (2017) (1)
	Turnover	Time: OR time (hours)	2 (2)	Kubala et al. (2021) (1); Monnickendam & de Asmundis (2018) (1)
		Money ($; €)	17 (13)	Aringhieri et al. (2022) (2); Beaulieu & Bentahar (2021) (1); Bottani et al. (2022) (1); Breuer et al. (2020) (1); Brüngger et al. (2021) (1); Egeland et al. (2017) (3); Ferreira & Marques (2019) (2); Glennie et al. (2019) (1); Hadaya et al. (2021) (1); Ibrahim et al. (2022) (1); Monnickendam & de Asmundis (2018) (1); Saporito et al. (2021) (1); Shehadeh & Padman (2022) (1)
		Patient (#)	9 (9)	Adams et al. (2022) (1); Auerbach et al. (2018) (1); Ferreira & Marques (2019) (1); Glaser et al. (2019) (1); Hadaya et al. (2021) (1); Ibrahim et al. (2022) (1); Kleiner (2019) (1); Saporito et al. (2021) (1); Shehadeh & Padman (2022) (1
		Surgery (#)	10 (7)	Adams et al. (2022) (2); Bath et al. (2019) (1); Ferreira & Marques (2019) (3); Ibrahim et al. (2022) (1); Marques & Captivo (2017) (1); Newsweek (2022) (1); Saporito et al. (2021) (1)
		Time: OR time (hours)	8 (6)	Aringhieri et al. (2022) (1); Belykh et al. (2018) (2); Glaser et al. (2019) (1); Marques & Captivo (2017) (1); Monnickendam & de Asmundis (2018) (2); Patel et al. (2022) (1)
Surgical performance		Error (#)	9 (6)	Bilgic et al. (2020) (1); Bretonnier et al. (2020) (1); Breuer et al. (2020) (1); Brun et al. (2021) (2); Chrouser et al. (2018) (1); El Boghdady & Tang (2022) (3)
		Money ($; €)	5 (4)	Levin & Lee (2019) (1); Collins et al. (2017) (1); Glaser et al. (2019) (1); Hadaya et al. (2021) (1)
		Surgery (#)	2 (2)	Adams et al. (2021) (1); Bath et al. (2019) (1)

Metric factor	Metric characteristic	Unit	Frequency (# phrases (# articles))	References (# phrases)
Survival	Mortality	Deaths (#)	44 (23)	Adams et al. (2021) (1); Adams et al. (2022) (2); Aringhieri et al. (2022) (1); Auerbach et al. (2018) (1); Bretonnier et al. (2020) (1); El Boghdady & Tang (2022) (1); Emond et al. (2022) (2); Glaser et al. (2019) (2); Hadaya et al. (2021) (1); Ibrahim et al. (2022) (3); Kleiner (2019) (2); Kuritzkes et al. (2019) (2); Lear et al. (2017) (1); Newsweek (2022) (1); Nilsson et al. (2018) (1); Olmsted et al. (2022) (7); Pattni et al. (2019) (1); Scali et al. (2020) (2); Sotto et al. (2021) (4); Truong et al. (2021) (2); Ukegjini et al. (2020) (2); Volk (2017) (2); Zingiryan et al. (2017) (2)
		Patient (#)	2 (2)	Adams et al. (2022) (1); Olmsted et al. (2022) (1)
Treatment type	Bed utilisation	Beds (#)	4 (2)	Ferreira & Marques (2019) (2); Moreira et al. (2017) (2)
		Money ($; €)	2 (2)	Patel et al. (2022) (1); Seelen et al. (2018) (1)
		Money ($; €)	37 (18)	Alban et al. (2019) (1); Auerbach et al. (2018) (6); Beaulieu & Bentahar (2021) (1); Bottani et al. (2022) (2); Brüngger et al. (2021) (4); Childers & Maggard-Gibbons (2018) (2); Cossio-Gil et al. (2022) (1); Crocitto et al. (2021) (3); Egeland et al. (2017) (1); Erhard et al. (2018) (1); Ferreira & Marques (2019) (2); Glaser et al. (2019) (4); Glennie et al. (2019) (3); Kleiner (2019) (1); Lai et al. (2022) (2); Lichtenberg (2015) (1); Moons et al. (2019) (1); Moreira et al. (2017) (1)
		Patient (#)	4 (4)	Breuer et al. (2020) (1); Kleiner (2019) (1); Koppka et al. (2018) (1); Pradere et al. (2022) (1)
		Time: stay (days)	3 (3)	Moreira et al. (2017) (1); Patel et al. (2022) (1); Zingiryan et al. (2017) (1)
Waiting list		Money ($; €)	3 (3)	Aringhieri et al. (2022) (1); Saporito et al. (2021) (1); Shehadeh & Padman (2022) (1)
Workforce		Money ($; €)	6 (4)	Erhard et al. (2018) (1); Ferreira & Marques (2019) (1); Glennie et al. (2019) (1); Patel et al. (2022) (2)
		Staff (# Nurses)	2 (2)	Adams et al. (2021) (1); Adams et al. (2022) (1)

Metric factor	Metric characteristic	Unit	Frequency (# phrases (# articles))	References (# phrases)
		Staff (#)	4 (4)	Alban et al. (2019) (1); Bottani et al. (2022) (1); Ferreira & Marques (2019) (1); Koppka et al. (2018) (1)
		Time: Idle time (hours)	2 (2)	Koppka et al. (2018) (1); Zweifel (2021) (1)

Appendix G The metric relations of "optimisation of the OR"

Table Appendix 7: The relations between metrics related to the performance optimisation of the OR, together with the corresponding number of studies and references, including the intermediate links. Between the brackets, the frequency of phrases within the articles are stated. All the metrics that occurred only once (n=1) in all articles or only occurred in one article have been removed.

Cause-metric	Result-metric	Frequency (# phrases (# articles))[1]	References[2]
Bed utilisation	Cancellation	26 (6)	Bovim et al. (2020); Jebali & Diabat (2017); Kheiri et al. (2021); Liu et al. (2019); M'Hallah & Visintin (2019); Schiele et al. (2021)
	Cost	66 (9)	Bam et al. (2017); Bovim et al. (2020); Britt et al. (2021); Fairley et al. (2019); Kheiri et al. (2021); Liu et al. (2019); Schiele et al. (2021); Vancroonenburg et al. (2019); Zhang et al. (2021)
	Patient flow	45 (6)	Abedini et al. (2017); Bovim et al. (2020); Fairley et al. (2019); Kheiri et al. (2021); Liu et al. (2019); Schiele et al. (2021)
	Patient satisfaction	7 (2)	Schiele et al. (2021); Vancroonenburg et al. (2019)
	Policy	7 (2)	Jebali & Diabat (2017); Liu et al. (2019)
	Schedule	12 (2)	Liu et al. (2019); M'Hallah & Visintin (2019)
	Start time	12 (3)	Fairley et al. (2019); Liu et al. (2019); Schiele et al. (2021)
	Surgery duration	5 (2)	Bam et al. (2017); Bovim et al. (2020)
	Surgery volume	12 (3)	Liu et al. (2019); M'Hallah & Visintin (2019); Schiele et al. (2021)
	Surgical performance	7 (2)	Burdett & Kozan (2018); Liu et al. (2019)
	Waiting list	11 (3)	Britt et al. (2021); Kheiri et al. (2021); Vancroonenburg et al. (2019)
Cancellation	Length of stay	11 (4)	Bovim et al. (2020); Jebali & Diabat (2017); Kheiri et al. (2021); M'Hallah & Visintin (2019)
	OR block	25 (3)	Breuer et al. (2020); Erekat et al. (2020); M'Hallah & Visintin (2019)
	Patient flow	16 (7)	Bovim et al. (2020); Coffey et al. (2018); Erekat et al. (2020); Jebali & Diabat (2017); Kheiri et al. (2021); Koppka et al. (2018); M'Hallah & Visintin (2019)
	Start time	19 (3)	Bovim et al. (2020); Erekat et al. (2020); Jebali & Diabat (2017)
Care outcomes	Treatment type	2 (2)	McKevitt et al. (2019); Popat et al. (2018)

Cause-metric	Result-metric	Frequency (# phrases (# articles))[1]	References[2]
Cost	Profit	29 (6)	Cichos et al. (2019); Fairley et al. (2019); Gunna et al. (2017); Liu et al. (2019); Roshanaei & Naderi (2021); Schiele et al. (2021)
	Revenue	47 (2)	Cichos et al. (2019); Coffey et al. (2018)
	Waste	7 (2)	Dyas et al. (2018); Farrelly et al. (2017)
Culture	Safety	24 (2)	Boet et al. (2021); Wakeman & Langham (2018)
Distribution equipment	Cost	21 (8)	Britt et al. (2021); Dyas et al. (2018); Farrelly et al. (2017); Fraifeld et al. (2021); Marchand (2020); Rath et al. (2017); Xiao & Yoogalingam (2021); Yoon et al. (2019)
	Equipment utilisation	25 (5)	Bovim et al. (2020); Burdett & Kozan (2018); Huynh et al. (2019); Marchand (2020); Naderi et al. (2021)
	OR utilisation	7 (4)	Deng et al. (2019); Dyas et al. (2018); Liu et al. (2019); Roshanaei et al. (2020a)
	Schedule	16 (2)	Breuer et al. (2020); Sagnol (2018)
	Shift	6 (4)	Britt et al. (2021); Fu et al. (2021); Marchand (2020); Naderi et al. (2021)
	Staff satisfaction	5 (2)	Breuer et al. (2020); Britt et al. (2021)
	Surgery duration	10 (2)	Britt et al. (2021); Liu et al. (2019)
	Surgery efficiency	7 (2)	Deng et al. (2019); Dyas et al. (2018)
	Surgery volume	7 (2)	Burdett & Kozan (2018); Naderi et al. (2021)
	Workload	6 (2)	Breuer et al. (2020); Coffey et al. (2018)
Equipment type	Cost	43 (9)	Ahmadi et al. (2019); Chasseigne et al. (2020); Cichos et al. (2019); Crosby et al. (2020); Dyas et al. (2018); Farrelly et al. (2017); Fu et al. (2021); Marchand (2020); Yoon et al. (2019)
	Equipment utilisation	31 (4)	Cichos et al. (2019); Dyas et al. (2018); Marchand (2020); Yoon et al. (2019)
	Inventory	12 (3)	Cichos et al. (2019); Dyas et al. (2018); Fu et al. (2021)
	Safety	29 (5)	Cichos et al. (2019); Crosby et al. (2020); Dyas et al. (2018); Farrelly et al. (2017); Fu et al. (2021)
	Staff (health) condition	14 (3)	Crosby et al. (2020); Dyas et al. (2018); Farrelly et al. (2017)
	Start time	7 (2)	Cichos et al. (2019); Dyas et al. (2018)

Cause-metric	Result-metric	Frequency (# phrases (# articles))[1]	References[2]
	Surgery duration	32 (7)	Cichos et al. (2019); Crosby et al. (2020); Dyas et al. (2018); Farrelly et al. (2017); Fu et al. (2021); Marchand (2020); Yoon et al. (2019)
	Surgery efficiency	12 (3)	Dyas et al. (2018); Fu et al. (2021); Marchand (2020)
	Surgical performance	14 (3)	Cichos et al. (2019); Crosby et al. (2020); Yoon et al. (2019)
	Waste	25 (4)	Dyas et al. (2018); Fu et al. (2021); Marchand (2020); Yoon et al. (2019)
	Workforce	7 (2)	Crosby et al. (2020); Farrelly et al. (2017)
	Workload	17 (4)	Cichos et al. (2019); Crosby et al. (2020); Dyas et al. (2018); Farrelly et al. (2017)
Equipment utilisation	Cost	59 (12)	Bam et al. (2017); Bargetto et al. (2019); Boet et al. (2021); Chasseigne et al. (2020); Crosby et al. (2020); Dyas et al. (2018); Fu et al. (2021); Gormley et al. (2017); Huynh et al. (2019); Marchand (2020); Naderi et al. (2021); Rath et al. (2017)
	Inventory	30 (2)	Boet et al. (2021); Huynh et al. (2019)
	Safety	12 (2)	Gormley et al. (2017); Wakeman & Langham (2018)
	Surgery duration	22 (3)	Broe et al. (2021); Dyas et al. (2018); Rath et al. (2017)
	Waste	8 (2)	Ahmadi et al. (2019); Gormley et al. (2017)
Idle time	Cost	23 (5)	Bam et al. (2017); Jung et al. (2019); Liu et al. (2019); Makboul et al. (2022); Xiao & Yoogalingam (2021)
	Staff satisfaction	16 (3)	Bender et al. (2015); Koppka et al. (2018); Kroer et al. (2018)
	Workload	21 (2)	McKevitt et al. (2019); Rath et al. (2017)
Inventory	Cost	21 (5)	Ahmadi et al. (2019); Dyas et al. (2018); Farrelly et al. (2017); Marchand (2020); Popat et al. (2018)
	Distribution equipment	17 (2)	Marchand (2020); Rath et al. (2017)
	Equipment utilisation	15 (3)	Burdett & Kozan (2018); Huynh et al. (2019); Marchand (2020)
	OR utilisation	12 (2)	Breuer et al. (2020); Chasseigne et al. (2020)
	Start time	28 (6)	Ahmadi et al. (2019); Chasseigne et al. (2020); Dyas et al. (2018); Huynh et al. (2019); Kroer et al. (2018); Yoon et al. (2019)
	Surgery efficiency	6 (2)	Breuer et al. (2020); Dyas et al. (2018)
	Surgical performance	11 (2)	Burdett & Kozan (2018); Popat et al. (2018)
	Waste	6 (2)	Ahmadi et al. (2019); Dyas et al. (2018)

