



ADOPTION BARRIERS FOR MEDICAL TECHNOLOGY IN SUB- SAHARAN AFRICA

ADDRESSING CHALLENGES IN MAINTENANCE, TRAINING,
ORGANISATIONAL AND BEHAVIOUR CHANGES

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PREFACE

In this report I present the findings of my master thesis research concluding the Complex Systems Engineering and Management (CoSEM) programme, conducted between October 2021 and March 2022. This research was executed in a collaboration of GOAL3 and the TU Delft. During my internship at GOAL3 my already existent interest in the field of medical technology has been extended towards a new, specific, interest in medical technology for low-resource settings. I have been inspired by all persons active at GOAL3, where dreaming big for a better world is not a problem. I am grateful to have been able to use knowledge from my Bsc. degree in Clinical Technology throughout this thesis. This period I have learned a lot, both at this internship and academically, and for this I would like to express gratitude to the persons helping me along.

I want to thank Jelle Schuitemaker, my supervisor at GOAL3, for helping me with all contacts of my case studies, and supervising me in the practical application possible with this research. I also want to express my gratitude to all other persons of GOAL3 that I have spoken with at some time along my thesis, for sharing your enthusiasm, subsequently helping me dive deep into the problems expressed in this thesis. I would also like to thank my TU Delft supervisors Saba Hinrichs-Krapels, Cees van Beers and Pieter Bots. To Saba, my primary supervisor, our weekly talks always helped me gain direction and structure my thesis. To Cees, thank you for your perspective on the research topic, giving insights into the possibilities of economic data with which I have no experience. To Pieter, thank you for making the time to have extensive meetings with me on how to structure my findings into a framework. Also, a great thanks to the many interviewees that are at the basis of this research. Your enthusiasm for the field in which you are active inspired me, and I am humbled to have been able to include your experiences within this thesis.

I would also like to express gratitude to my friends and family for the support you have given me throughout this thesis. Thank you for always listening to my rants on this topic, and allowing me to talk sense into myself even if the rant itself was not clear to you. Thank you to my family for always helping me if I needed a change of scenery, and for the never-ending encouragement. To Tippi, Daniëlle and Anouk, my roommates, thank you so much for all the small (and big) breaks that we took that helped me clear my head and regain motivation for this research. To Eva and Thomas, for the vrijmibo's that you spent here getting me out of my study bubble. To Tara, for always being available for my thesis complaints through WhatsApp, and even proofreading my thesis.

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EXECUTIVE SUMMARY

During the COVID-19 pandemic, a new focus was drawn to the importance of robust healthcare systems. This robustness can be enhanced by the availability of medical technology. There is however currently a lack of technology in Low- and Middle Income Countries (LMIC), due to a large part of the equipment available being non-functional in these settings. Even with new efforts in equipment being designed specifically for LMIC, research has found that this is not yet sufficient for adoption.

This thesis aimed to uncover barriers that exist for adoption, and develop a diagnostic tool for organizations implementing their medical technology in Sub-Saharan Africa (SSA). This tool enables guided analysis of their strategies, helping them to overcome those barriers in adoption. This is done in the context of a medical technical start-up, GOAL3, wanting to embed a smart monitoring system in Sub-Saharan Africa (SSA). The main research question for this research is:

“How can a medical technology organization overcome barriers in adoption of their medical technology in Sub-Saharan Africa?”

With a T-shaped case study design, e.g. a multiple case study leading into one in-depth case study, barriers were uncovered in the following, pre-identified, themes:

- *Maintenance*: Covering any notion of periodic and corrective maintenance (e.g. cleaning, repair, replacement) of the medical equipment implemented by the organization.
- *Training*: Covering any notion of training done on use and maintenance of the medical equipment implemented by the organization.
- *Organisational Change*: Covering any notion of spare parts and consumables and the management thereof needed by the medical equipment by the organization.
- *Behavioural Change*: Covering any notion of the need for behaviour change to support the adoption of medical equipment implemented by the organization.

Six organizations were included in the multiple-case study, all active in medical equipment implementation in one or more countries in SSA. Data gathered on each of the cases was done through semi-structured interviews with one executive per organization, combined with desk research on both online and on in-organization documentation. The data was analysed using thematic coding in ATLAS.ti, creating a first draft of the framework (e.g. the diagnostic tool). This framework was validated through the in-depth case study of one of the aforementioned six organizations, alongside expert interviews. This approach led to a multitude of contributions.

Firstly, through an extensive literature review, current barriers known within the different themes in scope were synthesized. It was however found that there is a lack of empirical evidence base on how to overcome such barriers, as well as a lack of consensus on existent barriers. This consensus was created by extending and comparing the barriers from literature with barriers found through the multiple case study. This resulted in this final list of barriers:

- *Time*: the organization or client not having enough time to perform tasks dictated within one or more themes.
- *Money*: the organization or client being inhibited by money.
- *Human resources*: the client not having the (correct) personnel to perform tasks dictated within one or more themes.

- *Materials*: unavailability of materials inhibiting one or more themes in scope.
- *Policy*: formal rules of a region or facility inhibiting the organization or client.
- *Trust*: trust within the client organization, or between client and implementing organization preventing needs for themes in scope from being carried out.
- *Breaking habits*: an indication for significant behaviour change needed for one or more of the themes in scope.
- *Communication*: a lacking in the client / organization relationship inhibiting one or more of the themes in scope.

In this list, *breaking habits* is a barrier indicating if there is a need for behaviour change. For behavioural change, the following barriers apply, derived from the COM-B model by Michie, Van Stralen, and West (2011):

- *Capability*: the client lacks the physical and / or psychological capability for obtaining and expressing the new behaviour.
- *Opportunity*: the client lacks the physical and / or social opportunity for obtaining and expressing the new behaviour.
- *Motivation*: the client lacks the reflective and / or automatic motivation for obtaining and expressing the new behaviour.

Secondly, an overview was made of mitigating strategies in current practice. This overview can be found in Table 1. The strategies are to overcome the barrier stated in the row, and has effects on the theme depicted in the columns.

Barrier	Maintenance	Training	Spare Parts	Consumables
Time	Design equipment to have low maintenance needs, to be modular, checklists to predict maintenance.	Design equipment for low training needs, quick guides on the spot, trainer-on-trainer model, gage knowledge beforehand.	Ensure spare parts are modularly replaceable, have local source of spare parts available.	Low consumables need, have local supply.
Money	Design equipment to have low maintenance needs, provide suggested spare parts lists, maintenance can be done by low-level technician, peer-to-peer support through WhatsApp.	Trainer-on-trainer, integral part of purchase.	Lease machines including spare parts, buying spare parts at Alibaba.	Consumables are autoclavable, other sources of consumables.
Human Resources	Representative does maintenance, regular check-ins, peer-to-peer sufficiency building.	Trainer-on-trainer, refresher materials like e-learning and webinars.		
Materials	Ensuring availability, small changes/updates.	Quick guides, manuals, videos, e-learning, webinar.	Ensuring availability, modularity, local availability.	Ensuring availability, autoclavable, other sources, local availability.
Policy			Local availability, sold with equipment.	Local availability.
Trust	Regular physical check-ins, regular phone calls, WhatsApp check-ins in group chats, helpdesk available.	Regular physical check-ins, regular phone calls.		

Barrier	Maintenance	Training	Spare Parts	Consumables
Breaking habits	Incentive system for maintenance checklists.	Training on clinical context.	Lease of machines including spare parts.	Providing charts necessary for change.
Communication	Regular physical check-ins, regular phone calls, WhatsApp check-ins in group chats, helpdesk available.	Ensure correct language for materials, translator available.	Contact info on equipment, contact-person for orders.	Contact-person for orders.

Table 1. Overview of mitigating strategies for adoption barriers discovered within the multiple-case study. The o. depicts the organization using this mitigating strategy.

Thirdly, because of the current lack of guiding frameworks, a practical application was made. For an organization to be able to overcome barriers in adoption, the organization must gain understanding of what influences adoption within specific implementation situations. This situation consists of an organization (e.g. the implementing party), their medical technology (e.g. the to be implemented equipment) and a client organization (e.g. the receiving facility at which this equipment is implemented). This research proposes to gain understanding of applicable barriers in an early stage in the implementation process through use of the framework. This schematic timeline is visualized in Figure 1. Integrating the framework gives the opportunity to create insights in barriers one might come across before actually experiencing them in the field. The subsequent possibility of analysis of strategies alongside successful current practice, provides opportunity for the implementing organization to apply mitigating strategies in development themselves. The trade-off between costs and lowering of barriers can be done more thoughtfully, fully aware of the risks in adoption their current strategies propose.

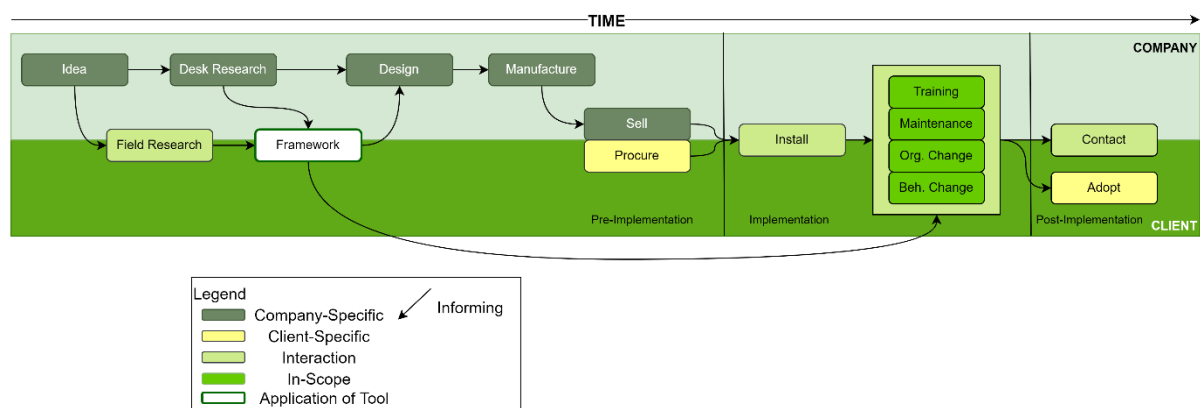


Figure 1. Simplified implementation process showing where the framework could be applied to inform design and implementation strategy.

In conclusion, the advice for a company such as GOAL3 would be to analyse their current strategies on themes and barriers uncovered within this research using the proposed framework at the early stage of implementation they are at. To be able to do this, knowledge is needed on the medical equipment and the client organization. For the medical equipment, possibilities of specifications of versions are sufficient. To gather information on the client organization, one should have both sources on-ground, through for example interviews, but also contextual factors that can be researched through desk research. This gives the opportunity for integrating the proposed mitigating strategies of Table 1 into their current plans, enabling them to overcome barriers in adoption.

LIST OF ACRONYMS

Acronym	Description
BME	Biomedical Engineer
CFIR	Consolidated Framework of Implementation Research
CO	Client Organization
CoSEM	Complex Systems Engineering and Management
GP	General Practitioner
HIC	High Income Countries
KPIs	Key Performance Indicators
LMIC	Low- and Middle Income Countries
ME	Medical Equipment
NASSS	Non-Adoption, Abandonment, Spread, Scale-Up and Sustainability
NGO	Non-Governmental Organization
SDG	Sustainable Development Goals
SSA	Sub Saharan Africa

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CHAPTER 1. INTRODUCTION

1.1 MEDICAL TECHNOLOGY IN DEVELOPING COUNTRIES

During the COVID-19 pandemic, the world has developed a new focus on availability of health technology in developing countries. The crisis has shown the importance of robust healthcare systems, and the role health technology has in providing this robustness (Mohammady, Ross, Olayo, & Otiangala, 2020). It is however also apparent that there is currently a lack of technology in these developing countries, classifiable as low- and middle income countries (LMICs) (Patterson & Rohrer, 2019). This lack of technology does not exist due to a lack of developed equipment, but due to the equipment being developed not properly working in developing hospitals in comparison to developed hospitals (Malkin, 2007). The WHO estimated 70% of this equipment is non-functional in LMIC settings (World Health, 1997). And even with new efforts in design for equipment specifically for these settings, it is still found that research is not yet sufficient for adoption of these technologies (Vasan & Friend, 2020).

This research is done in collaboration of the TU Delft and GOAL3, with GOAL3 providing resources during an internship. GOAL3 is a medical technical start-up with a focus on developing a smart monitoring system for neonates, with their starting market being in Sub-Saharan Africa (SSA) (GOAL3, nd). With the wish to extend this monitoring system into a platform enabling innovation, it is important that the initial technology is adopted into the medical system. To be able to do this, an overview of the current challenges existent in adoption of medical technologies is needed, with a focus on Sub-Saharan markets. With insights into the barriers and current mitigating strategies, this research can be used to evaluate GOAL3's current strategies, construing an advice on alterations to overcome these barriers.

1.2 SCOPING THE RESEARCH

The focus of this research will thus be adoption of medical technology. Adoption is in this research regarded as the phase after procurement of the technology, focussing on the technology being used as meant to by the implementing organization for a longer period of time. Within this, three themes were chosen to be within boundaries for this research: maintenance of the technology, training users for use of the technology and organisational and behavioural changes needed to sustain use of the technology. Organisational and behavioural change is herein regarded as being one theme. The placement of these themes in a simplified implementation process is visualized in Figure 2. The cycles of the design process are herein not part of the scope and thus not fully detailed.

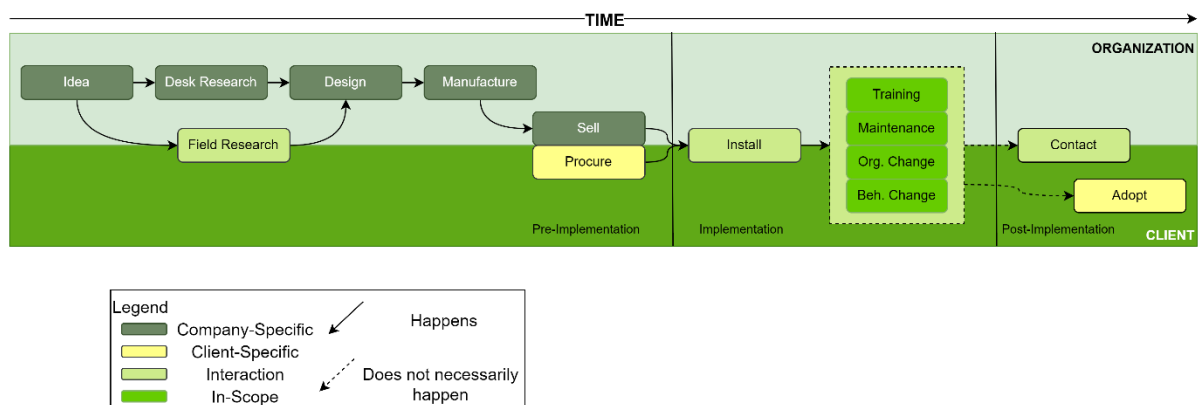


Figure 2. Visualization of the selected scope within the implementation process.

Furthermore, this research is focussed solely on LMIC, due to the problems sketched with adoption being set in this scope. Low- and middle income countries are classified on the basis of gross national income per capita, converted to American dollars using the World Bank Atlas method (World Bank, n.d.). Using this classification, low-income countries have a GNI of \$1,045 or less, lower-middle income countries fall between \$1,046 and \$4,095 and upper-middle income countries fall between \$4,096 and \$12,695. Everything above \$12,695 is classified as a high-income country. The importance herein for focussing on Sub-Saharan Africa can be found in the build-up of this region. Of the 48 countries, 23 countries classify as low-income, 18 classify as lower-middle income, 6 as upper-middle income and only 1 country classifies as high-income (World Bank, 2022).

The aim of this research is to determine existent barriers in adoption of medical technology within the themes in-scope in LMIC, specifically SSA. This determination will be done through a T-shaped case study approach, starting with a multiple case study to determine a preliminary framework of barriers. This framework can then be tested by extending one of the case studies with more perspectives, resulting in a framework that can be used by GOAL3 and other medical technical organizations to inform their strategies on themes in scope.

1.3 SOCIETAL RELEVANCE

The societal impact of this thesis lies within the contribution for the development of medical technologies for SSA. These efforts concluding in a framework entail building on experiences of companies included in the multiple-case study, all being versed with medical equipment implementation in SSA. This summation of experiences provides a better understanding of the problems that are at hand when wanting to have medical technology be adopted by the healthcare systems in SSA. Through providing this understanding, new and existent efforts in developing technologies could be supported in achieving adoption. This in turn could make for a greater presence of functional medical technology in Africa, directly contributing to the third Sustainable Development Goal by the United Nations: Good Health and Well-Being (UN, nd).

1.4 LINK TO COSEM PROGRAMME

This thesis concludes a Master's degree in Complex Systems Engineering and Management (CoSEM). This research connects to the programme by being embedded in two, and connected to the third, of the three pillars that are at the core of the CoSEM programme: complex problems consisting of technological interventions, their surrounding actor systems and the institutional system. The connection of this thesis to this complexity lies in medical technology being viewed as technological intervention in a complex system, consisting of the actor and institutional environment existent in Sub-Saharan Africa. And even if the institutional implications are not discussed in detail within the scope for this research, the interplay of the actors with the technological intervention determine adoption, which is the main topic of this research. Discovering barriers that exist on the verge of this human interaction with technology, is thus fitting to examine in a CoSEM thesis.

1.5 ACADEMIC RELEVANCE

In literature, there are many efforts of implementation and, although less so, adoption frameworks with a specific focus on medical interventions. Damschroder et al. (2009) created the Consolidated Framework for Implementation Research (CFIR), that depicts a menu of constructs associated with effective implementation. This framework already includes a multitude of sources, and arranges its constructs over five domains in order to provide context-specific evaluation of implementation. It however only describes adoption as being one of the outcomes after an implementation process, not yet integrating it into the framework itself as being a domain. It is also not tailored to LMIC.

Lau and Price (2017) made a framework for adoption by clinicians, specifically for eHealth systems. This framework is meant to make sense of this adoption, overarching a multitude of factors explaining the phenomena found within adoption. This framework however is specific to eHealth, bringing a logical emphasis on IT systems and services. The framework was also built specifically upon examples from Canada, a high-income country. Lastly, the most recent framework describing medical technology adoption is the NASSS (e.g. Non-Adoption, Abandonment, Spread, Scale-up and Sustainability) framework by Greenhalgh and Papoutsis (2019). It is meant to help real-time programmes identify and manage their uncertainties and interdependencies. This framework is compared to the other two described above the most wholesome, it was however not made while keeping in mind a low-resource context. The interdependencies depicted might thus also not be representative for LMIC.

The academic relevance for this research is thus to add to this field of knowledge by building a framework specifically applicable to LMIC, possibly depicting differences and similarities with these already built frameworks. Also, it is an addition to academic literature in providing a synthesis of current knowledge on issues within the themes in scope affecting adoption.

1.6 RESEARCH QUESTIONS

This thesis is a qualitative study building a framework by using a T-shaped approach to case studies, filtering a multiple case-study into a detailed single-case study. Using the approach by Eisenhardt (1989) as the structure for the multiple-case study, research questions are determined at the start of the multiple-case study to be able to search for existent constructs as a start of the research process. Based upon the scope and the research problem as presented above, the following research question has been formulated:

How can a medical technology organization overcome barriers in adoption of their medical technology in Low- and Middle- Income Countries?

SQ1: What are maintenance implications to take into account for adoption of medical technology in Low- and Middle Income Countries?

SQ2: What are training implications to take into account for adoption of medical technology in Low- and Middle Income Countries?

SQ3: What are organisational and behavioural implications to take into account for adoption of medical technology in Low- and Middle Income Countries?

SQ4: How can these implications for adoption of medical technologies in Low- and Middle Income Countries be integrated into a framework?

The interlinkage of these questions, and how the sub-questions answer the main research question is visualized in Figure 3.

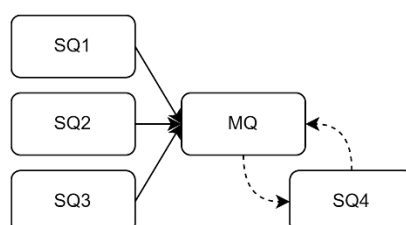


Figure 3. Interlinkage of sub-questions leading to answer of the main research question.

The connection of sub-questions is visualised this way because the answers to the first three sub-questions can already provide an answer to the main research question in this research. Using these answers feed into the build of the framework, which in turns enables the main research question to be answered for specific organizations.

1.7 THESIS OUTLINE

This thesis is built upon the following structure. Chapter 2 contains a literature review, reviewing existent knowledge on the subject of the multiple case study, already going into depth for sub-questions 1, 2 and 3. Chapter 3 contains a detailed overview of the T-shaped case-study approach and further methods used. Chapter 4 contains an analysis of general characteristics of cases included. Chapter 5, 6 and 7 contain the results of the multiple-case study, separated by theme. The findings of research thus far, the multiple case-study, are discussed in Chapter 8, providing a preliminary answer to the main research question. Chapter 9 tests and validates the preliminary framework drawn from discussed findings through the in-depth case studies and expert interviews. Chapter 10 concludes the research with an answer to the main research question, including discussion of the framework that is the result of this thesis.

A schematic overview of these chapters, the connections to the phases of the research approach by Eisenhardt (1989) and the subsequent combination of chapters that provide answers to the research questions can be found in Figure 4.

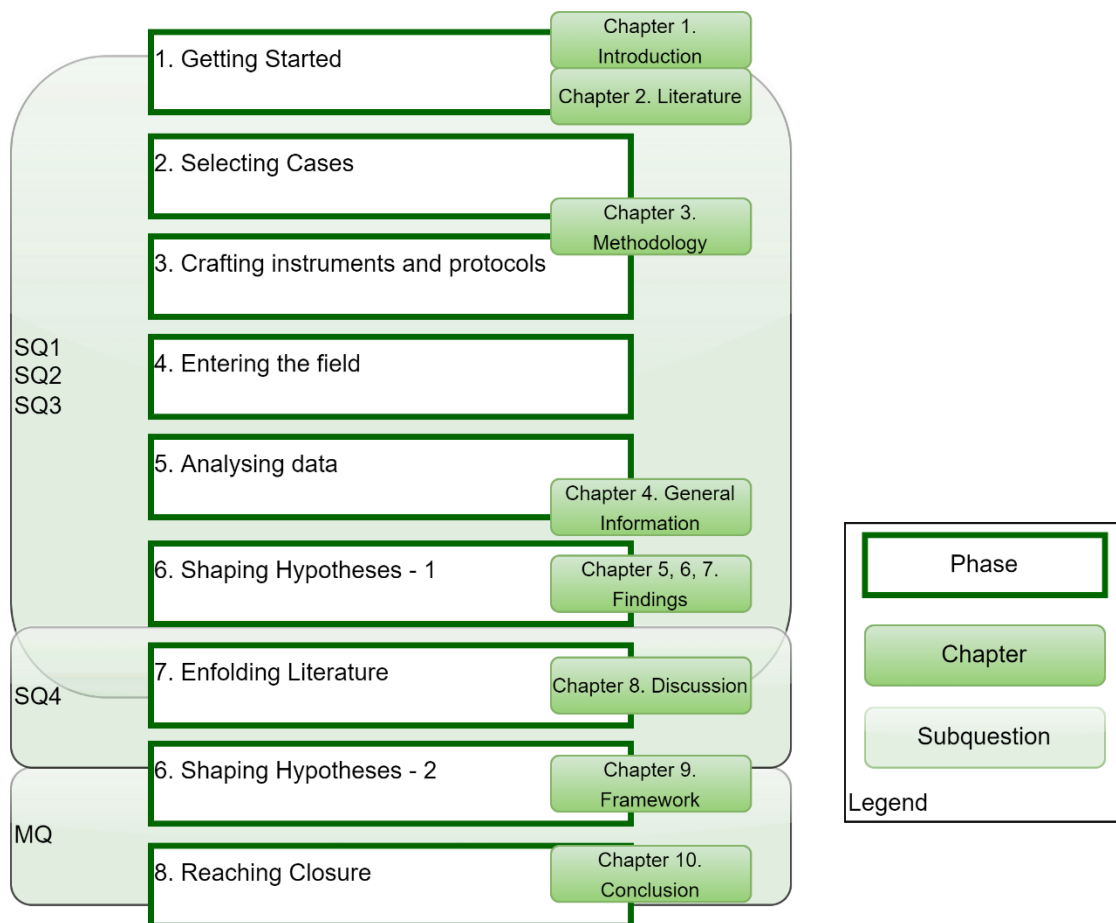


Figure 4. Simplified Research Flow Diagram.

CHAPTER 2. LITERATURE REVIEW

2.1 INTRODUCTION

In this chapter, the current state of knowledge on the themes in scope is determined through an extensive literature review, already providing background for the answer of sub-question 1, 2 and 3. Section 2.2 depicts the search strategy and selection process used to include articles for this review. Section 2.3 gives an overview of the articles that are included, discussing characteristics over the overall field of studies. Section 2.4 discusses the findings per theme, 2.5 discusses overarching and connecting findings between themes. Section 2.6 concludes the literature review with the summarization of current knowledge and the gaps to give structure for the multiple case study.

2.2 SEARCH STRATEGY

To determine if there were any articles discussing all themes in scope, a search was done in both Scopus and Pubmed with the following search strings:

- Maintenance AND (organisational OR organisational OR behaviour* OR behaviour*) AND change AND train* AND medical AND (tech* OR device* OR equipment) AND (lmic* OR (low* AND middle* AND income AND countr*))
- Maintenance[tiab] AND (organisational[tiab] OR organisational[tiab] OR behaviour*[tiab] OR behaviour*[tiab]) AND change[tiab] AND train*[tiab] AND medical[tiab] AND (tech*[tiab] OR device*[tiab] OR equipment[tiab]) AND (lmic*[tiab] OR (low*[tiab] AND middle*[tiab] AND income[tiab] AND countr*[tiab]))

Which lead to 2 results in Scopus and none in PubMed. Only 1 of 2 articles found in Scopus was deemed useful. To ensure coverage within each theme of the scope, this search string was reduced into three parts. This resulted in the following search strings displayed in Table 2.