Cause-metric	Result-metric	Frequency (# phrases (# articles))[1]	References[2]
	Workload	6 (2)	Ahmadi et al. (2019); Huynh et al. (2019)
Length of stay	Cost	7 (2)	Kheiri et al. (2021); Naderi et al. (2021)
	Patient flow	24 (3)	Fairley et al. (2019); Liu et al. (2019); M'Hallah & Visintin (2019)
Operational performance	Cost	12 (2)	Coffey et al. (2018); Fairley et al. (2019)
OR block	Bed utilisation	16 (2)	Bam et al. (2017); Bovim et al. (2020)
	Idle time	7 (4)	Bam et al. (2017); Naderi et al. (2021); Schiele et al. (2021); Xiao & Yoogalingam (2021)
	Operational performance	6 (3)	Breuer et al. (2020); Burdett & Kozan (2018); Jung et al. (2019)
	OR time	23 (4)	Erekat et al. (2020); Rath et al. (2017); Sagnol (2018); Xiao & Yoogalingam (2021)
	OR utilisation	14 (4)	Erekat et al. (2020); Rath et al. (2017); Xiao & Yoogalingam (2021); Zhang et al. (2021)
	Patient flow	16 (4)	Abedini et al. (2017); Britt et al. (2021); Gunna et al. (2017); Roshanaei et al. (2020a)
	Schedule	31 (2)	Kheiri et al. (2021); Sagnol (2018)
	Staff satisfaction	6 (2)	Bam et al. (2017); Breuer et al. (2020)
	Start time	7 (2)	Rath et al. (2017); Schiele et al. (2021)
	Waiting list	36 (2)	Erekat et al. (2020); Zhang et al. (2021)
OR opening hours	Cost	29 (6)	Deng et al. (2019); Kroer et al. (2018); Rath et al. (2017); Roshanaei & Naderi (2021); Sagnol (2018); Zhang et al. (2021)
	OR time	2 (2)	Koppka et al. (2018); Rath et al. (2017)
	OR utilisation	46 (4)	Britt et al. (2021); Koppka et al. (2018); Kroer et al. (2018); Sagnol (2018)
	Surgery duration	8 (2)	Britt et al. (2021); Sagnol (2018)
OR time	Cost	95 (16)	Abedini et al. (2017); Bam et al. (2017); Bargetto et al. (2019); Bovim et al. (2020); Debats et al. (2021); Deng et al. (2019); Eun et al. (2019); Fairley et al. (2019); Jung et al. (2019); Koppka et al. (2018); Liu et al. (2019); Makboul et al. (2022); Rath et al. (2017); Roshanaei & Naderi (2021); Sagnol (2018); Vancroonenburg et al. (2019)

Cause-metric	Result-metric	Frequency (# phrases (# articles))[1]	References[2]
	OR utilisation	34 (3)	Jung et al. (2019); Koppka et al. (2018); Vancroonenburg et al. (2019)
	Schedule	2 (2)	Rath et al. (2017); Zhang et al. (2020)
	Shift	30 (4)	Breuer et al. (2020); Makboul et al. (2022); Vancroonenburg et al. (2019); Xiao & Yoogalingam (2021)
	Surgery duration	50 (3)	Breuer et al. (2020); Makboul et al. (2022); Vancroonenburg et al. (2019)
	Surgical performance	8 (2)	Bam et al. (2017); Xiao & Yoogalingam (2021)
	Team structure	6 (2)	Breuer et al. (2020); Deng et al. (2019)
	Waiting list	12 (3)	Liu et al. (2019); Vancroonenburg et al. (2019); Xiao & Yoogalingam (2021)
	Workload	17 (2)	Eun et al. (2019); Sagnol (2018)
OR utilisation	Cost	53 (14)	Abedini et al. (2017); Bam et al. (2017); Bargetto et al. (2019); Britt et al. (2021); Broe et al. (2021); Jung et al. (2019); Liu et al. (2019); Makboul et al. (2022); Naderi et al. (2021); Rath et al. (2017); Roshanaei et al. (2020b); Sagnol (2018); Xiao & Yoogalingam (2021); Zhang et al. (2021)
	Equipment utilisation	39 (2)	Bargetto et al. (2019); Zhang et al. (2021)
	Operational performance	23 (5)	Breuer et al. (2020); Erekat et al. (2020); Kroer et al. (2018); Makboul et al. (2022); Roshanaei et al. (2020b)
	OR time	30 (4)	Britt et al. (2021); Fairley et al. (2019); Kroer et al. (2018); Makboul et al. (2022)
	Patient flow	24 (2)	Naderi et al. (2021); Schiele et al. (2021)
	Policy	36 (3)	Jebali & Diabat (2017); Koppka et al. (2018); Liu et al. (2019)
	Profit	6 (2)	Bargetto et al. (2019); Naderi et al. (2021)
	Safety	8 (2)	Bargetto et al. (2019); Schiele et al. (2021)
	Surgery volume	29 (4)	Bovim et al. (2020); Britt et al. (2021); Coffey et al. (2018); Naderi et al. (2021)
	Waiting list	15 (4)	Britt et al. (2021); Liu et al. (2019); Naderi et al. (2021); Xiao & Yoogalingam (2021)
	Workforce	18 (3)	Bargetto et al. (2019); Bender et al. (2015); Sagnol (2018)
Patient (health) condition	Surgery duration	9 (2)	Fairley et al. (2019); Makboul et al. (2022)
	Treatment type	7 (2)	Koppka et al. (2018); Schiele et al. (2021)

Cause-metric	Result-metric	Frequency (# phrases (# articles))[1]	References[2]
Patient flow	Bed utilisation	22 (3)	Debats et al. (2021); Liu et al. (2019); Vancroonenburg et al. (2019)
	Cancellation	7 (2)	Fairley et al. (2019); Vancroonenburg et al. (2019)
	Cost	57 (5)	Crosby et al. (2020); Fairley et al. (2019); Naderi et al. (2021); Popat et al. (2018); Ye et al. (2017)
	OR time	25 (3)	Abedini et al. (2017); Debats et al. (2021); Liu et al. (2019)
	OR utilisation	21 (2)	Abedini et al. (2017); Crosby et al. (2020)
	Patient satisfaction	9 (2)	Fairley et al. (2019); Wakeman & Langham (2018)
	Schedule	13 (3)	Breuer et al. (2020); Kroer et al. (2018); Liu et al. (2019)
	Shift	11 (2)	Burdett & Kozan (2018); Debats et al. (2021)
	Start time	14 (4)	Abedini et al. (2017); Bam et al. (2017); Fairley et al. (2019); Vancroonenburg et al. (2019)
	Surgery volume	39 (3)	Koppka et al. (2018); Liu et al. (2019); Popat et al. (2018)
	Surgical performance	13 (2)	Debats et al. (2021); Scrimshire et al. (2022)
	Waiting list	8 (2)	Abedini et al. (2017); Liu et al. (2019)
	Workforce	7 (2)	Coffey et al. (2018); Debats et al. (2021)
Policy	Bed utilisation	16 (4)	Britt et al. (2021); Debats et al. (2021); Vancroonenburg et al. (2019); Zhang et al. (2019)
	Cancellation	6 (2)	Bovim et al. (2020); Erekat et al. (2020)
	Care outcomes	12 (3)	Makboul et al. (2022); McKevitt et al. (2019); Wakeman & Langham (2018)
	Cost	62 (13)	Cichos et al. (2019); Fairley et al. (2019); Farrelly et al. (2017); Fu et al. (2021); Gormley et al. (2017); Jung et al. (2019); Koppka et al. (2018); Makboul et al. (2022); Roshanaei & Naderi (2021); Xiao & Yoogalingam (2021); Zhang et al. (2019); Zhang et al. (2021); Zhang et al. (2020)
	Culture	12 (2)	Boet et al. (2021); Fraifeld et al. (2021)
	Distribution equipment	10 (6)	Abedini et al. (2017); Britt et al. (2021); Chasseigne et al. (2020); Huynh et al. (2019); Marchand (2020); Wilson et al. (2020)
	Equipment utilisation	24 (4)	Boet et al. (2021); Scrimshire et al. (2022); Xiao & Yoogalingam (2021); Zhang et al. (2020)
	Idle time	7 (2)	Makboul et al. (2022); Xiao & Yoogalingam (2021)

Cause-metric	Result-metric	Frequency (# phrases (# articles))[1]	References[2]
	Inventory	7 (2)	Chasseigne et al. (2020); Huynh et al. (2019)
	Operational performance	8 (4)	Breuer et al. (2020); Britt et al. (2021); Burdett & Kozan (2018); Jung et al. (2019)
	OR design	7 (2)	Broe et al. (2021); Makboul et al. (2022)
	OR opening hours	14 (3)	McKevitt et al. (2019); Roshanaei & Naderi (2021); Sagnol (2018)
	OR time	13 (9)	Abedini et al. (2017); Gunna et al. (2017); Jebali & Diabat (2017); Jung et al. (2019); Makboul et al. (2022); Roshanaei et al. (2020a); Xiao & Yoogalingam (2021); Zhang et al. (2021); Zhang et al. (2020)
	OR utilisation	36 (8)	Britt et al. (2021); Erekat et al. (2020); Koppka et al. (2018); Makboul et al. (2022); Vancroonenburg et al. (2019); Xiao & Yoogalingam (2021); Zhang et al. (2021); Zhang et al. (2020)
	Patient satisfaction	28 (6)	Boet et al. (2021); Erekat et al. (2020); Vancroonenburg et al. (2019); Xiao & Yoogalingam (2021); Zhang et al. (2021); Zhang et al. (2020)
	Profit	21 (5)	Bender et al. (2015); Fairley et al. (2019); Gunna et al. (2017); Roshanaei & Naderi (2021); Vancroonenburg et al. (2019)
	Safety	9 (8)	Boet et al. (2021); Cichos et al. (2019); Gormley et al. (2017); Kroer et al. (2018); Makboul et al. (2022); Scrimshire et al. (2022); Wakeman & Langham (2018); Wilson et al. (2020)
	Shift	19 (3)	Makboul et al. (2022); McKevitt et al. (2019); Xiao & Yoogalingam (2021)
	Staff satisfaction	12 (3)	Bender et al. (2015); Boet et al. (2021); Vancroonenburg et al. (2019)
	Surgery duration	35 (3)	Abedini et al. (2017); Cichos et al. (2019); Makboul et al. (2022)
	Surgery efficiency	17 (4)	Chasseigne et al. (2020); Cichos et al. (2019); Coffey et al. (2018); Xiao & Yoogalingam (2021)
	Surgery volume	19 (4)	Bender et al. (2015); Jung et al. (2019); Liu et al. (2019); Xiao & Yoogalingam (2021)
	Surgical performance	34 (7)	Cichos et al. (2019); Erekat et al. (2020); Huynh et al. (2019); Jung et al. (2019); Kroer et al. (2018); Wilson et al. (2020); Xiao & Yoogalingam (2021)

Cause-metric	Result-metric	Frequency (# phrases (# articles))[1]	References[2]
	Waiting list	12 (9)	Abedini et al. (2017); Bovim et al. (2020); Jung et al. (2019); Liu et al. (2019); McKevitt et al. (2019); Xiao & Yoogalingam (2021); Zhang et al. (2019); Zhang et al. (2021); Zhang et al. (2020)
	Waste	24 (3)	Chasseigne et al. (2020); Cichos et al. (2019); Gormley et al. (2017)
	Workload	14 (3)	Debats et al. (2021); McKevitt et al. (2019); Wilson et al. (2020)
Profit	Policy	30 (2)	Boet et al. (2021); Schiele et al. (2021)
Responsiveness	Bed utilisation	6 (2)	Bovim et al. (2020); Jebali & Diabat (2017)
	Cancellation	11 (3)	Bovim et al. (2020); Jung et al. (2019); Xiao & Yoogalingam (2021)
	Cost	7 (2)	Bargetto et al. (2019); Crosby et al. (2020)
	OR time	25 (4)	Bargetto et al. (2019); Bovim et al. (2020); Kroer et al. (2018); Xiao & Yoogalingam (2021)
	Patient flow	7 (2)	Koppka et al. (2018); Kroer et al. (2018)
	Policy	6 (2)	Bargetto et al. (2019); Xiao & Yoogalingam (2021)
	Schedule	10 (3)	Bargetto et al. (2019); Bovim et al. (2020); Jebali & Diabat (2017)
	Staff (health) condition	6 (2)	Bargetto et al. (2019); Wakeman & Langham (2018)
	Start time	15 (4)	Bargetto et al. (2019); Bovim et al. (2020); Jung et al. (2019); Koppka et al. (2018)
	Surgery duration	12 (3)	Crosby et al. (2020); Makboul et al. (2022); Xiao & Yoogalingam (2021)
	Surgery volume	15 (4)	Bovim et al. (2020); Breuer et al. (2020); Jebali & Diabat (2017); Xiao & Yoogalingam (2021)
	Waiting list	6 (2)	Bargetto et al. (2019); Xiao & Yoogalingam (2021)
Revenue	Profit	45 (2)	Fairley et al. (2019); Gunna et al. (2017)
Safety	Care outcomes	15 (2)	Chasseigne et al. (2020); Scrimshire et al. (2022)
	Cost	48 (10)	Ahmadi et al. (2019); Britt et al. (2021); Dyas et al. (2018); Fairley et al. (2019); Farrelly et al. (2017); Fu et al. (2021); Gormley et al. (2017); Marchand (2020); Rath et al. (2017); Scrimshire et al. (2022)
	Inventory	7 (2)	Huynh et al. (2019); Marchand (2020)
	Patient satisfaction	6 (2)	Boet et al. (2021); Scrimshire et al. (2022) Wilson et al. (2020)
	Shift	13 (2)	Chasseigne et al. (2020); Kroer et al. (2018)

Cause-metric	Result-metric	Frequency (# phrases (# articles))[1]	References[2]
	Treatment type	13 (2)	Farrelly et al. (2017); Schiele et al. (2021)
Schedule	Bed utilisation	24 (7)	Britt et al. (2021); Burdett & Kozan (2018); Debats et al. (2021); Fairley et al. (2019); Kheiri et al. (2021); Roshanaei et al. (2020a); Zhang et al. (2019)
	Cancellation	13 (3)	Breuer et al. (2020); Roshanaei et al. (2020a); Schiele et al. (2021)
	Cost	64 (19)	Bam et al. (2017); Breuer et al. (2020); Britt et al. (2021); Burdett & Kozan (2018); Deng et al. (2019); Dyas et al. (2018); Eun et al. (2019); Farrelly et al. (2017); Gunna et al. (2017); Jebali & Diabat (2017); Liu et al. (2019); Makboul et al. (2022); Naderi et al. (2021); Rath et al. (2017); Roshanaei & Naderi (2021); Xiao & Yoogalingam (2021); Zhang et al. (2019); Zhang et al. (2021); Zhang et al. (2020)
	Idle time	16 (2)	Bam et al. (2017); Schiele et al. (2021)
	Operational performance	6 (3)	Britt et al. (2021); Burdett & Kozan (2018); Xiao & Yoogalingam (2021)
	OR opening hours	24 (3)	Bender et al. (2015); Naderi et al. (2021); Roshanaei et al. (2020b)
	OR time	24 (6)	Bam et al. (2017); Bovim et al. (2020); Breuer et al. (2020); Debats et al. (2021); Rath et al. (2017); Xiao & Yoogalingam (2021)
	OR utilisation	31 (11)	Abedini et al. (2017); Bam et al. (2017); Bovim et al. (2020); Breuer et al. (2020); Britt et al. (2021); Erekat et al. (2020); Jebali & Diabat (2017); Jung et al. (2019); Rath et al. (2017); Roshanaei et al. (2020a); Schiele et al. (2021)
	Patient flow	15 (11)	Abedini et al. (2017); Bam et al. (2017); Britt et al. (2021); Burdett & Kozan (2018); Debats et al. (2021); Fairley et al. (2019); Gunna et al. (2017); Liu et al. (2019); Roshanaei et al. (2020a); Schiele et al. (2021); Ye et al. (2017)
	Patient satisfaction	17 (6)	Breuer et al. (2020); Dyas et al. (2018); Schiele et al. (2021); Xiao & Yoogalingam (2021); Zhang et al. (2021); Zhang et al. (2020)
	Profit	7 (2)	Gunna et al. (2017); Schiele et al. (2021)
	Revenue	15 (2)	Abedini et al. (2017); Bender et al. (2015)
	Safety	9 (3)	Eun et al. (2019); Kroer et al. (2018); Schiele et al. (2021)

Cause-metric	Result-metric	Frequency (# phrases (# articles))[1]	References[2]
	Shift	43 (4)	Bam et al. (2017); Deng et al. (2019); Naderi et al. (2021); Xiao & Yoogalingam (2021)
	Start time	29 (5)	Bam et al. (2017); Breuer et al. (2020); Britt et al. (2021); Dyas et al. (2018); Schiele et al. (2021)
	Surgery duration	25 (5)	Bam et al. (2017); Breuer et al. (2020); Britt et al. (2021); Burdett & Kozan (2018); Naderi et al. (2021)
	Surgery efficiency	7 (4)	Breuer et al. (2020); Burdett & Kozan (2018); Roshanaei et al. (2020a); Xiao & Yoogalingam (2021)
	Surgery volume	22 (6)	Abedini et al. (2017); Bender et al. (2015); Bovim et al. (2020); Britt et al. (2021); Burdett & Kozan (2018); Naderi et al. (2021)
	Waiting list	11 (8)	Britt et al. (2021); Gunna et al. (2017); Liu et al. (2019); McKevitt et al. (2019); Roshanaei et al. (2020a); Xiao & Yoogalingam (2021); Ye et al. (2017); Zhang et al. (2019)
	Workload	3 (3)	Ahmadi et al. (2019); Burdett & Kozan (2018); Debats et al. (2021)
Shift	Cost	97 (19)	Ahmadi et al. (2019); Bam et al. (2017); Bender et al. (2015); Britt et al. (2021); Chasseigne et al. (2020); Coffey et al. (2018); Debats et al. (2021); Dyas et al. (2018); Erekat et al. (2020); Farrelly et al. (2017); Fu et al. (2021); Jung et al. (2019); Kroer et al. (2018); Makboul et al. (2022); Popat et al. (2018); Roshanaei & Naderi (2021); Sagnol (2018); Vancroonenburg et al. (2019); Xiao & Yoogalingam (2021)
	Staff satisfaction	50 (4)	Bender et al. (2015); Crosby et al. (2020); Koppka et al. (2018); Kroer et al. (2018)
	Surgery duration	32 (4)	Deng et al. (2019); Farrelly et al. (2017); Fu et al. (2021); Ye et al. (2017)
	Workload	19 (5)	Crosby et al. (2020); Farrelly et al. (2017); McKevitt et al. (2019); Rath et al. (2017); Sagnol (2018)
Staff (health) condition	Safety	6 (2)	Breuer et al. (2020); Erestam et al. (2021)
	Staff performance	24 (3)	Erestam et al. (2021); Makboul et al. (2022); Wakeman & Langham (2018)
	Staff satisfaction	9 (2)	Crosby et al. (2020); Erestam et al. (2021)
	Care outcomes	2 (2)	Britt et al. (2021); Farrelly et al. (2017)

Cause-metric	Result-metric	Frequency (# phrases (# articles))[1]	References[2]
	Cost	22 (7)	Chasseigne et al. (2020); Cichos et al. (2019); Coffey et al. (2018); Fairley et al. (2019); Fraifeld et al. (2021); Fu et al. (2021); Popat et al. (2018)
	Safety	25 (5)	Ahmadi et al. (2019); Chasseigne et al. (2020); Erestam et al. (2021); Makboul et al. (2022); Wakeman & Langham (2018)
	Surgery duration	83 (6)	Broe et al. (2021); Chasseigne et al. (2020); Fairley et al. (2019); Makboul et al. (2022); Sagnol (2018); Ye et al. (2017)
	Surgical performance	33 (2)	Boet et al. (2021); Dyas et al. (2018)
Start time	Cancellation	6 (2)	Abedini et al. (2017); Coffey et al. (2018)
	Cost	17 (4)	Bargetto et al. (2019); Deng et al. (2019); Jebali & Diabat (2017); Makboul et al. (2022)
	Distribution equipment	6 (2)	Breuer et al. (2020); Cichos et al. (2019)
	OR time	8 (2)	Abedini et al. (2017); Rath et al. (2017)
	OR utilisation	14 (3)	Abedini et al. (2017); Breuer et al. (2020); Coffey et al. (2018)
	Patient flow	12 (3)	Coffey et al. (2018); Koppka et al. (2018); Kroer et al. (2018)
	Safety	10 (3)	Ahmadi et al. (2019); Bam et al. (2017); Yoon et al. (2019)
	Shift	20 (3)	Breuer et al. (2020); Kroer et al. (2018); Makboul et al. (2022)
	Surgery efficiency	15 (4)	Bender et al. (2015); Breuer et al. (2020); Coffey et al. (2018); Debats et al. (2021)
	Waiting list	10 (2)	Breuer et al. (2020); Coffey et al. (2018)
Surgery duration	Bed utilisation	12 (3)	Coffey et al. (2018); Debats et al. (2021); M'Hallah & Visintin (2019)
	Cost	28 (5)	Dyas et al. (2018); Naderi et al. (2021); Popat et al. (2018); Roshanaei & Naderi (2021); Zhang et al. (2020)
	Idle time	19 (2)	Koppka et al. (2018); Makboul et al. (2022)
	OR block	42 (7)	Abedini et al. (2017); Bam et al. (2017); Eun et al. (2019); Roshanaei et al. (2020a); Sagnol (2018); Schiele et al. (2021); Zhang et al. (2020)
	OR time	21 (9)	Bargetto et al. (2019); Broe et al. (2021); Eun et al. (2019); Koppka et al. (2018); Makboul et al. (2022); Rath et al. (2017); Sagnol (2018); Ye et al. (2017); Zhang et al. (2020)
	OR utilisation	72 (4)	Breuer et al. (2020); Coffey et al. (2018); Fu et al. (2021); Zhang et al. (2021)

Cause-metric	Result-metric	Frequency (# phrases (# articles))[1]	References[2]
	Patient flow	25 (4)	Debats et al. (2021); Fu et al. (2021); Liu et al. (2019); Ye et al. (2017)
	Safety	16 (2)	Bargetto et al. (2019); Kroer et al. (2018)
	Schedule	39 (4)	Bam et al. (2017); Bargetto et al. (2019); Rath et al. (2017); Zhang et al. (2020)
	Shift	33 (3)	Dyas et al. (2018); Makboul et al. (2022); Roshanaei et al. (2020a)
	Staff performance	25 (2)	Broe et al. (2021); Erestam et al. (2021)
	Surgery efficiency	38 (6)	Abedini et al. (2017); Breuer et al. (2020); Gunna et al. (2017); Makboul et al. (2022); M'Hallah & Visintin (2019); Roshanaei et al. (2020a)
	Waiting list	9 (2)	Sagnol (2018); Zhang et al. (2021)
	Workload	9 (2)	Debats et al. (2021); Sagnol (2018)
Surgery efficiency	Cost	17 (3)	Jung et al. (2019); Liu et al. (2019); Vancroonenburg et al. (2019)
	OR time	15 (2)	Jebali & Diabat (2017); Xiao & Yoogalingam (2021)
Surgical performance	Care outcomes	29 (2)	Burdett & Kozan (2018); Scrimshire et al. (2022)
	Surgery volume	33 (2)	Broe et al. (2021); Scrimshire et al. (2022)
Surgery volume	Bed utilisation	20 (5)	Abedini et al. (2017); Bovim et al. (2020); Debats et al. (2021); Jebali & Diabat (2017); Sagnol (2018)
	Cost	43 (9)	Bam et al. (2017); Burdett & Kozan (2018); Erekat et al. (2020); Fu et al. (2021); Jebali & Diabat (2017); Jung et al. (2019); Liu et al. (2019); Popat et al. (2018); Vancroonenburg et al. (2019)
	OR block	11 (2)	Eun et al. (2019); Jebali & Diabat (2017)
	OR time	12 (3)	Bovim et al. (2020); Liu et al. (2019); Vancroonenburg et al. (2019)
	Patient flow	7 (2)	Kheiri et al. (2021); Vancroonenburg et al. (2019)
	Policy	9 (2)	Koppka et al. (2018); Xiao & Yoogalingam (2021)
	Surgical performance	11 (2)	Burdett & Kozan (2018); Xiao & Yoogalingam (2021)
	Waiting list	7 (2)	Liu et al. (2019); Xiao & Yoogalingam (2021)
	Workload	25 (3)	Breuer et al. (2020); Burdett & Kozan (2018); Debats et al. (2021)
Team structure	Cost	7 (2)	Broe et al. (2021); Popat et al. (2018)
	Staff performance	21 (2)	Farrelly et al. (2017); Wakeman & Langham (2018)
	Staff satisfaction	6 (2)	Breuer et al. (2020); Chasseigne et al. (2020)
	Surgical performance	12 (3)	Chasseigne et al. (2020); Popat et al. (2018); Wakeman & Langham (2018)