Theme	SCOPUS	PubMed
Maintenance	Maintenance AND medical AND (tech* OR device* OR equipment) AND (lmic* OR (low* AND middle* AND income AND countr*))	Maintenance[tiab] AND medical[tiab] AND (tech*[tiab] OR device*[tiab] OR equipment[tiab]) AND (lmic*[tiab] OR (low*[tiab] AND middle*[tiab] AND income[tiab] AND countr*[tiab]))
Training	Train* AND medical AND (tech* OR device* OR equipment) AND (lmic* OR (low* AND middle* AND income AND countr*))	Train*[tiab] AND medical[tiab] AND (tech*[tiab] OR device*[tiab] OR equipment[tiab]) AND (lmic*[tiab] OR (low*[tiab] AND middle*[tiab] AND income[tiab] AND countr*[tiab]))
Organisational and Behavioural changes	(organisational OR organisational OR behaviour* OR behaviour*) AND change AND medical AND (tech* OR device* OR equipment) AND (lmic* OR (low* AND middle* AND income AND countr*))	(organisational[tiab] OR organisational[tiab] OR behaviour*[tiab] OR behaviour*[tiab]) AND change[tiab] AND medical[tiab] AND (tech*[tiab] OR device*[tiab] OR equipment[tiab]) AND (lmic*[tiab] OR (low*[tiab] AND middle*[tiab] AND income[tiab] AND countr*[tiab]))

Table 2. Overview of search strings used in separate searches.

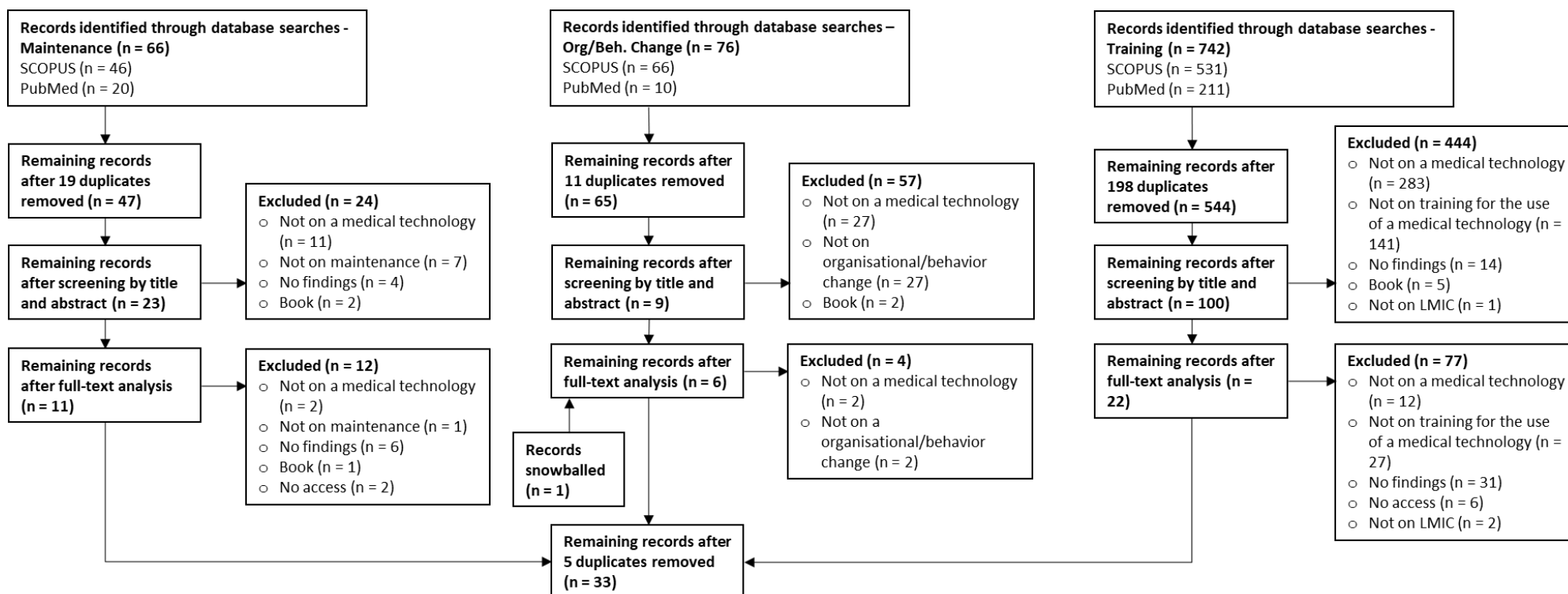


Figure 5. PRISMA chart of the literature search.

The following inclusion criteria were used to determine if articles were to be included for this review: 1) The article has to discuss a type of medical technology. For the purpose of this review, laboratory equipment was disregarded as being medical technology. 2) The article should discuss the theme of the search, being either maintenance, training, organisational / behaviour changes. For the training theme, this specifically meant training on the use of the medical technology. 3) The article should have findings on the theme discussed. 4) The article should have a focus on LMIC. 5) The article should be accessible. 6) The article should be a scientific article, and thus not be a (chapter of) a book.

The exclusion process was done separately per search, resulting in articles included per theme. Finally, the articles included per search were compared on duplicates, resulting in a total of 34 articles included in this literature review. The PRISMA chart of the search can be found in Figure 5. The articles were not cross-checked on including notions of a theme from a different search during title and abstract screening, due to this requiring full-text analysis. The cross-check was thus only done in the full-text analysis step, only leading to cross-overs in articles that were present in a multitude of the searches. The search term 'health' was in this review disregarded to ensure a focus on a body of literature not including medicine or laboratory equipment. This might have however lead to the missing of articles in-scope.

2.3 OVERVIEW OF SELECTED ARTICLES

An overview of the articles included can be found in Table 3. The table summarizes the technologies discussed and the geographical scope of the study. The righter columns stand for the themes in scope: maintenance (M), training (T) and organisational and/or behavioural changes (OB). The X's in the columns depict if the theme was discussed in the article.

	Article	Medical Technology	Geographical Scope	M	T	OB
1.	(Adams & Dobson, 2019)	Anaesthetic equipment	Uganda	X		
2.	(Ayah et al., 2020)	Maternal, neonatal and child health equipment	Sub-Saharan Africa	X		
3.	(Barkley et al., 2021)	Brain surgery equipment	Cambodia	X		
4.	(Brooke-Sumner, Petersen-Williams, Kruger, Mahomed, & Myers, 2019)	Health innovations	South Africa			X
5.	(Burger et al., 2021)	Radiotherapy	Cape Town, South Africa		X	
6.	(Choy, Kitto, Adu-Aryee, & Okrainec, 2013)	Laparoscopy	West Africa			X
7.	(Cowden et al., 2020)	Infection prevention interventions	Zambia			X
8.	(Dasari, Garbett, Miller, Machaín, & Puyana, 2016)	Electronic Health Records	Asuncion, Paraguay			X
9.	(Denny et al., 2021)	Ultrasound	Tanzania		X	
10.	(Diaconu et al., 2017)	Medical devices in general	LMIC in general	X	X	
11.	(Gaziano et al., 2015)	Risk assessment instrument	Bangladesh, Guatemala, Mexico, South Africa		X	
12.	(Hallweaver, McBeth, Stolz, Struder, & Schick, 2019)	Ultrasound	Low-resource settings		X	
13.	(Jiang et al., 2020)	Task shifting device for subcutaneous contraceptives	Ethiopia		X	

	Article	Medical Technology	Geographical Scope	M	T	OB
14.	(E. T. Kim, Singh, Moran, Armbruster, & Kozuki, 2018)	Obstetric ultrasound	LMICs in general	X	X	
15.	(J. Kim et al., 2021)	Obstetric ultrasound	Nepal	X	X	X
16.	(Labrique et al., 2018)	Digital health	LMICs in general		X	
17.	(Makokha-Sandell et al., 2020)	Vacuum extraction	Dar es Salaam, Tanzania		X	
18.	(Marks, Thomas, Bakhet, & Fitzgerald, 2019)	Donated surgical and anaesthesia equipment	Low-resource settings	X	X	
19.	(Masekela, Zurba, & Gray, 2019)	Spirometry	Africa		X	
20.	(McDonald, Fabbri, Parker, Williams, & Bero, 2019)	Donated medical equipment	LMICs in general		X	
21.	(McGuire & Weigl, 2014)	Medical devices for cardiovascular diseases	LMICs in general		X	
22.	(Merali, Visick, Amick, & Savich, 2020)	Neonatal care devices	LMICs in general		X	
23.	(Moyimane, Matlala, & Kekana, 2017)	Medical equipment	South Africa	X		
24.	(Muinga et al., 2020)	Digital health systems	Kenya		X	
25.	(O'Donnell, Kaner, Shaw, & Houghton, 2018)	Electronic medical records	North and South America, Europe, Middle East and Hong Kong		X	
26.	(Oosting, Wauben, Groen, & Dankelman, 2019)	Basic surgical equipment	9 countries across Africa	X		
27.	(Opie & Huynh, 2021)	Radiation therapy	Asia		X	
28.	(Rwebembera et al., 2021)	Cardiac catheterization	Uganda		X	
29.	(Sabiiti et al., 2016)	Molecular diagnostics	High burden TB settings		X	
30.	(Siddharthan et al., 2021)	Bronchoscopy	Uganda		X	
31.	(Silva & Viana, 2011)	CT scanners	Brazil			X
32.	(Tosif et al., 2018)	Basic equipment for neonatal care	Solomon Islands	X		
33.	(Zubizarreta, Fidarova, Healy, & Rosenblatt, 2015)	Radiotherapy	LMICs in general		X	

Table 3. Overview of selected articles for the literature review.

To be able to compare articles, the variety of articles and thus comparability has to be discussed. It is apparent that the theme most discussed is training. Within this theme, a total of 22 articles were included. Following this topic is maintenance, covering a total of 10 articles. Between training and maintenance there is an overlap of 3 articles (Diaconu et al., 2017; E. T. Kim et al., 2018; Marks et al., 2019). Organisational and behavioural changes are least discussed, only within 6 of the included articles. It has no individual overlap with one of the other themes. There is, as mentioned in section 2.2, one article with mentions of every theme of interest within the study (J. Kim et al., 2021).

2.3.1 MEDICAL TECHNOLOGIES

There is a wide variety of medical technologies presented, of which a high-level categorization can be made. A large part of the studies discuss diagnostic devices, varying from molecular diagnostics (Sabiiti et al., 2016) and spirometry (Masekela et al., 2019) to different imaging techniques. The imaging techniques can be further classified as ultrasound (Denny et al., 2021; Hallweaver et al., 2019; E. T. Kim et al., 2018; J. Kim et al., 2021), bronchoscopy (Siddharthan et al., 2021) and computed tomography (Silva & Viana, 2011). The second category discussed is digital health. Advances in electronic health records are discussed (Dasari et al., 2016; O'Donnell et al., 2018), as well as innovations in eHealth (Brooke-Sumner et al., 2019; Labrique et al., 2018; Muinga et al., 2020). The third category consists of equipment needed for surgery, encompassing anaesthetics (Adams & Dobson, 2019; Marks et al., 2019) and surgical equipment for the bigger surgical interventions (Barkley et al., 2021; Choy et al., 2013; Oosting et al., 2019). There are also articles discussing equipment for smaller surgical interventions (Jiang et al., 2020; Makokha-Sandell et al., 2020; McGuire & Weigl, 2014; Rwebembera et al., 2021). A final categorization made is equipment for maternal, neonatal and child health (Ayah et al., 2020; Merali et al., 2020; Tosif et al., 2018). Lastly, Diaconu et al. (2017), McDonald et al. (2019) and Moyimane et al. (2017) do not belong to any of these categories specifically, discussing medical equipment in general.

2.3.2 GEOGRAPHICAL BOUNDARIES

Even if the review itself does not have geographical boundaries, the geographical scope is still important to consider before analysing the results. Of the studies that had geographical boundaries, Africa as a continent was mostly represented having 14 articles based upon either one or more countries within Africa. Of these 14 articles, 11 articles had a scope of a singular country. The countries discussed were Uganda (Adams & Dobson, 2019; Rwebembera et al., 2021; Siddharthan et al., 2021), South-Africa (Brooke-Sumner et al., 2019; Burger et al., 2021; Moyimane et al., 2017), Tanzania (Denny et al., 2021; Makokha-Sandell et al., 2020), Kenya (Muinga et al., 2020), Ethiopia (Jiang et al., 2020) and Zambia (Cowden et al., 2020). The remaining 3 articles with a focus on Africa had a bigger scope, varying between West-Africa (Choy et al., 2013), Sub-Saharan Africa (Ayah et al., 2020) and Africa as a whole (Masekela et al., 2019). Furthermore, there were 4 studies with a focus on South America (Dasari et al., 2016; Gaziano et al., 2015; O'Donnell et al., 2018; Silva & Viana, 2011) and 3 studies with a focus on Asia (Opie & Huynh, 2021). The studies that did not have a specific geographical scope, but discussed LMIC or low-resource settings in general were mostly reviews (Diaconu et al., 2017; Hallweaver et al., 2019; E. T. Kim et al., 2018; Marks et al., 2019; McDonald et al., 2019; McGuire & Weigl, 2014; Zubizarreta et al., 2015), though also including one multiple case study (Labrique et al., 2018) and one survey (Merali et al., 2020).

2.4 FINDINGS PER THEME

Before comparing the findings of the articles with each other between themes, the findings per theme are discussed. The purpose of this is to give an overview of the status of knowledge of each field as though not being interconnected before trying to find possible interconnections of the themes with each other.

2.4.1 MAINTENANCE

Of the 33 articles included, 10 articles had findings on maintenance of medical technologies in LMIC. A more in-depth overview of these papers is given in Table 4, describing the purpose of each study and depicting if the technology discussed was donated equipment (Do), bought equipment (B) or if the study was focused on the design of the equipment described (De).

	Article	Purpose	Do	B	De
1.	(Adams & Dobson, 2019)	Providing an understanding of the workings of anaesthetic equipment			X
2.	(Ayah et al., 2020)	Description of setting up of the Maker Hub using a product development partnership approach			X
3.	(Barkley et al., 2021)	Assessing traumatic brain injury care in LMIC to build neurocritical care capacity in Cambodia	X	X	
4.	(Diaconu et al., 2017)	Review of methods for medical device and equipment procurement and prioritization in LMIC		X	
5.	(E. T. Kim et al., 2018)	Reviewing the use of obstetric ultrasound in LMIC	X	X	
6.	(J. Kim et al., 2021)	Evaluating an obstetric ultrasound education program in Nepal	X	X	
7.	(Marks et al., 2019)	Reviewing literature and guidelines for surgery and anaesthesia in LMIC		X	
8.	(Moyimane et al., 2017)	Compiling the experiences of nurses on the critical shortage of medical equipment in a rural hospital	X	X	
9.	(Oosting et al., 2019)	Assessing the availability, barriers and need for novel design of equipment for essential surgical care			X
10.	(Tosif et al., 2018)	Assessing the quality of neonatal care	X	X	

Table 4. Overview of the articles included for maintenance.

All articles discuss that maintenance is an issue in LMIC, although the source of this issue seems to be unclear. A possible cause is a lack of investment and funding regarding the maintenance aspects of medical technologies (Diaconu et al., 2017; Marks et al., 2019). Another problem that might cause maintenance issues is the presence of biomedical engineers in LMICs, or rather the lack thereof. This in turn causes sites to have no access to maintenance (Adams & Dobson, 2019; Marks et al., 2019; Oosting et al., 2019). Barkley et al. (2021) state that older models of machines present in hospitals make it harder to be able to do maintenance, due to spare parts not being manufactured anymore. J. Kim et al. (2021) highlights the difficulties of providing maintenance in rural areas.

These hardships in providing maintenance in turn have negative effects on the medical technology that is present in LMIC. The lack of maintenance causes machines to break (Oosting et al., 2019). The shortages of medical technology are even stated to be partly due to the combination of poor quality of the technologies present and the poor quality of maintenance these machines receive (Diaconu et al., 2017; Moyimane et al., 2017). All in all, there is a clear need for improved maintenance of equipment. Some papers propose doing this through a better maintenance system, leaving no machines unrepaired (Barkley et al., 2021; E. T. Kim et al., 2018; Tosif et al., 2018). Moyimane et al. (2017) go further into detail, stating that this would require planning, management and implementation controlled by the financial, physical and human resources available.

A few articles discuss the needs that exist that, if met, could possibly benefit existing maintenance issues. Ayah et al. (2020) propose that locally produced simple devices take away the financial strain on maintenance. Other studies emphasize that taking maintenance into account during training, be it preventive, short- and long-term, is necessary to ensure a longer lifespan of medical technologies in LMIC (Diaconu et al., 2017; E. T. Kim et al., 2018; Marks et al., 2019).

2.4.2 TRAINING

Of the 33 articles included, 22 articles included findings on training of medical technologies in LMIC. A more in-depth overview of these papers is given in Table 5 describing the purpose of each study and depicting if the technology discussed was donated equipment (Do), bought equipment (B) or if the study was focused on the design of equipment (De).

	Article	Purpose	Do	B	De
1.	(Burger et al., 2021)	Reporting activities of a radiotherapy education programme	X	X	
2.	(Denny et al., 2021)	Review of a four-year ultrasound teaching program	X	X	
3.	(Diaconu et al., 2017)	Review of methods for medical device and equipment procurement and prioritization in LMIC		X	
4.	(Gaziano et al., 2015)	Assessment of health workers' ability to screen for cardiovascular disease risk with a non-invasive instrument			X
5.	(Hallweaver et al., 2019)	Reviewing ultrasound in LMIC	X	X	
6.	(Jiang et al., 2020)	Assessing the usability of a task-shifting device for inserting subcutaneous contraceptive implants			X
7.	(E. T. Kim et al., 2018)	Reviewing the use of obstetric ultrasound in LMIC	X	X	
8.	(J. Kim et al., 2021)	Evaluating an obstetric ultrasound education program in Nepal	X	X	
9.	(Labrique et al., 2018)	Finding the best practices in the scaling of digital health in LMIC		X	
10.	(Makokha-Sandell et al., 2020)	Trying to find the reason of the low use of vacuum extraction	X	X	
11.	(Marks et al., 2019)	Reviewing literature and guidelines for surgery and anaesthesia in LMIC		X	
12.	(Masekela et al., 2019)	Giving commentary on challenges and solutions for spirometry access	X	X	
13.	(McDonald et al., 2019)	Assessing the compliance of donations with WHO guidelines	X		
14.	(McGuire & Weigl, 2014)	Review of medical devices and diagnostics for cardiovascular diseases in LMIC	X	X	
15.	(Merali et al., 2020)	Speaking with global trainers in the helping babies survive programme on lessons learned over the years	X		
16.	(Muinga et al., 2020)	Survey on the status of digital health systems among County Health Records Information Officers		X	
17.	(O'Donnell et al., 2018)	Compiling the attitudes of primary care physicians on the adoption of electronic health records		X	
18.	(Opie & Huynh, 2021)	Reviewing current status of training of radiation therapy technologists	X	X	
19.	(Rwebembera et al., 2021)	Reviewing eight years of a public cardiac catheterization laboratory	X	X	
20.	(Sabiiti et al., 2016)	Describing the optimisation of molecular diagnostic capacity of tuberculosis			X

	Article	Purpose	Do	B	De
21.	(Siddharthan et al., 2021)	Description of the development of a pilot program for assessing bronchoscopy training and program initiation			X
22.	(Zubizarreta et al., 2015)	Description of the need for radiotherapy in LMIC	X	X	X

Table 5. Overview of articles included in training theme.

Seeing that training is most widely discussed of the three themes, it is clear that training is seen as an important theme when discussing medical equipment in LMIC. Most studies mention a lack in training, be it in overall training (Masekela et al., 2019), regularity of training (Burger et al., 2021; Hallweaver et al., 2019; J. Kim et al., 2021; Marks et al., 2019; Merali et al., 2020; O'Donnell et al., 2018), structured training (Makokha-Sandell et al., 2020) basic training in med school (Denny et al., 2021; J. Kim et al., 2021) or a lack of adequate training (Muinga et al., 2020; O'Donnell et al., 2018). Some articles discuss that even if end-user training is adequate, there is a lack of training the surrounding personnel on the implementation of the technology (E. T. Kim et al., 2018; Labrique et al., 2018; Makokha-Sandell et al., 2020). Studies included discuss possible causes for this lacking of training, the effects this lack of training has and the needs for training that exist. Furthermore, studies discuss learnings gathered on training over the years, compiling them into best-practices and important tips for designing training programs.

CAUSES AND EFFECTS OF LACK OF TRAINING

With lack of training being an apparent problem, it is important to distinguish possible causes of this lack of training, and the effects on adoption and functionality of medical equipment. Siddharthan et al. (2021) is one of two studies providing causes of a lack of training overall: prohibitive costs and lack of training providers. Burger et al. (2021) takes this notion of cost prohibition as being the prohibitive nature of the costs of training materials. The effects of lack of training is not widely discussed. The most damaging result seems to be the shortening of the useful lifespan of the technologies that are present due to inexperience (Diaconu et al., 2017; Marks et al., 2019; McDonald et al., 2019). What can be logically concluded though, is that with a lack of overall training on the use of medical technologies, the technologies might be unusable, which can then directly lead to the aforementioned shortage of functional medical technologies in LMIC.

The effects of regular training are discussed by some of the authors. J. Kim et al. (2021) state that the lack of regular training is a barrier to adoption. Hallweaver et al. (2019) discuss the importance of an increase in training in order to upkeep the skills necessary for ultrasound adoption. This is adhered by Merali et al. (2020), Marks et al. (2019) and O'Donnell et al. (2018), discussing the same phenomenon for a range of medical technologies. Burger et al. (2021) proposed a possible issue solved by regular training, due to a problem with retention of skills with equipment over longer periods of time if not used regularly.

TRAINING NEEDS AND BEST PRACTICES

Besides the described causes and effects of the lack of training, training needs and best practices were discovered. Some studies found that there is a need for accreditation after a training is completed (J. Kim et al., 2021; Masekela et al., 2019). Masekela et al. (2019) state the importance of training programmes be standardised and context specific, partly contradicting the statement of Labrique et al. (2018) stating that training should be easy to replicate and roll out at large. The contextualised training need is more widely recognized (Makokha-Sandell et al., 2020; Opie & Huynh, 2021; Siddharthan et al., 2021). Makokha-Sandell et al. (2020) even state that usage of vacuum extraction by doctors only changed if the training was contextualised.

Another positive influence on training within contextualisation, is incorporation of daily practices of the user into the training materials. This incorporation builds the confidence of the user, improving adoption (J. Kim et al., 2021; Marks et al., 2019). This need for confidence-building is also mentioned by Sabiiti et al. (2016), stating it is necessary to achieve self-sustenance.

There are also needs connected to community aspects of the trainings given. Engagement of local communities and stakeholders is seen to be beneficial to the outcomes of training (McGuire & Weigl, 2014; Merali et al., 2020). To provide the training and training materials in the local language is seen as a pre (Gaziano et al., 2015; Merali et al., 2020). E. T. Kim et al. (2018) emphasize the importance of the training provided not interrupting the schedules of health workers. Besides these factors that can be incorporated in the training itself, there are also some needs mentioned that are connected to training but not within the programme. One of them is the need for devices to be simple in design, in order to have them be used properly according to McGuire and Weigl (2014). Another need exists in the assessment of training prior to donations, in order to have these donations be successful (McDonald et al., 2019).

2.4.3 ORGANISATIONAL AND/OR BEHAVIOURAL CHANGE

Of the 33 articles included, only 6 articles discussed findings on organisational and/or behavioural changes need for medical technologies in LMIC. A more in-depth overview of these papers is given in Table 6, describing the purpose of each study and depicting if the technology discussed was donated equipment (Do), bought equipment (B) or if the study was focused on the design of equipment (De).

	Article	Purpose	Do	B	De
1.	(Brooke-Sumner et al., 2019)	Investigating perceptions of health service managers on implementation of health services		X	
2.	(Choy et al., 2013)	Looking for barriers in the uptake of laparoscopic surgery		X	
3.	(Cowden et al., 2020)	Compiling perceptions of healthcare workers of the implementation context of an infection prevention intervention		X	
4.	(Dasari et al., 2016)	Describing the process of implementation of an electronic health surgical registry		X	
5.	(J. Kim et al., 2021)	Evaluating an obstetric ultrasound education program in Nepal	X	X	
6.	(Silva & Viana, 2011)	Looking at the diffusion of CT scanners in Brazil	X	X	

Table 6. Overview of articles included in the organisational/behavioural change theme.

The topics of organisational change and behaviour change are not discussed as widely as maintenance and training, and even less as problem area. Some articles do touch upon factors hinting that there might be barriers within this theme impeding adoption of medical technology. Brooke-Sumner et al. (2019) describe that a lack of understanding of the technology by health workers constraints adoption. They also state that the health system might portray resistance to change, due to high workloads. These high workloads are also described by Cowden et al. (2020), more specifically a physical crowding of patients combined with understaffing, which in turn impedes organisational readiness for change. This organisational readiness for change is being recognized as a necessity for adoption for medical technology.

Choy et al. (2013) see this organisational readiness mostly as being financially ready, which is partially backed up by the notion of Silva and Viana (2011) that organisational change is dependent upon expected financial returns of the investment. Dasari et al. (2016) see this organisational readiness for change being more of an individual readiness of the end-users to be able to use the technology, and are thus also the only study with a detailed mention of the behaviour change needs that come with adoption of medical technologies. A last mention of an organisational constraint on adoption, is improper regulation by authorities causing problems in adoption of medical technologies (Silva & Viana, 2011).

Contrasting to the themes of training and maintenance, this theme is underdiscussed. There is not yet a mention of organisational factors like spare parts or consumables management. Also, the acknowledgement of behaviour changes and how this could affect adoption of medical technologies seem to be not yet researched.

2.5 CONNECTED FINDINGS

Since the purpose of this review is not only to find the status of knowledge on the individual themes, but also the interconnections within those themes, connected findings are discussed. Firstly, the articles that are present in multiple searches are discussed. Then, connections within themes found through comparing of topics within the literature are explored.

2.5.1 ARTICLES PRESENT IN MULTIPLE SEARCHES

The included articles per theme were compared on duplicates. J. Kim et al. (2021) is the only article discussing aspects of maintenance, training and organisational change. It does however not discuss all these aspects into detail. The only mention on maintenance is that it is difficult for rural areas. As for organisational aspects, it states that there is ambiguity in policies on the use of ultrasound and the validation of results. Also, there are restrictions on how to certify personnel for use. The article discusses the training in detail, being an evaluation of a training programme on obstetric ultrasound use. The findings on training include that training overall does not meet standards set by the WHO. It is stated to be already limited in med-school, followed by a lack of regular training that is needed for adoption of the medical technology. The training connects back to the need for knowledge on after what training a health worker is certified to perform ultrasound.