Cause-metric	Result-metric	Frequency (# phrases (# articles))[1]	References[2]
Teamwork	Culture	6 (2)	Boet et al. (2021); Wakeman & Langham (2018)
	Safety	7 (2)	Erestam et al. (2021); Wakeman & Langham (2018)
	Staff (health) condition	11 (2)	Erestam et al. (2021); Wakeman & Langham (2018)
	Staff performance	36 (5)	Chasseigne et al. (2020); Coffey et al. (2018); Huynh et al. (2019); Popat et al. (2018); Wakeman & Langham (2018)
	Team structure	7 (2)	Broe et al. (2021); Wakeman & Langham (2018)
	Workload	7 (2)	Huynh et al. (2019); Wakeman & Langham (2018)
Treatment type	Bed utilisation	7 (2)	Burdett & Kozan (2018); M'Hallah & Visintin (2019)
	Care outcomes	7 (2)	McKevitt et al. (2019); Popat et al. (2018)
	Cost	14 (4)	Jung et al. (2019); Kheiri et al. (2021); McKevitt et al. (2019); Popat et al. (2018)
	Equipment utilisation	9 (2)	Kroer et al. (2018); Rath et al. (2017)
	OR design	7 (2)	Koppka et al. (2018); Rath et al. (2017)
	Patient satisfaction	8 (2)	McKevitt et al. (2019); Popat et al. (2018)
	Surgery duration	25 (4)	Fairley et al. (2019); Makboul et al. (2022); Rath et al. (2017); Roshanaei et al. (2020a)
Waiting list	Care outcomes	6 (2)	Britt et al. (2021); McKevitt et al. (2019)
	Cost	19 (5)	Bam et al. (2017); Bargetto et al. (2019); Britt et al. (2021); Vancroonenburg et al. (2019); Xiao & Yoogalingam (2021)
	OR utilisation	9 (3)	Bovim et al. (2020); Vancroonenburg et al. (2019); Xiao & Yoogalingam (2021)
	Patient satisfaction	16 (4)	Britt et al. (2021); Coffey et al. (2018); Vancroonenburg et al. (2019); Xiao & Yoogalingam (2021)
	Safety	15 (4)	Breuer et al. (2020); Britt et al. (2021); Eun et al. (2019); Vancroonenburg et al. (2019)
Waste	Cost	17 (4)	Fraifeld et al. (2021); Fu et al. (2021); Gormley et al. (2017); Yoon et al. (2019)
Workforce	Patient flow	13 (2)	Debats et al. (2021); Fairley et al. (2019)
Workload	Care outcomes	12 (2)	Debats et al. (2021); Roshanaei et al. (2020b)

Cause-metric	Result-metric	Frequency (# phrases (# articles))[1]	References[2]
	Staff (health) condition	2 (2)	Erestam et al. (2021); Roshanaei et al. (2020b)
	Surgical performance	4 (2)	Debats et al. (2021); Roshanaei et al. (2020b)

[1] This are the number of phrases is the number of causalities, including the intermediate links. The number of references is the articles that directly mentioned the causality.

[2] The number of phrases per article is not mentioned, due to that many causalities are including intermediate links.

Appendix H Generalised metric relations of the performance optimisation of the OR

Table Appendix 8: The generalised metrics with its causal metrics related to the performance optimisation of the OR, together with the corresponding number of studies and references. Between the brackets, the frequency of phrases within the articles are stated. All the metrics that occurred only once (n=1) in all articles or only occurred in one article have been removed.

Cause-metric	Result-metric	Frequency (# phrases (# articles))[1]	References[2]
Equipment	Equipment	55 (13)	Ahmadi et al. (2019); Boet et al. (2021); Bovim et al. (2020); Burdett & Kozan (2018); Cichos et al. (2019); Dyas et al. (2018); Fu et al. (2021); Gormley et al. (2017); Huynh et al. (2019); Marchand (2020); Naderi et al. (2021); Rath et al. (2017); Yoon et al. (2019)
	Finance	41 (20)	Ahmadi et al. (2019); Bam et al. (2017); Bargetto et al. (2019); Boet et al. (2021); Britt et al. (2021); Chasseigne et al. (2020); Cichos et al. (2019); Crosby et al. (2020); Dyas et al. (2018); Farrelly et al. (2017); Fraifeld et al. (2021); Fu et al. (2021); Gormley et al. (2017); Huynh et al. (2019); Marchand (2020); Naderi et al. (2021) ; Popat et al. (2018); Rath et al. (2017); Xiao & Yoogalingam (2021); Yoon et al. (2019)
	Operational performance	36 (7)	Cichos et al. (2019); Crosby et al. (2020); Dyas et al. (2018); Farrelly et al. (2017); Fu et al. (2021); Gormley et al. (2017); Wakeman & Langham (2018)
	Patients	18 (2)	Burdett & Kozan (2018); Naderi et al. (2021)
	Result	25 (5)	Burdett & Kozan (2018); Cichos et al. (2019); Crosby et al. (2020); Popat et al. (2018); Yoon et al. (2019)
	Schedule	70 (12)	Ahmadi et al. (2019); Breuer et al. (2020); Chasseigne et al. (2020); Cichos et al. (2019); Deng et al. (2019); Dyas et al. (2018); Huynh et al. (2019); Kroer et al. (2018); Liu et al. (2019); Roshanaei et al. (2020a); Sagnol (2018); Yoon et al. (2019)
	Staff	61 (12)	Ahmadi et al. (2019); Breuer et al. (2020); Britt et al. (2021); Cichos et al. (2019); Coffey et al. (2018); Crosby et al. (2020); Dyas et al. (2018); Farrelly et al. (2017); Fu et al. (2021); Huynh et al. (2019); Marchand (2020); Naderi et al. (2021)

Cause-metric	Result-metric	Frequency (# phrases (# articles))[1]	References[2]
	Surgery	89 (13)	Breuer et al. (2020); Britt et al. (2021); Broe et al. (2021); Cichos et al. (2019); Crosby et al. (2020); Deng et al. (2019); Dyas et al. (2018); Farrelly et al. (2017); Fu et al. (2021); Liu et al. (2019); Marchand (2020); Rath et al. (2017); Yoon et al. (2019)
Finance	Equipment	7 (2)	Dyas et al. (2018); Farrelly et al. (2017)
	Finance	121 (7)	Cichos et al. (2019); Coffey et al. (2018); Fairley et al. (2019); Gunna et al. (2017); Liu et al. (2019); Roshanaei & Naderi (2021); Schiele et al. (2021)
	Operational performance	30 (2)	Boet et al. (2021); Schiele et al. (2021)
Operational performance	Equipment	79 (14)	Abedini et al. (2017); Boet et al. (2021); Britt et al. (2021); Broe et al. (2021); Chasseigne et al. (2020); Cichos et al. (2019); Gormley et al. (2017); Huynh et al. (2019); Makboul et al. (2022); Marchand (2020); Scrimshire et al. (2022); Wilson et al. (2020); Xiao & Yoogalingam (2021); Zhang et al. (2020)
	Finance	150 (25)	Ahmadi et al. (2019); Bargetto et al. (2019); Bender et al. (2015); Britt et al. (2021); Cichos et al. (2019); Coffey et al. (2018); Crosby et al. (2020); Dyas et al. (2018); Fairley et al. (2019); Farrelly et al. (2017); Fu et al. (2021); Gormley et al. (2017); Gunna et al. (2017); Jung et al. (2019); Koppka et al. (2018); Makboul et al. (2022); Marchand (2020); Rath et al. (2017); Roshanaei & Naderi (2021); Scrimshire et al. (2022); Vancroonenburg et al. (2019); Xiao & Yoogalingam (2021); Zhang et al. (2019); Zhang et al. (2021); Zhang et al. (2020)
	Operational performance	23 (14)	Bargetto et al. (2019); Boet et al. (2021); Breuer et al. (2020); Britt et al. (2021); Burdett & Kozan (2018); Cichos et al. (2019); Gormley et al. (2017); Jung et al. (2019); Kroer et al. (2018); Makboul et al. (2022); Scrimshire et al. (2022); Wakeman & Langham (2018); Wilson et al. (2020); Xiao & Yoogalingam (2021)
	Patients	97 (18)	Bender et al. (2015); Boet et al. (2021); Bovim et al. (2020); Breuer et al. (2020); Britt et al. (2021); Debats et al. (2021); Erekat et al. (2020); Jebali & Diabat (2017); Jung et al. (2019); Koppka et al. (2018); Kroer et al. (2018); Liu et al. (2019); Scrimshire et al. (2022); Vancroonenburg et al.

Cause-metric	Result-metric	Frequency (# phrases (# articles))[1]	References[2]
			(2019); Xiao & Yoogalingam (2021); Zhang et al. (2019); Zhang et al. (2021); Zhang et al. (2020)
	Result	61 (12)	Bam et al. (2017); Erekat et al. (2020); Huynh et al. (2019); Jung et al. (2019); Kroer et al. (2018); Makboul et al. (2022); McKevitt et al. (2019); Scrimshire et al. (2022); Wakeman & Langham (2018); Wilson et al. (2020); Xiao & Yoogalingam (2021)
	Schedule	148 (21)	Abedini et al. (2017); Bargetto et al. (2019); Bovim et al. (2020); Britt et al. (2021); Erekat et al. (2020); Gunna et al. (2017); Jebali & Diabat (2017); Jung et al. (2019); Koppka et al. (2018); Kroer et al. (2018); Liu et al. (2019); Makboul et al. (2022); McKevitt et al. (2019); Roshanaei et al. (2020a); Roshanaei & Naderi (2021); Sagnol (2018); Vancroonenburg et al. (2019); Xiao & Yoogalingam (2021); Zhang et al. (2019); Zhang et al. (2021); Zhang et al. (2020)
	Staff	83 (13)	Bargetto et al. (2019); Bender et al. (2015); Boet et al. (2021); Chasseigne et al. (2020); Debats et al. (2021); Fraifeld et al. (2021); Kroer et al. (2018); Makboul et al. (2022); McKevitt et al. (2019); Vancroonenburg et al. (2019); Wakeman & Langham (2018); Wilson et al. (2020); Xiao & Yoogalingam (2021)
	Surgery	77 (9)	Abedini et al. (2017); Chasseigne et al. (2020); Cichos et al. (2019); Coffey et al. (2018); Crosby et al. (2020); Farrelly et al. (2017); Makboul et al. (2022); Schiele et al. (2021); Xiao & Yoogalingam (2021)
Patients	Finance	173 (18)	Bam et al. (2017); Bovim et al. (2020); Britt et al. (2021); Burdett & Kozan (2018); Crosby et al. (2020); Erekat et al. (2020); Fairley et al. (2019); Fu et al. (2021); Jebali & Diabat (2017); Jung et al. (2019); Kheiri et al. (2021); Liu et al. (2019); Naderi et al. (2021); Popat et al. (2018); Schiele et al. (2021); Vancroonenburg et al. (2019); Ye et al. (2017); Zhang et al. (2021)
	Operational performance	16 (4)	Jebali & Diabat (2017); Koppka et al. (2018); Liu et al. (2019); Xiao & Yoogalingam (2021)

Cause-metric	Result-metric	Frequency (# phrases (# articles))[1]	References[2]
	Patients	185 (14)	Abedini et al. (2017); Bovim et al. (2020); Debats et al. (2021); Fairley et al. (2019); Jebali & Diabat (2017); Kheiri et al. (2021); Koppka et al. (2018); Liu et al. (2019); M'Hallah & Visintin (2019); Popat et al. (2018); Sagnol (2018); Schiele et al. (2021); Vancroonenburg et al. (2019); Wakeman & Langham (2018)
	Result	14 (5)	Burdett & Kozan (2018); Debats et al. (2021); Liu et al. (2019); Scrimshire et al. (2022); Xiao & Yoogalingam (2021)
	Schedule	179 (17)	Abedini et al. (2017); Bam et al. (2017); Bovim et al. (2020); Breuer et al. (2020); Britt et al. (2021); Crosby et al. (2020); Debats et al. (2021); Eun et al. (2019); Fairley et al. (2019); Jebali & Diabat (2017); Kheiri et al. (2021); Kroer et al. (2018); Liu et al. (2019); M'Hallah & Visintin (2019); Schiele et al. (2021); Vancroonenburg et al. (2019); Xiao & Yoogalingam (2021)
	Staff	43 (4)	Breuer et al. (2020); Burdett & Kozan (2018); Coffey et al. (2018); Debats et al. (2021)
	Surgery	21 (6)	Bam et al. (2017); Bovim et al. (2020); Fairley et al. (2019); Koppka et al. (2018); Makboul et al. (2022); Schiele et al. (2021)
Result	Patients	33 (2)	Broe et al. (2021); Scrimshire et al. (2022)
	Result	29 (2)	Burdett & Kozan (2018); Scrimshire et al. (2022)
	Surgery	2 (2)	McKevitt et al. (2019); Popat et al. (2018)
Schedule	Equipment	45 (4)	Bargetto et al. (2019); Breuer et al. (2020); Cichos et al. (2019); Zhang et al. (2021)
	Finance	305 (33)	Abedini et al. (2017); Bam et al. (2017); Bargetto et al. (2019); Bender et al. (2015); Bovim et al. (2020); Breuer et al. (2020); Britt et al. (2021); Broe et al. (2021); Burdett & Kozan (2018); Debats et al. (2021); Deng et al. (2019); Dyas et al. (2018); Eun et al. (2019); Fairley et al. (2019); Farrelly et al. (2017); Gunna et al. (2017); Jebali & Diabat (2017); Jung et al. (2019); Koppka et al. (2018); Kroer et al. (2018); Liu et al. (2019); Makboul et al. (2022); Naderi et al. (2021); Rath et al. (2017); Roshanaei et al. (2020b); Roshanaei & Naderi (2021); Sagnol (2018); Schiele et al.