Besides this, there are three studies that were included in both the maintenance and the training search. E. T. Kim et al. (2018) discusses in a narrative review that the establishment of a maintenance protocol can be hard in low-resource settings, leaving machines unrepaired. There is a focus on the importance of an integrated training module that incorporates training management personnel on establishing such maintenance protocols. Furthermore it discusses the importance of training not only including machine use, but also extending the curriculum into care and ethics. Marks et al. (2019) discuss challenges in the donation of medical equipment to LMIC. They state that the reduction in useful lifespan of materials is due to the combination of inexperienced operators and the lack of repair. Diaconu et al. (2017) also touch upon the combination of lack of training and maintenance being at the root of the problem of the large portion of medical technologies in LMIC being broken, unused or unfit. They state that procurement tends to neglect maintenance, servicing and training requirements.

2.5.2 INTERCONNECTIONS IN THEMES

Besides the articles that were found in a multitude of the searches, there were articles discussing similar topics in different themes, showing interconnections. These interconnections are explained underneath. The first topic of interest in all themes is the financial needs present in each of the aspects discussed, and the difficulties financial restrictions propose. The lack of resources it has as an effect, impacts both materials and personnel needed for proper maintenance and training. It also impedes the procurement process on the organisational side.

Another aspect connecting maintenance and training financially, is the lack of considering needs connected to these themes within the procurement process of medical technologies in LMIC.

The training topic seems to be a connecting factor between the three themes in scope. Other articles, outside of the ones included in both the maintenance and training search, speak of the importance of having maintenance factors be integrated into the training program (McDonald et al., 2019; McGuire & Weigl, 2014). Organisational factors, including management of maintenance, finances, human resources and other managerial factors should be included into a training program for supervisors of the end-user of the actual medical technology. This is however only mentioned by a small amount of the studies included.

2.6 CONCLUSION

The purpose of this review was to gain insights into existent barriers within scope, already touching upon the first three sub-questions. To summarize the barriers already found in literature that have to be taken into account when constructing the case study protocols, the barriers are organized per theme, and thus sub-question, in Table 7.

Theme	Barrier
Maintenance	Non-existence of maintenance systems Financial resources Accessibility
Training	Irregularity Language Availability of materials Basic knowledge Financial resources Time Context-specificity
Organisational / Behaviour changes	Readiness Workload

Table 7. Overview of barriers found within literature review.

To contextualize the barriers already found within this literature review, further investigation is needed into the strategies that are taken by organizations implementing their medical technologies in LMIC. The multiple case study can uncover barriers not found within this review, subsequently creating narratives surrounding those barriers. To ensure there is comparability among cases, the geographical scope is limited to Sub-Saharan Markets, enabling the advice to be constructed with the framework be applicable to GOAL3. The setting of this geographical scope asks for a re-phrasing of the research questions determined in Chapter 1:

How can a medical technology organization overcome barriers in adoption of their medical technology in Sub-Saharan Africa?

SQ1: What are maintenance implications to take into account for adoption of medical technology in Sub-Saharan Africa?

SQ2: What are training implications to take into account for adoption of medical technology in Sub-Saharan Africa?

SQ3: What are organisational and behavioural implications to take into account for adoption of medical technology in Sub-Saharan Africa?

SQ4: How can these implications for adoption of medical technologies in Sub-Saharan Africa be integrated into a framework?

In the following chapter, the approach and methods to conduct this research are explained. This builds upon further knowledge needed to answer the first three sub-questions, consequently preparing for the build of the framework and the answer of the main research question.

CHAPTER 3. METHODOLOGY

3.1 INTRODUCTION

With current knowledge on the themes within scope reviewed, the detailed approach and methodologies for this research are determined. Section 3.2 elaborates upon the chosen research approach, reasoning why this combination of known approaches was chosen. To be able to visualize this, the simplified research flow diagram from chapter 1 is detailed in section 3.2. With the approach determined and explained, the case selection is discussed in section 3.3. Then, the procedures of conduct for the multiple case study are explained in section 3.4 as being the data collection methods for this research. Then, data analysis is explained in section 3.5. Within section 3.6, the validation of the framework is elaborated upon. Finally, section 3.7 provides a conclusion to this chapter.

3.2 RESEARCH APPROACH

The motivation for doing a case study lies in “the desire to derive a(n) (up-)close or otherwise in-depth understanding of a single or small nr of cases set in their real-world contexts” (Bromley & Dennis Basil, 1986, p. 1). Since answering the main research question asked for exploratory research, a case-study approach was chosen. This exploratory approach researches operational links over time. A case-study approach is also recommended if wanting to cover contextual contexts of a problem as well as the problem itself (Yin, 2012). This was also an objective within this research, since not only internal factors of influence were investigated.

The case study approach also gave the opportunity to build the framework, with the framework serving as a theoretical lens for the problem at hand. Because generalizability within case study research is difficult using only one case, a multiple-case study approach was chosen. Cases were chosen following replication logic, each case serving as its own unit of analysis (Eisenhardt, 1989). The units of analysis were chosen to represent different entities of medical technologies, to be able to cover a larger scope of barriers that might exist in a SSA. To build the theoretical lens, one of the case studies was extended into an in-depth case study. This was done to ensure the most complete view possible on these barriers, while being able to complete the research in the limited timeframe.

This research followed the process as described by Eisenhardt (1989) combined with the notions of Greene and David (1984). This combination was chosen to ensure both the build of a framework and generalizability of multiple case. To be able to do the T-shaped approach (e.g. the multiple case study leading into an in-depth case study), the in-depth case study was regarded as limit-testing of the multiple case studies. This adjusted process proposed by Eisenhardt (1989) combined with steps from Greene and David (1984) can be found in Table 8. Because the objective research is to design a framework concluding from the case studies, the conceptual framework serving as the first step from the Greene and David (1984) method was included in the data analysis, instead of in one of the first steps for this research.

	Step	Activity	Reason
1.	Getting started	Definition of research question Possibly a priori constructs Neither theory nor hypotheses	Focuses efforts Provides better grounding of construct measures Retains theoretical flexibility
2.	Selecting cases	Specified population / <u>Defining target population</u> Theoretical, not random, sampling	Constrains extraneous variation and sharpens external validity Focuses efforts on theoretically useful cases – i.e., those that replicate or extend theory by filling conceptual categories / <u>Ensuring the accurate representation of population</u>
3.	Crafting instruments and protocols	Multiple data collection methods Qualitative and quantitative data combined <u>Procedures of conduct</u>	Strengthens grounding of theory by triangulation of evidence Synergistic view of evidence <u>Ensuring comparability of cases</u>
4.	Entering the field	Overlap data collection and analysis, including field notes Flexible and opportunistic data collection methods	Speeds analyses and reveal helpful adjustments to data collection Allows investigators to take advantage of emergent themes and unique case features
5.	Analysing data	Within-case analysis Cross-case pattern search using divergent techniques	Gains familiarity with data and preliminary theory generation Forces investigators to look beyond initial impressions and see evidence through multiple lenses
6.	Shaping hypotheses	Iterative tabulation of evidence for each construct Replication, not sampling, logic across cases Search evidence for "why" behind relationships <u>Making a conceptual framework</u>	Sharpens construct definition, validity and measurability Confirms, extends, and sharpens theory Builds internal validity <u>Giving a superordinate structure of the found constructs within research</u>
7.	Enfolding literature	Comparison with conflicting literature Comparison with similar literature <u>Validating framework constructs</u>	Builds internal validity, raises theoretical level, and sharpens construct definitions Sharpens generalizability, improves construct definition, and raises theoretical level <u>Builds internal and external validity, testing limits of the constructs</u>
8.	Reaching closure	Theoretical saturation when possible	Ends process with marginal improvement becomes small

Table 8. The research approach, consistent of the structure and steps of Eisenhardt (1989) altered through the addition of the underlined steps originating in the multiple-case study approach of Greene and David (1984).

A visual overview of the approach is given following phases that this research took is given in Figure 6. It depicts how these phases were executed through certain research activities, and which sub-questions were subsequently answered. The relations of these phases and activities to the chapters in this thesis are also shown. The grey boxes depict sub-deliverables that are not necessarily shown within chapters but do show importance in this research.

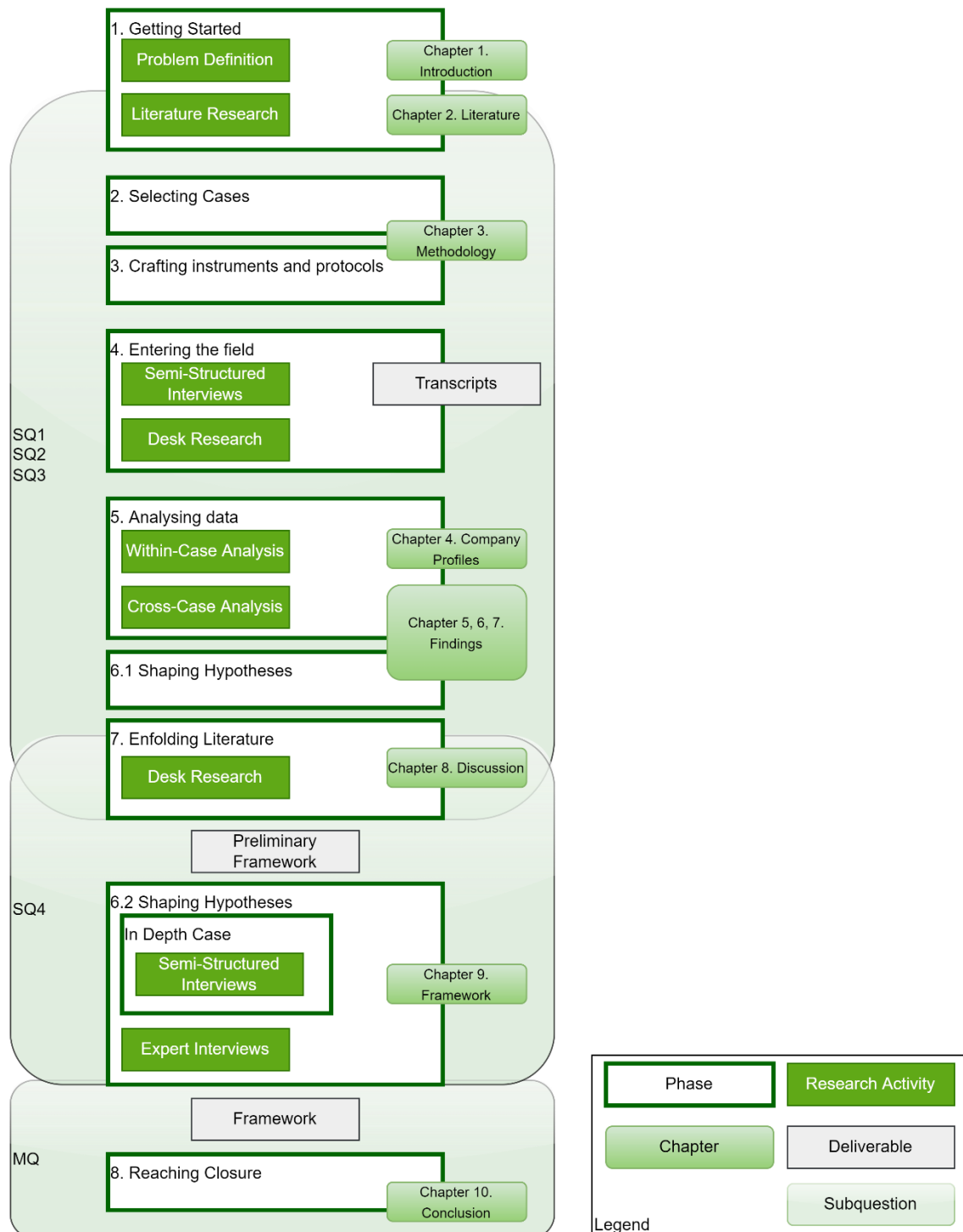


Figure 6. Detailed Research Flow Diagram.

3.3 CASE SELECTION

Both Eisenhardt (1989) and Greene and David (1984) emphasize the importance of selection of cases when doing multiple-case study research. Eisenhardt (1989) discusses this selection through theoretical sampling. This is done to ensure that the selected cases are likely to replicate or extend theory. Greene and David (1984) speak of a sampling plan, with the goal of obtaining a set of cases that vary in explanatory factors. Combining those logics into a selection of cases that might uncover new barriers in adoption, but also strengthen the current constructs of barriers thus requires a certain resemblance, but also dissimilarities between cases. These differences allow the uncovering of barriers and characteristics determining those barriers while doing the cross-case analysis.

For this research, the cases selected were also dependent upon reachability and availability of interviewees of interest. The organizations chosen had experience with maintenance, training and organisational/behavioural changes that come with the adoption of medical technologies. Furthermore, the organizations had experience in at least one country in SSA. The companies differed in size and scope, as well as medical technology. This resulted in the six companies shown, with a summation of characteristics, in Table 9. Company 3 is split in a and b since both the Ghanaian and Dutch branch of the company were spoken with, and they do differ in some characteristics.

Nr.	Category	Medical Technology	Bought / Developed	Country of origin	Employees	Geographical Scope	Founded
1.	Foundation	Donated Equipment	Bought Equipment	Australia	6	>25 countries within Africa	2010
2.	For profit	Anaesthesiology	Developed in-house	UK	8	<25 countries within Africa	2000
3a. 3b.	For profit	X-Ray, AI software	Developed in-house	NL	12 25	15 to 20 in total 62 in total	2016 2003
4.	NGO	Ventilators, CPAP	Developed in-house	USA	9	3 countries in total	2018
5.	Foundation	Wide range	Partnerships / Developed by corporate	NL	6	>25 countries in Africa	2014
6.	For profit	Technology-powered diagnostics	Partnerships / Connective platform in-house	Kenya	130	Kenya, South Africa	2019

Table 9. Overview of selected companies for case studies.