Cause-metric	Result-metric	Frequency (# phrases (# articles))[1]	References[2]
			(2021); Vancroonenburg et al. (2019); Xiao & Yoogalingam (2021); Zhang et al. (2019); Zhang et al. (2021); Zhang et al. (2020)
	Operational performance	113 (19)	Ahmadi et al. (2019); Bam et al. (2017); Bargetto et al. (2019); Breuer et al. (2020); Britt et al. (2021); Burdett & Kozan (2018); Erekat et al. (2020); Eun et al. (2019); Jebali & Diabat (2017); Jung et al. (2019); Koppka et al. (2018); Kroer et al. (2018); Liu et al. (2019); Makboul et al. (2022); Roshanaei et al. (2020b); Schiele et al. (2021); Vancroonenburg et al. (2019); Xiao & Yoogalingam (2021); Yoon et al. (2019)
	Patients	218 (28)	Abedini et al. (2017); Bam et al. (2017); Bender et al. (2015); Bovim et al. (2020); Breuer et al. (2020); Britt et al. (2021); Burdett & Kozan (2018); Coffey et al. (2018); Debats et al. (2021); Dyas et al. (2018); Erekat et al. (2020); Fairley et al. (2019); Gunna et al. (2017); Jebali & Diabat (2017); Kheiri et al. (2021); Koppka et al. (2018); Kroer et al. (2018); Liu et al. (2019); M'Hallah & Visintin (2019); Naderi et al. (2021); Roshanaei et al. (2020a); Schiele et al. (2021); Vancroonenburg et al. (2019); Xiao & Yoogalingam (2021); Ye et al. (2017); Zhang et al. (2019); Zhang et al. (2021); Zhang et al. (2020)
	Result	14 (4)	Bam et al. (2017); Britt et al. (2021); McKevitt et al. (2019); Xiao & Yoogalingam (2021)
	Schedule	475 (33)	Abedini et al. (2017); Bam et al. (2017); Bender et al. (2015); Bovim et al. (2020); Breuer et al. (2020); Britt et al. (2021) Britt et al. (2021); Coffey et al. (2018); Debats et al. (2021); Dyas et al. (2018); Erekat et al. (2020); Fairley et al. (2019); Gunna et al. (2017); Jebali & Diabat (2017); Jung et al. (2019); Kheiri et al. (2021); Koppka et al. (2018); Kroer et al. (2018); Liu et al. (2019); Makboul et al. (2022); McKevitt et al. (2019); M'Hallah & Visintin (2019); Naderi et al. (2021); Rath et al. (2017); Roshanaei et al. (2020a); Roshanaei et al. (2020b); Sagnol (2018); Schiele et al. (2021); Vancroonenburg et al. (2019); Xiao & Yoogalingam (2021); Ye et al. (2017); Zhang et al. (2019); Zhang et al. (2021); Zhang et al. (2020)

Cause-metric	Result-metric	Frequency (# phrases (# articles))[1]	References[2]
Staff	Staff	166 (16)	Ahmadi et al. (2019); Bam et al. (2017); Bargetto et al. (2019); Bender et al. (2015); Breuer et al. (2020); Burdett & Kozan (2018); Debats et al. (2021); Deng et al. (2019); Eun et al. (2019); Kroer et al. (2018); Makboul et al. (2022); Naderi et al. (2021); Sagnol (2018); Schiele et al. (2021); Vancroonenburg et al. (2019); Xiao & Yoogalingam (2021)
	Surgery	105 (13)	Bam et al. (2017); Bender et al. (2015); Breuer et al. (2020); Britt et al. (2021); Burdett & Kozan (2018); Coffey et al. (2018); Debats et al. (2021); Makboul et al. (2022); Naderi et al. (2021); Roshanaei et al. (2020a); Sagnol (2018); Vancroonenburg et al. (2019); Xiao & Yoogalingam (2021)
	Finance	149 (24)	Ahmadi et al. (2019); Bam et al. (2017); Bender et al. (2015); Britt et al. (2021); Broe et al. (2021); Chasseigne et al. (2020); Cichos et al. (2019); Coffey et al. (2018); Debats et al. (2021); Dyas et al. (2018); Erekat et al. (2020); Fairley et al. (2019); Farrelly et al. (2017); Fraifeld et al. (2021); Fu et al. (2021); Jung et al. (2019); Kroer et al. (2018); Liu et al. (2019); Makboul et al. (2022); Popat et al. (2018); Roshanaei & Naderi (2021); Sagnol (2018); Vancroonenburg et al. (2019); Xiao & Yoogalingam (2021)
	Operational performance	113 (7)	Ahmadi et al. (2019); Boet et al. (2021); Breuer et al. (2020); Chasseigne et al. (2020); Erestam et al. (2021); Makboul et al. (2022); Wakeman & Langham (2018)
	Patients	13 (2)	Debats et al. (2021); Fairley et al. (2019)
	Result	63 (9)	Boet et al. (2021); Britt et al. (2021); Chasseigne et al. (2020); Debats et al. (2021); Dyas et al. (2018); Farrelly et al. (2017); Popat et al. (2018); Roshanaei et al. (2020b); Wakeman & Langham (2018)
	Staff	235 (19)	Bender et al. (2015); Boet et al. (2021); Breuer et al. (2020); Broe et al. (2021); Chasseigne et al. (2020); Coffey et al. (2018); Crosby et al. (2020); Erestam et al. (2021); Farrelly et al. (2017); Huynh et al. (2019); Koppka et al. (2018); Kroer et al. (2018); Makboul et al. (2022); McKevitt et al. (2019); Popat et al. (2018); Rath et al. (2017); Roshanaei et al. (2020b); Sagnol (2018); Wakeman & Langham (2018)

Cause-metric	Result-metric	Frequency (# phrases (# articles))[1]	References[2]
	Surgery	95 (9)	Broe et al. (2021); Chasseigne et al. (2020); Deng et al. (2019); Fairley et al. (2019); Farrelly et al. (2017); Fu et al. (2021); Makboul et al. (2022); Sagnol (2018); Ye et al. (2017)
Surgery	Equipment	16 (3)	Koppka et al. (2018); Kroer et al. (2018); Rath et al. (2017)
	Finance	59 (10)	Dyas et al. (2018); Jung et al. (2019); Kheiri et al. (2021); Liu et al. (2019); McKevitt et al. (2019); Naderi et al. (2021); Popat et al. (2018); Roshanaei & Naderi (2021); Vancroonenburg et al. (2019); Zhang et al. (2020)
	Operational performance	16 (2)	Bargetto et al. (2019); Kroer et al. (2018)
	Patients	52 (9)	Burdett & Kozan (2018); Coffey et al. (2018); Debats et al. (2021); Fu et al. (2021); Liu et al. (2019); McKevitt et al. (2019); M'Hallah & Visintin (2019); Popat et al. (2018); Ye et al. (2017)
	Result	7 (2)	McKevitt et al. (2019); Popat et al. (2018)
	Schedule	198 (19)	Abedini et al. (2017); Bam et al. (2017); Bargetto et al. (2019); Breuer et al. (2020); Broe et al. (2021); Coffey et al. (2018); Eun et al. (2019); Fu et al. (2021); Jebali & Diabat (2017); Koppka et al. (2018); Makboul et al. (2022); Rath et al. (2017); Roshanaei et al. (2020a); Sagnol (2018); Schiele et al. (2021); Xiao & Yoogalingam (2021); Ye et al. (2017); Zhang et al. (2021); Zhang et al. (2020)
	Staff	86 (8)	Broe et al. (2021); Debats et al. (2021); Dyas et al. (2018); Erestam et al. (2021); Koppka et al. (2018); Makboul et al. (2022); Roshanaei et al. (2020a); Sagnol (2018)
	Surgery	63 (8)	Abedini et al. (2017); Breuer et al. (2020); Fairley et al. (2019); Gunna et al. (2017); Makboul et al. (2022); M'Hallah & Visintin (2019); Rath et al. (2017); Roshanaei et al. (2020a)

[1] This are the number of phrases is the number of causalities, including the intermediate links. The number of references is the articles that directly mentioned the causality.

[2] The number of phrases per article is not mentioned, due to that many causalities are including intermediate links.

Performance Operating Room Counselling (PORC-) tool

Decision-support tool for (the optimisation of) the performance of the OR

Version 1.0

Guidance manual
Date of this version: 25 October 2022

By questions or problems, contact Karlijn E. van Beekum:
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Purpose

The tool has as goal to support the decision-making of healthcare professionals (HCPs) on innovations for the operating room (OR) by counselling in creating a holistic view of the performance objective and its metrics. This holistic view is required since many stakeholders are involved in (the optimisation of) the performance of the OR and have different perspectives. Therefore, it is important that the decisions will be based on information acknowledging the whole OR.

To compensate for the lack of holistic view and enable and standardise the decision-making, the tool provides insight in the performance objective and its metrics. The tool aims to cover-up the blind spots of the HCPs.

The tool can help to gather information more easily, since the tool provides a clear, structural overview of the metrics and causalities of the OR. This contributes to a more insight into the OR organisation and goals before the decision-making of the HCP, leading to a well-informed decision on the OR and standardisation of this process.

TYPES OF QUESTIONS ADDRESSED

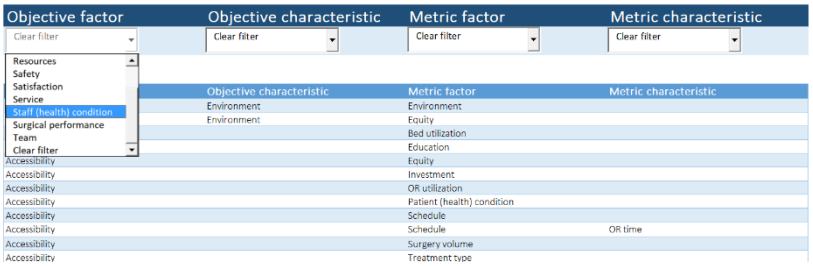
- Interest: establishing the interest of the situation or problem on (the optimisation of) the performance of the OR.
  "What is the interest within the OR?"
- Problem choice: establishing the (most concerning) problem with (the optimisation of) the performance of the OR.
  "Which problem should be addressed (first)?"
- Product choice: establishing the effects of an innovation on (the optimisation of) the performance of the OR.
  "What is the value of choosing this innovation/product?"
- Solution choice: establishing the effects of a solution on (the optimisation of) the performance of the OR.
  "What is the value of this solution?"

Structure

The Performance Operating Room Counselling (PORC-)tool is an Excel-based tool. The tool provides the related objectives or metrics, when a metric or objective is selected and the causalities between metrics.

The steps of the tool are provided in a flowchart and the data from the objectives and metrics are presented in a matrix table.

The tool has an interactive function, whereby the user can select one code (objective factor, objective characteristic, metric factor or metric characteristic). All the relations of this code will be presented and the non-related relations will be hidden.