3.4 PROCEDURES OF CONDUCT

As was stated in the research approach elaborated upon in the section 3.2, the case studies were held through a procedure of conduct to ensure a comparability between cases. These procedures of conduct were partially dictated by the results found in the literature review from phase 1, that can be found in the previous chapter. This literature review in this sense served the purpose of “enhancing and gaining subject vocabulary” (Hart, 2018, p. 31). This way, the existent constructs needed for concluding phase 1 were found.

3.4.1 MULTIPLE CASE STUDY

Moving on, the procedures of conduct for the multiple-case study were constructed. As seen in Figure 6, the case studies consisted of a combination of desk research and semi-structured interviews. The desk research was done on information available on the internet and sales brochures if provided by the company, giving context to interviews done with a company executive on strategies regarding the themes in scope. The interviews gave an understanding of the topics of interest, while allowing the interviewee to elaborate upon topics they have knowledge on (Stuckey, 2013). The topics and questions for these interviews are summarized in Table 10. The complete interview protocols guiding these interviews can be found in Appendix A. Further materials used are summarized in Appendix B.

Theme	Main Question	Probes
General Information	Can you shortly introduce your company for me?	Medical Technology Intended use Intended users Nr. of countries active Nr. of persons active Years active Nr. of offices
	What do you do within the company?	Role Field experience in LMIC
Maintenance	What was your strategy for maintenance regarding your technology? And how has this changed over time?	Initial strategy Design / Preventive / Training / Manuals Personal experiences
	How did you decide on this strategy?	Basis of knowledge Own research
	<i>If not discussed: What were your own experiences when testing and using your technology, regarding maintenance?</i>	<i>Examples of success</i> <i>Examples of failure</i>
Training	What was your strategy on training the intended users? And how has this changed over time?	Initial strategy Remote / On-site Manuals
	How did you decide on this strategy?	Basis of knowledge Own research
	<i>If not discussed: What were your own experiences when testing and using your technology, regarding user training?</i>	<i>Examples of success</i> <i>Examples of failure</i>
Organisational / Behavioural Change	Does your product influence the daily practices of hospital staff? If so, did you support this, and how?	Behaviours Routines Organisational processes
	How did you account for organisational features that ensure proper and long-term use of your products?	Consumables Spare parts Regulatory alterations Certifications

Table 10. Overview of questions asked within interviews with companies in multiple case study.

3.4.2 IN-DEPTH CASE STUDY

Since the in-depth case study served as both a limit-testing and partly validating tool for the preliminary framework built through the cross-case analysis, the questions asked within these interviews were determined after the build of the framework. The goal for these interviews was to gain insights from other perspectives connected to the topics discussed and analysed within the multiple-case study. The perspectives interviewed were:

- An anaesthetic nurse working in Somaliland with anaesthetic equipment of company 2, also being responsible for the maintenance of this equipment;
- A NICU nurse from Zambia working with the bubble CPAP equipment of company 2;
- The sales & marketing coordinator of company 2.

The questions asked regarded characteristics of the implementation situation in which the interviewee was present, followed by questions based upon the indications given by the framework based upon these characteristics. This way the profile that was sketched using the company case study could be tested, and framework indications could be validated.

3.5 DATA ANALYSIS

Since this research consists of separate parts of data collection, as was discussed in paragraph 3.3, the data analysis is discussed accordingly.

3.5.1 MULTIPLE CASE STUDY

The analysis of a multiple case study consisted of two parts: a within-case analysis concluding an individual report per company and a cross-case analysis on both general characteristics of the included organizations and themes in scope

WITHIN CASE ANALYSIS

To build a report on each individual company, the desk research was compared to the interviews. To do this, the interviews were transcribed and anonymized. Then, the interviews were sorted into statements that were fitting with each of the themes included in this research. This gave an opportunity to determine and summarize the strategies and experiences of these companies individually per theme. A narrative analysis method was used to connect interview statements with the desk research. This narrative analysis constructed the individual details of companies within these singular interviews instead of connective patterns which would be the case with deductive analysis methods (Azungah, 2018).

CROSS CASE ANALYSIS

Since the goal of the cross-case analysis was to produce a preliminary framework depicting barriers and determinants of these barriers, a deductive analysis method was used. The interviews were coded and analysed using ATLAS.ti. This software gave the opportunity to build upon the themes that were predefined for this research. The familiarity gathered through the within-case analysis was herein helpful, through definition of barrier categories. Coding the interviews using these categories, gave the opportunity to do a thematic content analysis, depicting also the connections between barriers. Soratto, Pires, and Friese (2020) discuss an approach to do this using ATLAS.ti. This approach, adjusted for this research can be found in Table 11.

	Phase of thematic content analysis	Steps in ATLAS.ti
1.	Pre-Analysis	Creating the project Adding the interview transcripts
2.	Material Exploration	Reading transcripts Creating and applying codes Writing memos and comments Grouping codes and memos
3.	Interpretation	Exploring the coded data using various analysis tools Linking quotations, codes and memos on the conceptual level Generating network views

Table 11. Adjusted thematic content analysis steps in ATLAS.ti.

Both the pre-analysis and material exploration phase of the thematic content analysis were partly concluded within the within-case analysis of this research. The goal of the third phase within this research was to determine characteristics of the cases indicating a barrier. An extensive table was made that guided the interpretation of the results of the thematic content analysis. The combination of these two analyses produced the preliminary framework.

3.5.2 IN DEPTH CASE STUDY

The in-depth case study was the extension of the multiple case study into a T-shaped approach. The data used for this case study solely consisted of interviews. These interviews were inductively analysed, using the predetermined framework as a guiding structure. This narrative analysis allowed the interviews to be used as either further validating evidence for the constructs and relations found within the framework, or as extra information extending the framework build (Azungah, 2018). Narratives from the interviews were used to do this. Through the analysis of this framework, the limits of the multiple-case study results and thus the study itself were also tested. This adhered to the study approach by Greene and David (1984).

3.6 FRAMEWORK VALIDATION

With the T-shaped approach, a framework depicting the barriers of adoption within maintenance, training and organisational/behavioural changes and indicating characteristics was proposed. By extending the search for the 'why' of relationships through this T-shaped approach, internal validity was strengthened (Eisenhardt, 1989). This also partially searched for the validity of the constructs within the framework, which strengthened internal and external validity of constructs by testing the limits of these constructs (Greene & David, 1984). However, since this research was purely qualitative, the research validity is of utmost importance to ensure readers are convinced by its accuracy (Creswell, 2014). To ensure this, two expert interviews were carried out to ensure the understanding and non-ambiguousness of the framework. The first expert interview was done with a TU Delft professor specializing in frugal innovations, of which adoption is an integral part of design. The second was a UNops employee, managing projects in the medical field in LMIC. This validation completed the framework build. The complete process leading to this framework is visualised in Figure 7. A full list of persons interviewed throughout this research with descriptions is given in Table 12.

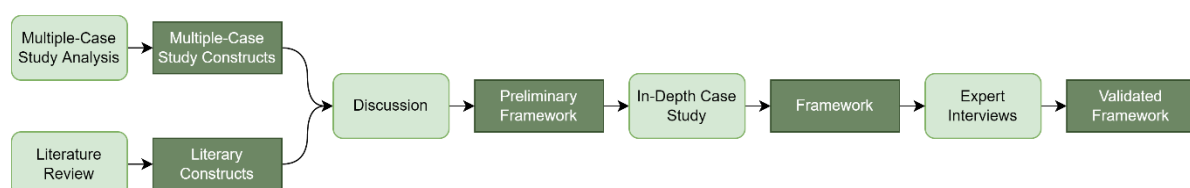


Figure 7. Flowchart visualising the research tasks and sub-deliverables leading to the final framework. The light green boxes depict research actions, the dark green boxes depict sub-deliverables.

Interviewee Nr.	Study Phase	Company	Function
1.	Multiple Case Study	1.	Account, equipment and programme work
2.	Multiple Case Study	2.	Managing director
2b.	In-Depth Case Study	2.	Anaesthetic nurse
2c.	In-Depth Case Study	2.	NICU nurse
2d.	In-Depth Case Study	2.	Sales & Marketing coordinator
3a.	Multiple Case Study	3.	Managing Director Ghana
3b.	Multiple Case Study	3.	CEO
4.	Multiple Case Study	4.	VP of Growth and Partnerships
5.	Multiple Case Study	5.	Innovation Lead
6.	Multiple Case Study	6.	CEO
E1.	Expert Validation	TU Delft	Associate Professor at the faculty of Industrial Design Engineering
E2.	Expert Validation	UN	UNops project manager

Table 12. Full list of persons interviewed throughout this research.

3.7 CONCLUSION

This research follows a T-shaped case study method. With the first stage of the proposed methodology concluded through the literature study in the previous chapter, the next phase of the study can be described. Moving on, the following chapter provides an analysis on the general characteristics of the 6 selected organizations, providing more depth on the organizations without going into detail on the themes in scope for this research.

CHAPTER 4. COMPANY PROFILES

4.1 INTRODUCTION

Within this chapter, the main characteristics of the six organizations included in the multiple case study are elaborated upon. The in-depth company profiles underlying this analysis can be found in Appendix C, and an overview of characteristics was already given in section 3.3 in Table 9. The chapter is structured as follows. In section 4.2 the geographical scope of this research is explained through some world bank statistics providing background on the financial and medical resource situation in SSA. Section 4.3 provides the organization's views on the importance of field research and design when active in medical technology in SSA. Section 4.4 gives an overview of the medical technologies produced and/or implemented by the organizations included. Section 4.5 provides the concise implementation processes, with only stages in-scope considered. Within section 4.6 the chapter is concluded.

The following is to be kept in mind before providing the analysis of general characteristics of the organizations. Of the totalling 6 organizations included within this multiple-case study, half were for-profit and half non-for-profit. Of the non-for-profits one other distinction could be made, seeing that organization 4 is an NGO. However, all of these organizations are focussed on addressing specific LMIC needs and thus not solely focussed on profits.

- Organization 1: *"We're interested in direct outputs now... as a small foundation we think that we have impact in being agile and doing things now"*
- Organization 2: *"With the specific remit of initially building anaesthetic equipment for low resource settings."*
- Organization 3: *"We are an impact company... of course we are a for-profit, but that is profit is not our main goal"*
- Organization 4: *"So that's what our focus is on, addressing that particular need."*
- Organization 5: *"We wanted to become better, more effective and more transparent, more clear, to share learnings... Maybe you want to do grander projects with greater impact, also a sustainable impact."*
- Organization 6: *"No education of the clinicians and no access to medical devices... So we go to those small practices and give them one or more diagnostic devices"*

4.2 GEOGRAPHICAL CONTEXT

As explained, the focus of the research is Sub-Saharan Africa, consistent mostly of low- and lower-middle income countries. To be able to interpret why certain areas propose difficulties, a general setting of this geographical scope is done through descriptive World Bank Data. The classification given in the first chapter shows the financial difficulties that exist in SSA, with the majority of the countries classifying as low-income and thus having a GNI per capita of \$1,045 or less (World Bank, 2022). The classification of each country is visualized in Figure 8. Through the use of other indicators this region is further described. This is done through two types of data: financial data, to look at health expenditure cash flows, and data on the availability of medical personnel within SSA. To put the data in perspective, everything is compared to HIC and LMIC.

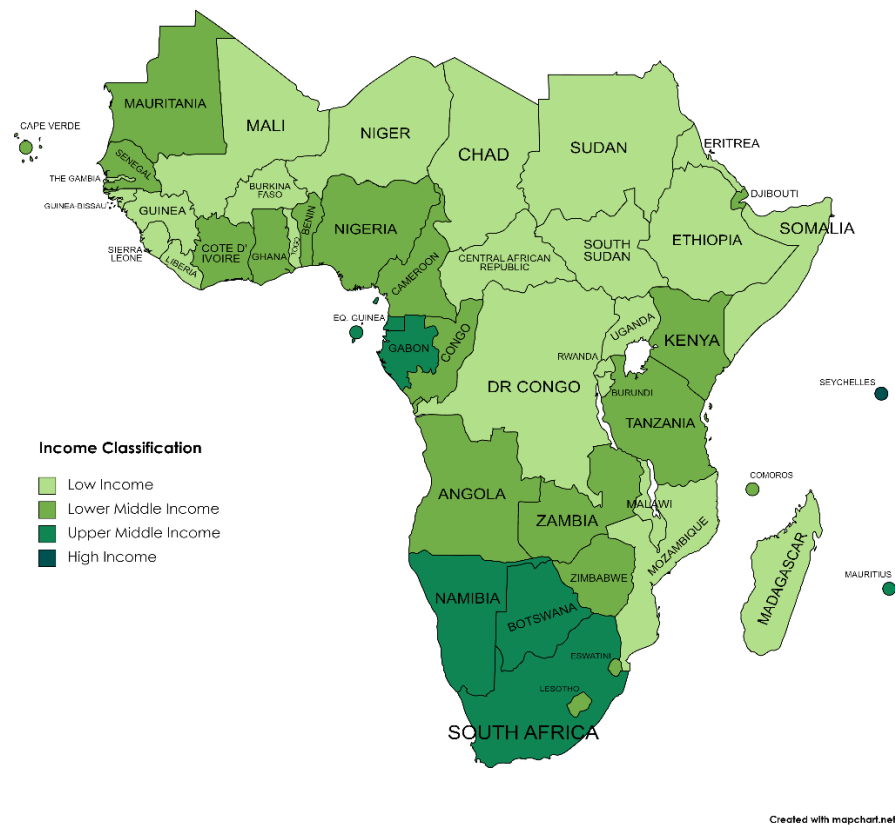


Figure 8. Map of Sub Saharan Africa with income classification.