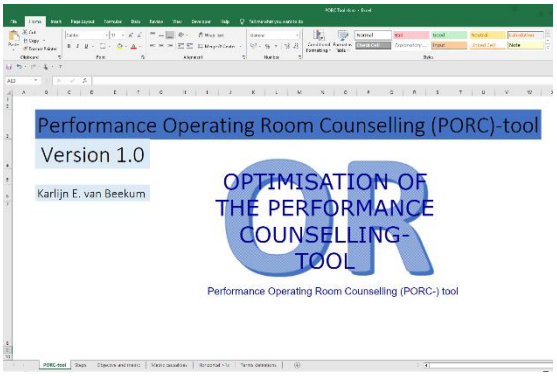


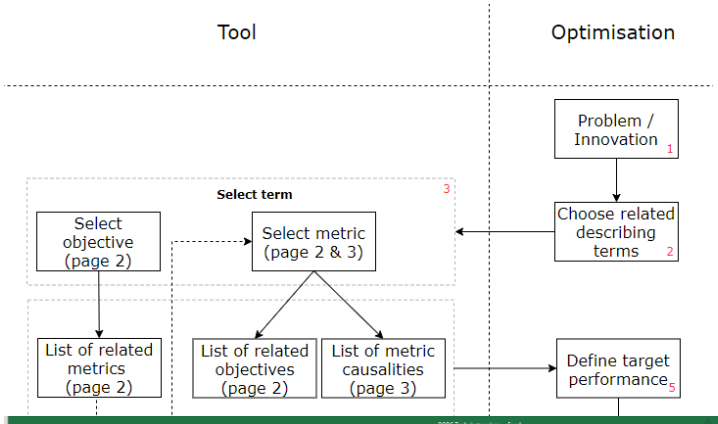
The tool provides a list of all the related objectives or metrics, whenever one metric or objective is selected. It can be used on different levels, since there are opportunities to select an objective factor, objective characteristic, metric factor and metric characteristic. It is important to realise a more specified term leads to more specific causalities are provided by the tool. Whenever the user has a broad term of interest, there will be found a high variety in relations, which does not help with creating the target performance. Next to that, the tool a work reversibly, since it can provide related metrics if the objective is selected, or related objectives when the metric is selected.

Design

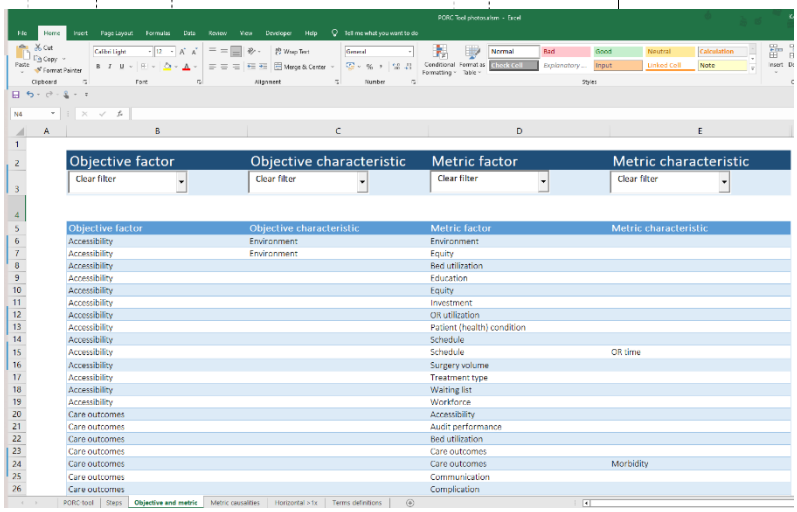
The tool consists of six pages:

Page 1 The introduction page with a title, logo and the name of the developer.

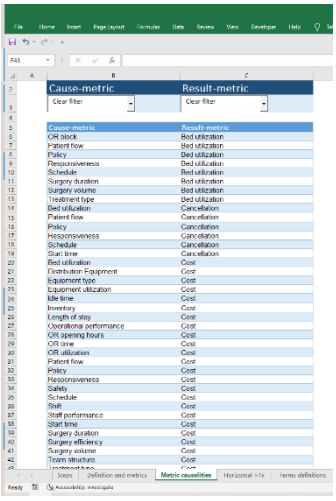




PAGE 2 A short description of the decision-making process and the steps that are required to use the tool.

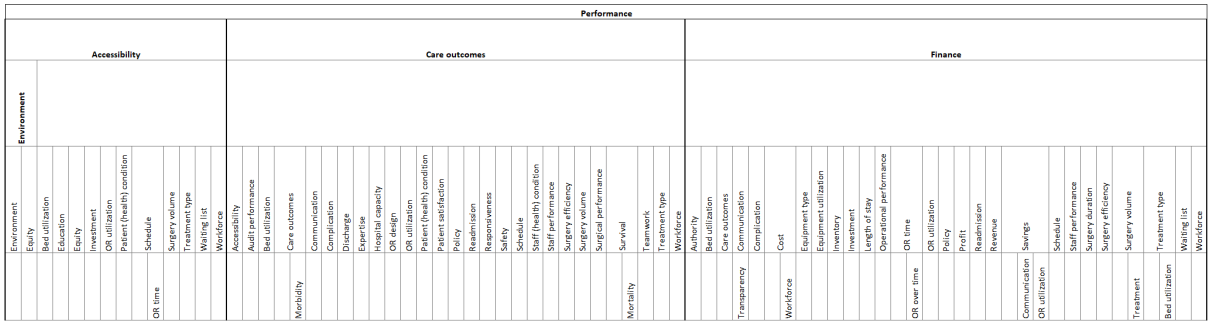


PAGE 3 An interactive overview of the objectives and metrics of the performance optimisation of the OR, whereby the relations between the objectives or metrics can be shown.

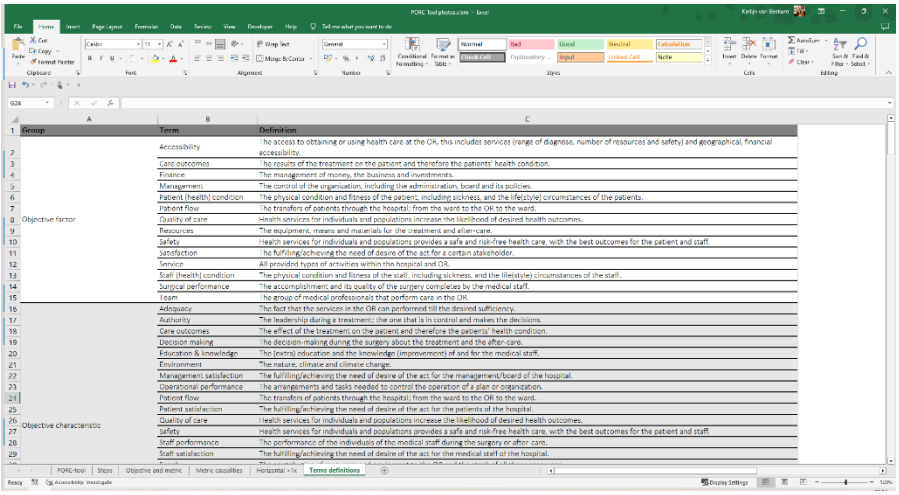


PAGE 4 An interactive overview of the causalities of the metrics of the performance optimisation of the OR.

PAGE 5 An overview of all the relations between objectives and metrics of the performance optimisation of the OR.



PAGE 6 An overview of the definitions of the codes, objectives and metrics.



Group	Term	Definition
Objective factor	Accessibility	The access to obtaining or using health care at the OR, this includes services (range of diagnosis, number of resources and safety) and geographical, financial accessibility.
	Care outcomes	The results of the treatment on the patient and therefore the patients' health condition.
	Finance	The management of money, the business and investments.
	Management	The control of the organisation, including the administration, board and its policies.
	Patient (health) condition	The physical condition and fitness of the patient, including sickness, and the life(style) circumstances of the patients.
	Patient flow	The transfers of patients through the hospital; from the ward to the OR to the ward.
	Quality of care	Health services for individuals and populations increase the likelihood of desired health outcomes.
	Resources	The equipment, means and materials for the treatment and after-care.
	Safety	Health services for individuals and populations provides a safe and risk-free health care, with the best outcomes for the patient and staff.
	Satisfaction	The fulfilling/achieving the need of desire of the act for a certain stakeholder.
	Service	All provided types of activities within the hospital and OR.
	Staff (health) condition	The physical condition and fitness of the staff, including sickness, and the life(style) circumstances of the staff.
	Surgical performance	The accomplishment and its quality of the surgery complexes by the medical staff.
	Team	The group of medical professionals that perform care in the OR.
Objective characteristic	Adequacy	The fact that the services in the OR can performed till the desired sufficiency.
	Authority	The leadership during a treatment; the one that is in control and makes the decisions.
	Care outcomes	The effect of the treatment on the patient and therefore the patients' health condition.
	Decision making	The decision-making during the surgery about the treatment and the after-care.
	Education & knowledge	The (extra) education and the knowledge (improvement) of and for the medical staff.
	Environment	The nature, climate and climate change.
	Management satisfaction	The fulfilling/achieving the need of desire of the act for the management/board of the hospital.
	Operational performance	The arrangements and tasks needed to control the operation of a plan or organization.
	Patient flow	The transfers of patients through the hospital; from the ward to the OR to the ward.
	Patient satisfaction	The fulfilling/achieving the need of desire of the act for the patients of the hospital.
	Quality of care	Health services for individuals and populations increase the likelihood of desired health outcomes.
	Safety	Health services for individuals and populations provides a safe and risk-free health care, with the best outcomes for the patient and staff.
	Staff performance	The performance of the individuals of the medical staff during the surgery or after care.
	Staff satisfaction	The fulfilling/achieving the need of desire of the act for the medical staff of the hospital.

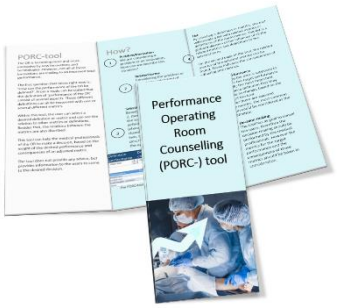
SUPPORTING MATERIALS

PORC-TOOL

This Excel-based tool guides the user by creating a holistic view of the OR, by providing the information of the performance optimisation of the OR and the impact for the OR.

BROCHURE

This brochure is a reminder and a first help for the users, since it is easy to distribute and includes a short explanation of the tool. The goal of this brochure is to provide a short but clear overview of all the functionalities of the tool and the steps that should be taken for usage.



THESIS

This thesis provides the literature for the tool and the design process. All the taken decisions are described in this thesis, including an explanation. Also, the limitations of the tool are noted.

Practice

The tool can be used in many situations; problem, product, solution related and by several stakeholders. Therefore, a quick guide of the steps and the target audience are defined.

TARGET AUDIENCE

The PORC-tool is aimed for the healthcare professionals in general, that have a saying in the optimising or decision-making process of the OR. The participant should have knowledge of the healthcare and the OR itself. Knowledge about an innovation or problem could facilitate the process. A basic knowledge of Excel could be helpful, especially by updating the tool. If the decision-support tool is used, it will be beneficial for at least one healthcare professional to be familiar with the tool; however, this is not required.

The healthcare professionals include medical staff, scientist and hospital management, as long as they are gathering information of the medical OR for a hospital or university research.

QUICK GUIDE

This tool helps the decision-makers to create a holistic view and gather information about the impact of an innovation required for the decision.

1. Problem/innovation:
   The healthcare professionals come up with a problem or an interesting innovation.
2. Choose related describing terms:
   The healthcare professionals think of describing terms (for the objective or metric) related to the problem or innovation.
3. Select objective or metric:
   The healthcare professionals compare the describing terms with the in the tool provided terms. The most related terms can be selected in the matrix table.
4. List of related metrics or objectives:
   After selecting an objective on page 3, a list of metrics will appear. These metrics can be selected on page 4, which causes a list of metric causalities.
   After selecting a metric, a list of objectives will appear. The metric should also be selected on page 4, which causes a list of metric causalities.
5. Define target performance:
   The target performance should be established by the healthcare professionals, by stating what is most important for them. Comparing and analysing the found relations and causalities, it might help to find the most common terms and therefore the most important objective or metrics.
6. Information for decision-making:
   A holistic vision of the OR is made and therefore the decision can be made based on information.

TIMELINE

There is no prescribed length for the process, which can vary from a couple of hours to over a week. The exact timeline is likely to depend on a number of factors, including the number, profile and schedule of the healthcare professionals, the urgency and importance of the problem/innovation and the knowledge of the healthcare professionals about the situation or innovation.

The usages of the tool itself is not time-consuming, since selecting the terms in not hard. However, the conversation about the problem/innovation, thinking of describing terms and analysing the results for the target performance require time and effort from the healthcare professionals.

Minimally half an hour is required to come up with the describing terms and for analysing the results for the target performance. 10 minutes have to be reserved to select the right terms, so comparing the describing terms to the stated codes in the tool. 5 minutes are required to create the multiple lists of relations and causalities. This results in 75 minutes; however, it can be eligible to calculate some time to rethink over the terms and results. Notable is that the time to gather information of and discuss the innovation is not considered, since this depends too much on the group and is not tool related.

Guide per step

Per step from the flowchart is an elaborated description in this chapter. Starting with a short overview of the aim of the step, the involved participants and the essentials for this step.