4.2.1 HEALTH EXPENDITURE

To be able to describe the differences in health expenditure, this notion first has to be defined. To put a value to this, the current health expenditure in percentage of GDP per capita is used. This is expressed in an estimate of the amount of US dollars spent on healthcare, including healthcare goods and services consumed during the year, and taken as percentage of GDP. This is visualized between 2011 and 2018 in Figure 9. It is shown that within HIC, the health expenditure is more than double of the GDP than in LMIC/SSA.

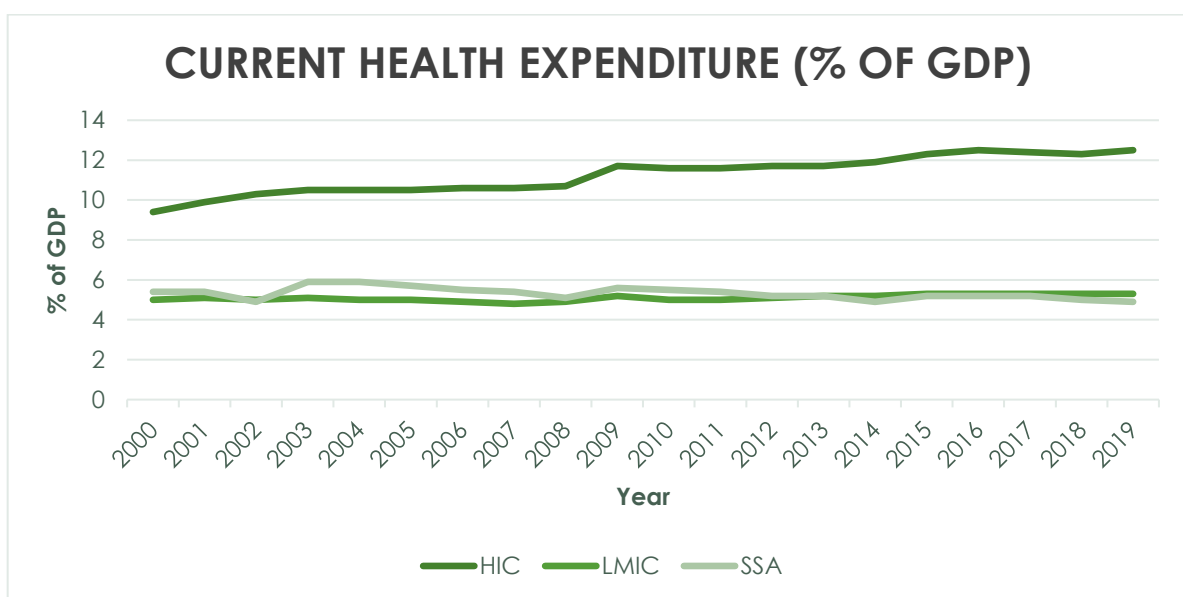


Figure 9. Health expenditure between 2000 and 2018 as percentage of GDP for HIC, LMIC and SSA (World Bank, 2018a).

With this figure, it is apparent that there is quite gap in expenditures in HIC and LMIC/SSA. This is however not the only difference, with the shares of this expenditure also differing. The expenditure is built up of the following shares:

- **Domestic general government health expenditure (DGG):** The share of current health expenditures funded from domestic public sources (World Bank, 2018b).
- **Domestic private health expenditure (DP):** The share of current health expenditures funded from domestic private sources (World Bank, 2018c). This stems from households, corporations and NGOs, going to either voluntary health insurance or directly to healthcare providers (World Health Organization, n.d.).
 - o **Out-of-pocket expenditure (OP):** The share of out-of-pocket payments of total current health expenditures, spend by households directly on health (World Bank, 2018e).
 - o **Non-out-of-pocket expenditure (NP):** The share of DP that does not come from out-of-pocket expenditures. This share entails the share of corporations and NGOs, and everything towards voluntary health insurance.
- **External health expenditure (E):** The share of current health expenditure funded from external sources (World Bank, 2018d).

The shares for HIC, LMIC and SSA are shown Figure 10.

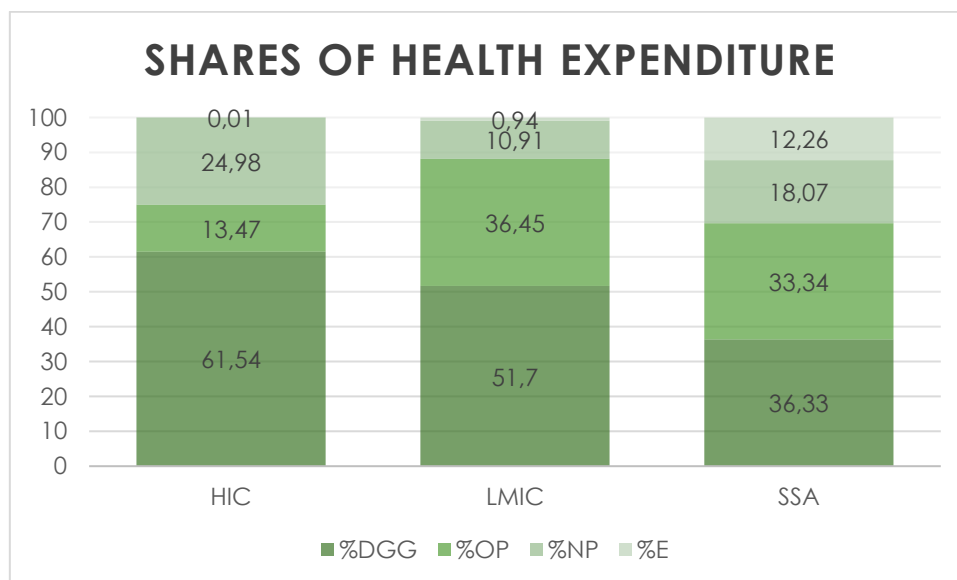


Figure 10. Health expenditure shares for HIC, LMIC and SSA in 2018.

Figure 10 shows that the shares of financial flows within healthcare expenditure differ between HIC, LMIC and SSA. Firstly, it is apparent that in HIC, health expenditure is mostly funded from domestic public sources. This is already a lower percentage in LMIC, but more significantly so in SSA. The larger share of expenditure in SSA comes from private and external sources, with out-of-pocket expenses being as high as 33,34%. This means that a large share of health expenses are paid for by the consumer directly. What is also noticeable, is a 10 times larger share of health expenditure within SSA funded from external sources.

4.2.2 AVAILABILITY OF MEDICAL PERSONNEL

Another set of indicators that give an overview of the difficulties existent in SSA, is the availability of medically trained persons. For this, the following types are considered:

- **Specialist surgical workforce** is the number of specialist surgical, anaesthetic, and obstetric (SAO) providers who are working in each country (W. H. I. World Bank, 2017).
- **Physicians** including generalists and specialist medical practitioners (World Bank, 2017b).

- **Nurses and midwives** include professional nurses, professional midwives, auxiliary midwives, enrolled nurses, enrolled midwives and other associated personnel, such as dental nurses and primary care nurses (World Bank, 2017a).

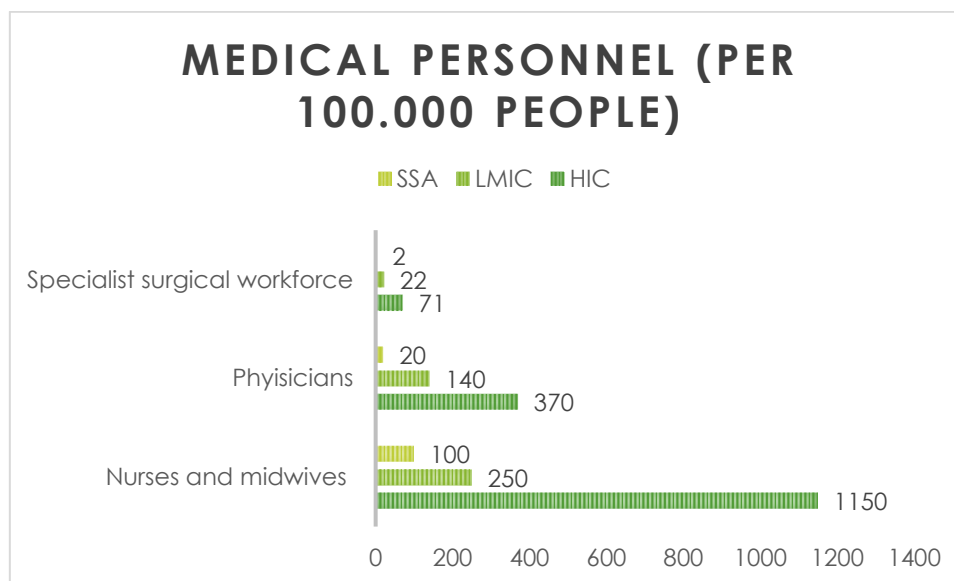


Figure 11. Medical personnel in HIC, LMIC and SSA in 2017.

Figure 11 shows that in comparison to high-resource settings, the availability of medical personnel in LMIC and especially in SSA is significantly lower. This could already be an explanation of the HIC equipment not being adopted in LMIC, due to the intended user for of equipment not being available.

4.3 VIEWS ON FIELD RESEARCH AND DESIGN

Not all organizations included develop medical equipment in-house. The organizations that do develop equipment make notions on the importance of the design of the equipment meeting the needs specific for LMIC. Organization 1, though not developing in-house, even made statements on this being of upmost importance. The organizations however differ in amount of research they have done before design and implementation of their equipment. The statements made on this matter are summarized in Table. *Design* in this table reflects statements made on the importance of the design especially fit for low-resource settings. *Field research* reflects on the efforts done prior to and during the design and implementation process to ensure this is the case.

Organization Nr.	Field Research	Design	Corroborating Quotes
1.		X	"I don't think I've come across anyone that is not asking, trying to find out before they give equipment whether it suits the context, who are designing for context."
2.	X	X	"But this business of designing stuff to work in those environments is extremely important." "And that research can only be done on the ground, not only paper exercise. It's not asking question. I'm afraid you need to go there, roll your sleeves up, get into theatre and see what's going on, and see what the issues are."
3.	X	X	"So we don't have internet access. We also don't have energy supply, so all our solutions work with solar energy and that kind of stuff." "Many field tests, prototypes, you have to be there a lot with your own people in the field, stand there and watch the client use your equipment and see what happens."

4.		X	"We need to build a ventilator that is fit for purpose. One that is easy to use, affordable and easy to maintain. So if it does break down, it's easy to repair with a local technician. So, our ventilators were designed with that specific use case."
	X		"The problem that arises is the use case changes when you get into, we'll just speak Zambia right now."
5.	X		"So we believe, and we have done clinical research into it in collaboration with a number of organizations."
6.		X	"So we built it for primary care, because there's nothing really in primary care."
	X		"So it took me a while, it took me a year before I even launched [organization 6], so to research the market and pick clinicians to go to the field."

Table 13. Company statements on design and field research.

This overview was provided to give background on the stance companies take when they go about designing solutions specifically for low-resource settings. It also reflects knowledge that exists within companies pre-implementation.

Vignette: Field research and its effect on design.

Some telling examples of how field research affects the design process come from organization 2 and 3. Organization 2, while in Chad, found that in the operating theatre temperatures would get very high, but humidity was low. This caused dangers for static electricity that had to be thought out in their design. During field-tests of one of organization 3 its X-Ray solutions in Zambia, they actually noticed that rain does not always fall vertically out of the sky, it can actually rain horizontally. This impacted the design of the X-Ray clinic to ensure the rain could not damage the equipment. A 3 month field test of their ultrasound equipment also gave information on the use of this equipment being different then firstly envisioned, informing further design.

4.4 MEDICAL EQUIPMENT

To understand the implications of the themes in scope, the similarities and differences between the medical technologies that are implemented by the organizations are to be understood. Table 14 gives an overview of the medical equipment developed per company. It herein also depicts the categories of the equipment, the given warranty and support contracts. A more detailed description of the technologies can be found in Appendix C. The foundations are herein disregarded because of the nature of the donations of equipment, making for a large range in types of equipment, and the contracts not being the same for each project. Hereby the needed information for this table is thus unknown.

Nr.	Total	Anaesthetic	X-Ray	Ultrasound	Ventilator	Diagnostics	Contract
2.	15	X			X		2-year warranty, lifelong support
3.	4		X	X			2-year warranty, service and spare parts dependent upon contract, lifelong support
4.	2				X		1-year warranty
6.	8			X		X	Lease contract with device replacement

Table 14. High-level overview of medical equipment.

The similarities and differences in medical equipment portrayed are to be kept in mind when interpreting further findings, for example a difference in service contract directly affects the taken approach to maintenance because of bound responsibilities. Also, the amount of technologies implemented by the organizations gives more insights into the scope and focus a company has.

4.5 IMPLEMENTATION PROCESSES

To further understand the differences between the organizations before moving on to the themes in scope, the working methods for each of the organizations while implementing equipment have to be summarized. Steps included as implementation are steps following the purchase of the equipment, or for organization 1, 4 and 5 the steps after the decision to donate is made. Everything done before is regarded as pre-implementation. This adheres to the visualization of the implementation process sketched in section 1.2. The steps taken by the organizations within this implementation are summarized in Table 15.