STEP 0

PREPARATION

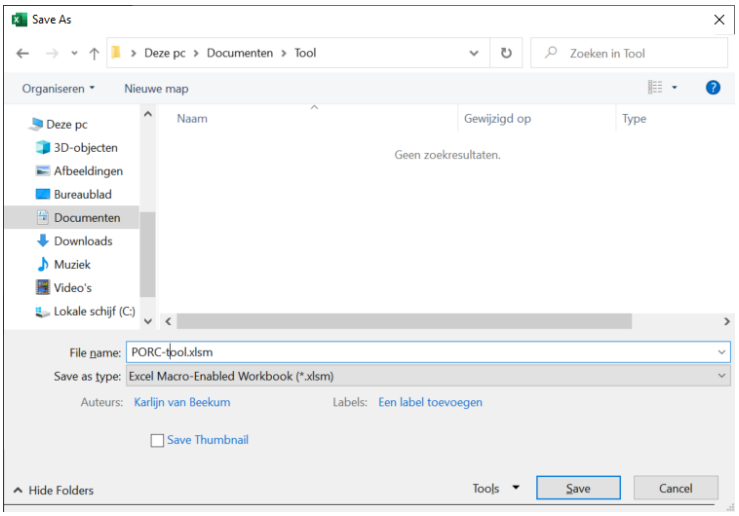
AIM: GETTING READY FOR THE DECISION-MAKING PROCESS

PARTICIPANTS: HEALTHCARE PROFESSIONAL WHO IS PROFICIENT WITH EXCEL

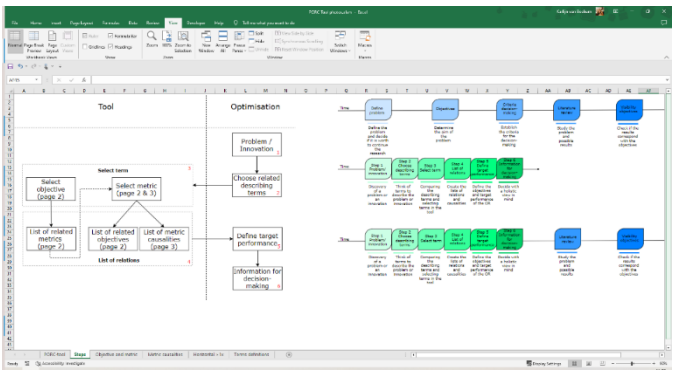
ESSENTIALS: COMPUTER, EXCEL PROGRAMME

1) To get started, the healthcare professional should open the Excel application on the computer.
    a. Ensure that the most current version of Excel is opened.

2) Open the Excel file: PORC-tool and save the tool as PORC-tool.xlsm.
    a. Change the "Save as type" from *Excel Workbook (*.xlsx)* to *Excel Macro-Enabled Workbook (*.xlsm)*.
    b. If saving the tool is not possible yet, ensure that the macros are enables, by clicking "Enable Content".



3) Open the tool on the second page "Steps".



STEP 1

PROBLEM/INNOVATION

AIM: DISCUSSING THE PROBLEM OR INNOVATION FOR THE OR
PARTICIPANTS: THE INITIATOR
ESSENTIALS: INFORMATION ABOUT THE PROBLEM OR INNOVATION

1) A healthcare professional identifies a problem in the OR or discovers an innovation for the OR.
    a. "*What is the problem? What kind of innovation are we considering?*"

2) The HCP gathers background information about the topic (problem or innovation).
    a. This can be by requesting more information at the developer of the innovation or discussing the problems with the stakeholders of the OR.

3) The HCP informs the decision-makers about this topic.

STEP 2

CHOOSE RELATED DESCRIBING TERMS

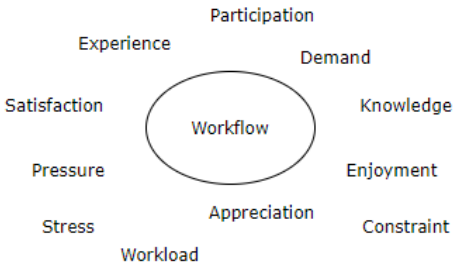
AIM: DEFINING THE OBJECTIVES OR MEASUREMENTS FOR THE OPTIMISATION
PARTICIPANTS: MULTIPLE INVOLVED HEALTHCARE PROFESSIONALS (AT LEAST 3 PEOPLE)
ESSENTIALS: PAPER, PENCIL

1) The decision-makers plan a meeting to get informed about the topic.
    a. As long as the decision-makers are interested or enthusiastic towards the topic.
    b. This can also be done by a report.

2) The group of HCPs discusses the topic.
    a. The main goal of the topic should be stated.
    b. The main measurement methods should be stated.

3) The group decides the main focus of their topic.
    a. *"What is the focus of this problem/innovation?".*
    b. This can be an objective of or a metric for the performance optimisation of the OR.

4) The group writes down words related to the main goal and the measurements to the topic.
    a. In the figure is an example of the workflow.



5) The group decides on the describing terms that are most related to the problem or innovation.
    a. There is no maximum number of words; however, more words make the results of the tool less specific and therefore less helpful.

STEP 3

SELECT TERM

AIM: CREATE INPUT FOR THE PORC-TOOL
PARTICIPANTS: MULTIPLE INVOLVED HEALTHCARE PROFESSIONALS (AT LEAST 3 PEOPLE)
ESSENTIALS: LIST OF TERMS OF THE TOOL

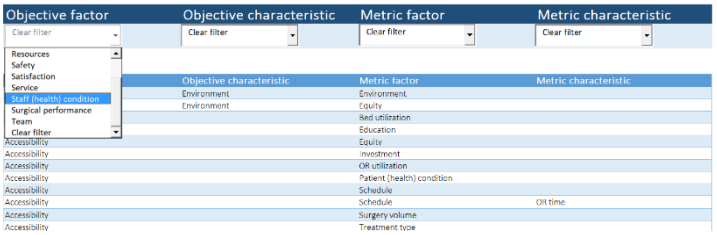
1) Open page 6 “Terms definitions” from the PORC-tool.
    a. Herein the description of all the input terms is presented.

2) Compare the describing terms that are most related to the problem or innovation to the selecting terms from the list.
    a. *“What are the (most) related terms in the tool?”*.
    b. Search for the words, synonyms or correlating words.

3) Choosing selecting terms from the list.
    a. The list is presented below (and the definitions of the terms at page 6).

Performance	Terms
Objective factor	Accessibility, Care outcomes, Finance, Management, Patient (health) condition, Quality-of-care, Resources, Safety, Satisfaction, Service, Staff (health) condition, Surgical performance, Team
Objective characteristic	Adequacy, Care outcomes, Decision-making, Environment, Operational performance, Patient satisfaction, Safety, Staff performance, Staff satisfaction, Surgical performance, Teamwork, Technology, Value-based healthcare, Workload
Metric factor	Accessibility, Accreditation, Accuracy, Audit performance, Authority, Bed utilisation, Behaviour, Care outcomes, Communication, Complexity, Complication, Cost, Culture, Decision-making, Diagnose, Discharge, Distribution equipment, Disturbance, Education, Environment, Equipment type, Equipment utilisation, Equity, Ergonomics, Expertise, Hospital capacity, hygiene, Idle time, Inventory, Investment, Length of stay, Maintenance, Operational performance, OR block, OR design, OR time, OR utilisation, Patient (health) condition, Patient flow, Patient satisfaction, Pharmaceuticals, Policy, Profit, Readmission, Responsiveness, Revenue, Safety, Savings, Schedule, Shift, Skill, Staff (health) condition, Staff performance, Staff satisfaction, Start time, Stressors, Surgery duration, Surgery efficiency, Surgery volume, Surgical performance, Survival, Team structure, Teamwork, Technology, Treatment type, Trust, Waiting list, Waste, Workforce, Workload
Metric characteristic	Accuracy, Anatomy, Anxiety, Authority, Bed utilisation, Behaviour, Cancellation, Communication, Complexity, Complication, Delay, Distribution equipment, Disturbance, Energy, Equipment, Equipment inventory, Equity, Ergonomics, Expertise, Hospital capacity, Length of stay, Maintenance, Morbidity, Mortality, Nutrition, OR block, OR break, OR design, OR over time, OR time, OR utilisation, Patient satisfaction, Physical work, Psychological condition, Responsiveness, Robustness, Sensory factors, Shift, Skill, Sleep, Staff satisfaction, Start time, Stressors, Surgery efficiency, Surgery volume, Task, Technology, Transparency, Treatment, Turnover, Workforce

4) Select the term on the third page “Objective and metric” at the right level; objective or metric and factor or characteristic.
    a. Select the drop-down at the right level:
        i. Objective factor: the general terms for the performance optimisation of the OR.
        ii. Objective characteristic: a specification on the objective factor, elaboration on the topic.
        iii. Metric factor: the general methods to measure the performance optimisation of the OR.
        iv. Metric characteristic: a specification on the metric factor itself, elaboration on the topic.
    b. Select the correct term in the drop-down.



5) If a metric has been selected, select the metric also on the fourth page “Metric causalities” at the right level.
    a. Select the drop-down at the right level:
        i. Cause-metric: the influencing metric.
        ii. Result-metric: the metric that received the influence.
    b. Select the correct term in the drop-down.

STEP 4

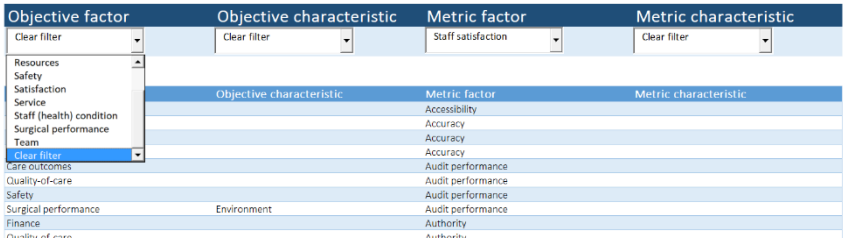
LIST OF RELATIONS

AIM: CREATING A LIST OF THE RELATIONS AND CAUSALITIES FROM THE SELECTED TERMS
PARTICIPANTS: HEALTHCARE PROFESSIONAL WHO IS PROFICIENT WITH EXCEL
ESSENTIALS: PORC-TOOL, PAPER, PENCIL

1) Create the list of relations by selecting the terms in the drop-down.
    a. “*What are the relations of those terms?*”.

2) Copy the list of relations.
    a. This can by hand, photograph or on the computer.

3) Clear the list by putting all the drop-downs on “Clear filter”
    a. If this does not work, clear the list with ALT+D+F+S



4) In case of a selected objective in step 3, identify the most related metric and perform step 3.5

5) In case of multiple chosen words, perform step 3.4 and 3.5 again.

STEP 5

DEFINE TARGET PERFORMANCE

AIM: STATING THE FOCUS OF THE REST OF THE DECISION-MAKING PROCESS

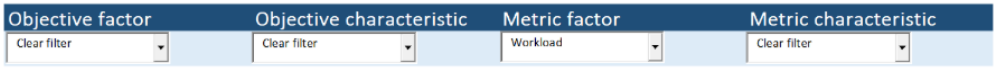
PARTICIPANTS: ALL INVOLVED HEALTHCARE PROFESSIONALS

ESSENTIALS: PAPER, PENCIL

The fifth step is to analyse these relations and define the target performance (box 5): The suggestion is to notice the overlapping objectives and metrics and to discuss the results with other professionals. With this analysis and the conversation, the targeted performance, which is similar to the objective of the performance optimisation of the OR, or metrics should be determined, including the related influences.

1) Create a clear overview of all the relations and causalities of the selected terms.
    a. In case of multiple terms, compare the results with each other and search for the overlapping objectives and metrics.
    b. In case of a single term, determine the most important relation.

Cause-metric	Result-metric
Workload	Care outcomes
Workload	Staff (health) condition
Workload	Surgical performance



Objective factor	Objective characteristic	Metric factor	Metric characteristic
Quality-of-care		Workload	
Safety		Workload	
Staff (health) condition		Workload	
Surgical performance	Staff performance	Workload	
Surgical performance		Workload	

2) Discuss the overview with the HCPs.
    a. Let all the HCPs share their perspective on this topic.

3) Define the target performance
    a. *"What was the goal of this problem/innovation? Does this agree with the given relations?"*.
    b. Often is this related to the overlapping objectives and metrics or the most important relation.
    c. Consider the causalities of the metrics, while defining the target performance.

STEP 6

INFORMATION FOR DECISION-MAKING

AIM: CONSIDERING THE HOLISTIC VIEW OF THE OR WHILE DECISION-MAKING

PARTICIPANTS: THE DECISION-MAKING HEALTHCARE PROFESSIONALS

ESSENTIALS: INFORMATION FROM THE PORC-TOOL

1) Holistic view.
    a. At the end of this step, the HCPs should have a thorough understanding of the influences of a problem or an innovation on (the optimisation of) the performance of the OR.
    b. The HCPs should be well-informed to make a decision.

2) Decide if the topic is worth discussing.
    a. "*Should we invest more time or money in researching this innovation?*".

ENDING

DECISION-MAKING

AIM: DECIDE ON AN INNOVATION OR PROBLEM

PARTICIPANTS: THE DECISION-MAKING HEALTHCARE PROFESSIONALS

ESSENTIALS: HOLISTIC VIEW (OF THE OPTIMISATION) OF THE PERFORMANCE OF THE OR

1) Decision-making.
    a. The tool itself does not provide all the information, the user should still think rationally and critically to make sure to pick the correct terms (therefore the suggestion is to perform this in a group) and to analyse the relations.

2) Implementation of the topic.
    a. If the topic is purchased or more focus on development is agreed on, the innovation can be implemented in research or in the OR.

3) Evaluation.
    a. After the implementation, the innovation should be evaluated to discover its value.

Updating

The tool is developed in the computer software programme Excel, to make it available for all the HCPs and easily updateable to the desires of the users. The update could be concerning the appearance of the tool, or to the relations. Updating the appearance will not be discussed, but below, updating the relations and causalities will be discussed.

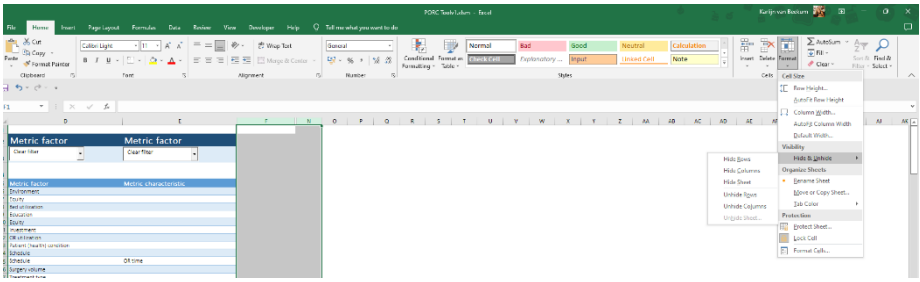
UPDATE RELATIONS/CAUSALITIES

1) Open the tool as described in Step 0.

2) Determine the update that is required.

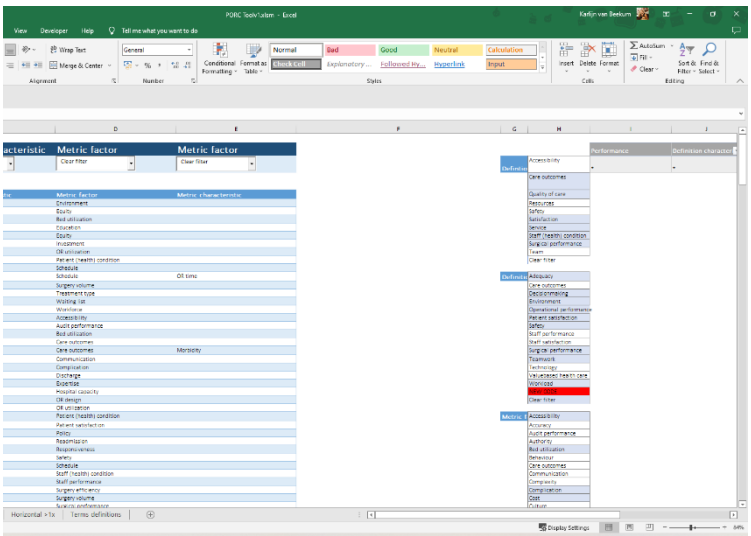
3) Open the correlating page in the PORC-tool.
    a. Determine on what page this update should be.

4) Unhide all the information on that page.
    a. Select the whole sheet by pressing Ctrl + A.
    b. Go to tabled “Home”, select “Format” and select “Unhide Columns”.



5) Add the relation/causality at the bottom of the long list with relations/causalities.
    a. This list is blue/white striped.

6) In case of adding a new term/new terms, at this to the to-be-selected terms.
    a. Column H provides the to-be-selected terms.
    b. Note: place the term with the right level, so the objective with the objective factor and the metric with the metric factor.



7) Save the Excel file as PORC-tool version X.
    a. Change the “Save as type” from *Excel Workbook (* .xlsx)* to *Excel Macro-Enabled Workbook (* .xlsm)*.

8) Check if the relation/causality appears when a corresponding term is selected.
    a. It does not matter what term of the relation is selected.
    b. If not, check the steps above.

9) Hide the columns again.
    a. Select the columns on the right side from the list.
    b. Go to tabled “Home”, select “Format” and select “Unhide Columns”.

10) Save the Excel file as PORC-tool version X.

Appendix J Brochure

Who?

For medical professionals that would like to improve the optimisation of the performance of the OR and have been interested in the consequences of their decisions.

What?

A tool that helps counselling on the optimisation of the performance of the OR and indicates the effects of an optimisation on this performance.

Where?

The operating centre of public medical hospital.

When?

The tool can be used for identifying the effects of a problem and for the counselling of an optimisation.

Why?

This tool is developed to provide insight to the optimisation decision-makers of the OR on the different aspects of performance and the effects of adjusting an aspect.

Contact

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PerformanceORcounsellingtool.com
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Performance Operating Room Counselling (PORC-) tool

Figure Appendix 1: The foreground of the brochure for the PORC-tool in a trifold outline.

PORC-tool

The OR is becoming more and more innovative by new innovations and technologies. However, not all of those innovations are leading to an improved total performance.

The first question that raises right now is; 'How can the performance of the OR be defined?'. From a study can be stated that the objective of 'the optimisation of the performance of the OR' consist of several aspects. Those different objectives can all be measured with one or several different metrics.

Within this tool, the user can select a desired objective or metric and can see the relation to other metrics or objectives. Besides that, the relations between the metrics are also discribed.

This tool can help the medical professionals of the OR to make a decision, based on the insight of the desired performance and consequences of an adjusted metric.

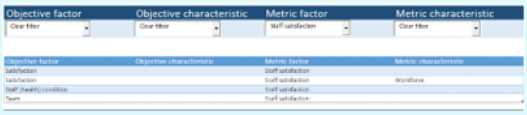
The tool does not provide any advice, but provides information to the users to come to the desired decision.

How?

1 **Problem/Innovation**
We are considering a problem or an innovation. How can we describe this situation?

2 **Related terms**
Considering the problem or innovation, what kind of terms are related to this situation. This can be terms that describe an objective or metric.

3 **Selecting terms in tool**
Based on the choosen terms in step 2, there can be selected a term in the tool, again this can be a objective (factor/characteristic) or a metric (factor/characteristic). The terms that is closest related to the terms in step two, should be selected. The description of all the terms if given in the appendix of the tool.



The PORC-tool with selected metric Staff satisfaction.

4 **List**
By selecting an objective or a metric, the tool will provide a list with related metrics or objectives of the performance. This list is a global indication of the influence of all the related metrics and objectives to the selected term.

On the second page of the tool, the related metrics of the selected metrics can be found. These indicates the consequences of adjusting one metrics.

5 **Target performance**
In this step the user is supposed to determine the target performance for the OR; the most important performance objective that they would like to change, based on the counsel of the tool.
Whenever there are selected multiple metrics, the most common objective could be considered as the main objective.

6 **Decision-making**
The tool has as goal to consel the users, therefore the decision-making should be performed by the medical proffesionals. However the metrics for the target performance and the consequences of these metrics should be taken in consideration.

Figure Appendix 2: The background of the brochure for the PORC-tool in a trifold outline.

Appendix K Horizontal table with the relations between objectives and metrics

Table Appendix 9: The full overview of the relations, including the objective factors, objective characteristics, metric factors, metric characteristics. The first horizontal row is the goal, namely performance; the second row is the objective factor; the third row is vertical and state the objective characteristic; the fourth row is metric factor and the fifth row states the metric characteristic.

Goal	Objective factor	Objective characteristic	Metric factor	Metric characteristic
Performance	Accessibility	Environment	Environment	
			Equity	
			Bed utilization	
			Education	
			Equity	
			Investment	
			OR utilization	
			Patient (health) condition	
			Schedule	
				OR time
			Surgery volume	
			Treatment type	
			Waiting list	
			Workforce	
	Care outcomes		Accessibility	
			Audit performance	
			Bed utilization	
			Care outcomes	
				Morbidity
			Communication	
			Complication	
			Discharge	
			Expertise	
			Hospital capacity	
			OR design	
			OR utilization	
			Patient (health) condition	
			Patient satisfaction	
			Policy	
			Readmission	
			Responsiveness	
			Safety	
			Schedule	
			Staff (health) condition	
			Staff performance	
			Surgery efficiency	
			Surgery volume	
			Surgical performance	
			Survival	
				Mortality
			Teamwork	
			Treatment type	
			Workforce	
	Finance		Authority	
			Bed utilization	
			Care outcomes	
			Communication	Transparency
			Complication	
			Cost	
				Workforce
			Equipment type	
			Equipment utilization	
			Inventory	
			Investment	
			Length of stay	
			Operational performance	
			OR time	
				OR over time
			OR utilization	
			Policy	
			Profit	
			Readmission	
			Revenue	
			Savings	
				Communication
				OR utilization
			Schedule	
			Staff performance	
			Surgery duration	
			Surgery efficiency	
			Surgery volume	
				Treatment
			Treatment type	
				Bed utilization
			Waiting list	
			Workforce	

Goal	Objective factor	Objective characteristic	Metric factor	Metric characteristic
Performance	Management	Environment	Shift	
			OR time	
		Workload	Schedule	
			OR utilization	
			Schedule	
				Bed utilization
				Cancellation
				Communication
				Delay
				Distribution equipment
				Equipment inventory
				Equity
				OR block
				OR design
				OR utilization
				Robustness
				Shift
				Staff satisfaction
				Workforce
			Treatment type	
	Patient		Bed utilization	
			OR utilization	
			Schedule	
			Workforce	
	Quality of care	Adequacy	Treatment type	
		Care outcomes	Technology	
		Surgical performance	Complication	
			Treatment type	
		Teamwork	Communication	
		Valuebased health care	Patient satisfaction	
			Audit performance	
			Authority	
			Care outcomes	
				Morbidity
			Communication	
			Complication	
			Cost	
			Diagnose	
			Discharge	
			Disturbance	
			Education	
			Environment	
			Equipment type	
			Expertise	
			Length of stay	
			OR design	
			OR time	OR break
			Patient (health) condition	
			Patient flow	
			Patient satisfaction	
			Pharmaceuticals	
			Policy	
			Quality of life	
			Readmission	
			Responsiveness	
			Safety	
			Staff performance	
			Surgery duration	
			Surgery efficiency	
				Accuracy
				Technology
			Surgery volume	
				Surgery efficiency
				Task
			Surgical performance	
			Survival	Mortality
			Teamwork	
			Treatment type	
			Waiting list	
			Waste	
			Workload	
	Resources	Technology	Cost	
			Education	
			Equipment type	
			Maintainance	
			Operational performance	
			Distribution equipment	
			Equipment type	
				Equipment inventory
			Expertise	
			Inventory	
			OR design	
				Sensory factors
			OR utilization	
			Schedule	
				Equipment
			Workforce	

Performance
Safety
Satisfaction
Service
Staff (health) condition
Patient satisfaction
Staff satisfaction
Operational perform
Accuracy
Audit performance
Behaviour
Care outcomes
Morbidity
Communication
Complexity
Complication
Culture
Disturbance
Education
Equipment type
Expertise
Length of stay
Operational performance
OR break
OR time
Patient (health) condition
Pharmaceuticals
Policy
Responsiveness
Safety
Skill
Staff (health) condition
Staff performance
Surgery volume
Mortality
Survival
Teamwork
Treatment type
Workload
Communication
Shift
Patient satisfaction
Staff satisfaction
Workforce
Equipment utilization
Schedule
Bed utilization
Care outcomes
Cost
Equipment type
Equipment utilization
OR utilization
Patient flow
Patient satisfaction
Profit
Cancellation
OR block
OR over time
OR utilization
Robustness
Staff satisfaction
Start time
Staff performance
Surgery efficiency
OR utilization
OR utilization
Surgery volume
Treatment type
Ergonomics
Expertise
Staff (health) condition
Nutrition
Sleep
Stressors
Staff satisfaction
Stressors
Sleep
Workforce
Physical work
Workload
Performance
Surgical performance
Team
Environment
Safety
Staff performance
Adequacy
Decisionmaking
Audit performance
Waste
Expertise
Disturbance
Communication
Education
Expertise
Skill
Staff (health) condition
Ergonomics
Expertise
Nutrition
Physical work
Psychological condition
Sleep
Staff performance
Decision making
Stressors
Workforce
Workload
Accuracy
Morbidity
Care outcomes
Communication
Complication
Culture
Distribution equipment
Energy
Environment
Equipment type
Expertise
Operational performance
OR design
OR break
OR time
OR utilization
Patient satisfaction
Policy
Responsiveness
Safety
Skill
Accuracy
Staff (health) condition
Staff performance
Complexity
Stressors
Responsiveness
Surgery efficiency
Equipment
Start time
Surgery volume
Surgery efficiency
Surgical performance
Mortality
Survival
Teamwork
Workforce
Workload
Responsiveness
Care outcomes
Accuracy
Authority
Behaviour
Care outcomes
Morbidity
Communication
Culture
Diagnose
Education
Expertise
Responsiveness
Staff performance
Staff satisfaction
Stressors
Responsiveness
Surgery volume
Surgery efficiency
Survival
Mortality
Team structure
Teamwork
Treatment type
Policy
Trust
Communication