Step	Organization 1	Organization 2	Organization 3	Organization 4	Organization 5	Organization 6
<i>Pre-Implementation.</i>	Identification of partner with need for ME, acquire ME through export company.	ME is bought by facility where end-user is active.	ME is procured by preferably a health program.	ME is procured by preferably a Ministry.	Find project* to support with money / knowledge / ME of corporate	Visit possible client clinics, client org. decide to lease ME.
<i>Installation.</i>	-	ME installation guided by company BMEs.	ME installation with company engineers, subsequently training CO engineer.	ME installation with company engineers.	Measure KPIs before and after installation.	Employee visit for installation.
<i>Training.</i>	Dependent upon needs of partner.	Materials provided with ME, on-site or online training by company.	On-site / Online training.	Physical trainer-on-trainer programme with 3 visits.	Dependent upon project.	Physical training on use and importance.
<i>Post-Implementation.</i>	Contact initiated from company-side to check in.	Reactive contact.	Company check-ins for equipment in-contract, otherwise reactive.	Reactive contact.	Post-Market surveillance	Physical check-ins by employees.

Table 15. The implementation processes of medical equipment per company.

4.6 CONCLUSION

The similarities and differences of the organizations have been sketched within this chapter on a general level. The firstly introduced geographical scope was meant to shine a light on the financial situation in SSA, showing the shares of different cash flows in the health system. This combined with the low number of health professionals, makes the themes being indicated as problem areas more logical.. The general organization profiles inform the choices they have made regarding maintenance, training and organisational/behavioural change. This chapter thus gives the needed information to be able to interpret the following chapters which contain the findings of the multiple-case study. The following chapter is dedicated to findings within the theme of maintenance.

CHAPTER 5. MAINTENANCE

5.1 INTRODUCTION

Within this chapter, the maintenance implications are to be identified through the results of the within-case and cross-case analysis focussed on themes connected to maintenance. Firstly, within section 5.2 the strategies taken by the organizations within the field of maintenance are discussed, alongside their preconceptions informing this strategy in section 5.3. Then, barriers that have effects on this strategy, or on maintenance as a whole are discussed in section 5.4. The aim of this chapter is to find relations in organization characteristics as described in chapter 4, connecting them to hardships within the field of maintenance that are posing as a barrier to adoption. Also, any other implications within the field of maintenance that are connected to other factors outside of the organization itself are discussed. Section 5.5 summarizes all implications found in the theme of maintenance, subsequently answering sub-question 1 of this research: *"What are maintenance implications to take into account for adoption of medical technology in Sub-Saharan Africa?"*

5.2 IDENTIFIED STRATEGIES

Before discussing any successes and failures of the organizations regarding maintenance, the maintenance strategies of the organizations are described and compared. The main points of the strategy for each organization are firstly summarized in Table 16. For organization 1 and 5, the foundations, the strategies discussed are their main path taken when providing maintenance within a project. The points described in the table are further elaborated in the sections underneath the table.

Nr.	Design	P	C	Executor	Provided by	Training	Support	Stance	Communication
1.	-	X		BME	Partnered network of BMEs	Dependent upon project	No	-	-
	-		X	BME	Partnered network of BMEs	Dependent upon project	Online Peer-to-peer	Proactive	Email, WhatsApp, videocall. WhatsApp group chat
2.	Yes	-	X	Technician	Client Org.	Videos, Physical	Within warranty BME support, otherwise online	Reactive	Email, Whatsapp, Videocall
3.	Yes	X		Engineer	Freelance of company	Physical	No	Proactive	Checklists on equipment status
			X	Engineer	Freelance of company	Physical	Within warranty physical, otherwise online helpdesk Peer-to-peer	Proactive	Email, WhatsApp, Videocall WhatsApp group chat
4.	Yes	-	X	Technician	Local	Physical	Online	Reactive	Email, calls

Nr.	Design	P	C	Executor	Provided by	Training	Support	Stance	Communication
5.	-	-	X	BME	Corporate	No	Physical	Reactive	Within supported project
6.	-	-	-	-	-	-	-	-	-

Table 16. Overview of maintenance strategies. P stands for preventive, C for corrective.

With the first column, *Nr*, the organization number is depicted in line with the organization numbers given in Table 9. *Design* depicts if the organization at hand discusses the relations of the design of equipment with its maintenance needs. *Preventive* stands for any servicing of the equipment without it being broken first. *Corrective* is all maintenance done after there is need for an actual repair. *Executor* stands for the intended person that the organization foresees to carry out maintenance tasks. *Provided by* notes which party is responsible for this executor. *Training* depicts if the organization provides training specifically for maintenance of their equipment. *Support* indicates if there is any ongoing support during maintenance, and if so in what way. *Stance* dictates the organization's attitude in customer/client relationship regarding problems with equipment. *Communication* summarizes the methods of communication in the client/organization relationship.

5.2.1 DESIGN

As discussed in the previous chapter, it is important that equipment for LMIC is properly designed for this context. There is however also a notion of designing the equipment to minimize maintenance, which seems to be a theme adhered to by all companies developing their equipment in-house. This minimization can be seen as a way of avoiding the need for preventive maintenance as a whole, and corrective maintenance for as long as possible. The philosophy behind it is stated by Interviewee 2 as being comparative to the engineering of a satellite:

"You don't go up and service a satellite every three months. You build it to run and run and run and appropriate engineering can do that to a large degree. So we've tried to minimize the amount of maintenance that our equipment would need, and that's a relatively straightforward thing to do if it's high up on your list of priorities."

Other organizations adhere to this, by keeping their product as simple as possible while being very robust in nature. This way, even if the product breaks, repair is relatively easy to do. Nice-to-have features are in a sense thus disregarded to make the product as a whole function for a longer period of time (interview transcript company 2; 3; 4).

Vignette: The use of equipment in LMIC

Most equipment in LMIC is not used as in HIC. Equipment might be designed to be portable, but is thus also dragged around on motorcycles, boats, into war zones, from one floor to another in hospitals. A telling example herein is a portable ultrasound donated by organization 1 to a partner in Myanmar, to be carried over the border into ethnic minorities to do scans. The ultrasound was just robust enough to carry from one location to the next. However, the probes are in these project likely to deteriorate over time, and if that is not the issue, it might be that crystals are dislodged from banging the equipment around. Same goes for the ventilators designed by organization 4, in contrast to HIC ventilators the ventilators are expected to be moved around a lot. This makes the use-case different and has direct effects on the design in terms of maintenance needs.

5.2.2 PREVENTIVE MAINTENANCE

Within this research, preventive maintenance is used to express all actions that are to maintain the equipment that cannot be classified as repair. It seems to be a notion that is not yet widely applied within LMIC settings. This is adhered to by most companies, making statements that planned, and thus preventive, maintenance is not a thing that is standard practice in LMIC hospitals. *“Things like planned maintenance, sort of quick fixes on small problems, really don’t happen much.”* (interview transcript organization 1). *“It’s just not gonna happen in an African environment. It’s just not gonna be serviced by, not somebody who knows what he’s doing.”* (Interview transcript organization 2). This is then also pointed at as a reason of modern equipment not being functional in LMIC, since these types of equipment have short service periods. Not adhering to those service periods might make the equipment non-functional in that sense.

The only organization actively implementing a preventive maintenance scheme, is organization 3. They are actively training engineers on doing preventive maintenance after installation, using a passbook to ensure the engineer in-training is able to perform the actions needed for this scheme. They do however recognize that periodic maintenance is not something that is given priority in LMIC settings. While doing this periodic maintenance, the local engineers are also asked to fill in checklists on the equipment. This way, the organization can try to predict when equipment is about to break, making it easier to send assistance for corrective maintenance (Interview transcript organization 3a;3b).

5.2.3 CORRECTIVE MAINTENANCE

Corrective maintenance is the repair that takes place after equipment breaks. The pipeline of communication when there is a problem with equipment, is similar for organizations included. This process is visualized in Figure 12, with this figure being a visualization constructed from the statements made within interviews. This process can be kept in mind when discussing the differences and similarities in maintenance strategies, as well as how certain barriers can have such effects that the equipment will not get repaired.

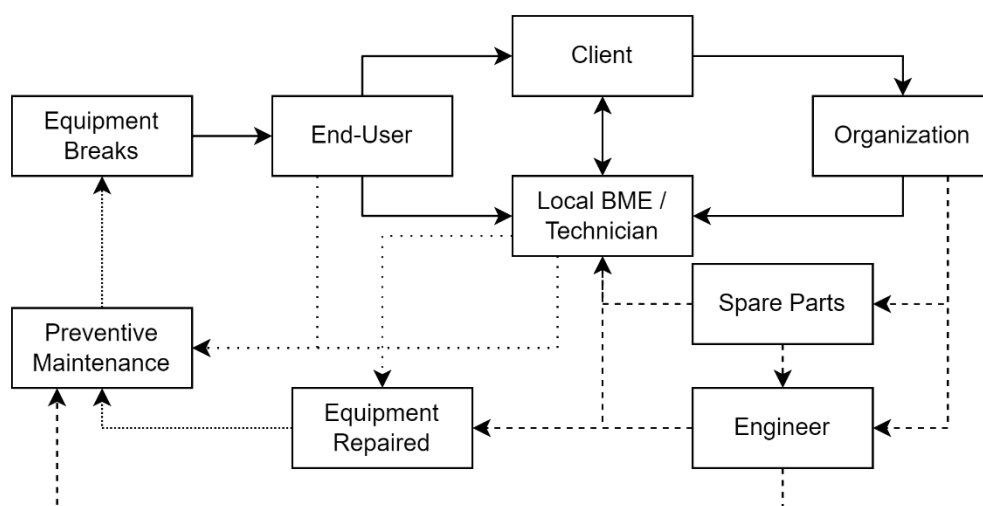


Figure 12. Process flow of maintenance after breakage of equipment. Black lines depict communication pathways that can be taken, dashed lines are dependent upon contract and financial resources and the dotted line stands for action. The small-dotted line depict changes in state of the equipment.

The way an organization handles corrective maintenance is firstly dependent on if the equipment that has broken is still under warranty. If this is the case, the organization is under contract to help service the equipment, sometimes including providing the spare parts needed to repair the equipment. In most cases the organization has trained a local engineer or technician to be able to do maintenance of their equipment. All equipment is also delivered with manuals, aiding the client's technical staff to do repair on their own. If the repair cannot be done this way, the client can contact the organization to aid them with the repair. This contact can also be carried out proactively from the organization's side (organization 1, 3, 4), checking in on the functionality of their equipment regularly. The organization can then provide support in diagnosis of the issue, solving the issue doing walkthroughs on videocalls or even providing physical support by sending an engineer.

Vignette: Pathway of corrective maintenance – Organization 2.

Organization 2 provides a lifelong support with their equipment. This gives the client an open invitation to contact the organization if there is a problem with the equipment. With contact, accompanied by photos and possibly videocalls, they are enabled to detect the issue causing the equipment to fail. After diagnosis, possibly spare parts are ordered, and the organization can do a walkthrough with the executor of the repair to ensure the repair is done correctly. However, it can also happen that on these photos or during videocalls, one can see that the equipment has been completely taken apart and put back together in a manner not comparative to how the equipment was delivered. Safety switches might even have been turned off. And to start off, if the breakage is not being passed on in the first place, maintenance might not happen at all.

5.2.4 REPLACEMENT OF EQUIPMENT

Another strategy, or solution, for maintenance can be that the equipment that is broken is replaced as a whole. This is the case when the repair of equipment is deemed more beneficial, be it financially or simply because it cannot be repaired. *"Sometimes it is just cheaper to also just replace the equipment itself."* (interview transcript organization 5). For organization 6, this is its whole strategy. Since the equipment is not bought or donated, but leased, breakage of equipment is solved by simply replacing the broken equipment. They do not try to repair the equipment because of its digital nature, comparable to modern mobile phones. *"That's exactly with these of them, most of those machines are purely digital. There's nothing really to fix."* (interview transcript organization 6).

5.3 PRECONCEPTIONS

The above identified strategies by the organizations were built upon assumptions and field research, determining how they went about maintenance. Firstly there is the need for minimization of maintenance through proper design of equipment. For this, it is of utmost importance to actually test out your prototypes to see if your assumptions in use are correct (interview transcript organization 3b). But even with the design requirement of having low maintenance needs, it is important to understand that *"everything needs maintenance"* (interview transcript organization 1). It is thus important for an organization to transfer knowledge to the client on how to do repairs when needed. The latter will be further elaborated within the next chapter.

5.4 IDENTIFIED BARRIERS

With the strategies and preconceptions identified, barriers that impede maintenance can be discussed. The barriers are grouped per theme. Herein the barriers are not distinguished in barriers for preventive and corrective maintenance, regarding preventive maintenance as an approach to delay corrective maintenance.

5.4.1 RESOURCES

The first identified theme is a lack of resources. This lack of resources can be time, money, human and/or materials. Each of these are elaborated how they pose as a barrier, and how this is supported by this multiple case study.

TIME

Time proposes issues in both preventive and corrective maintenance schemes. However, it is not widely mentioned by the interviewees as being the reason for maintenance not being done. Only within the discussion of the preventive maintenance tactic for company 3, is time mentioned as an issue: *"Still 15-20% of the persons do not do it, they don't have the time for it."* (interview transcript organization 3a). It is however logical that time can prevent maintenance due to high workloads, long travel times for persons to come to rural hospitals, waiting times for parts necessary for repair, etcetera. Time is thus seen as one of the resource barriers.

MONEY

A second resource barrier that can impede maintenance is money. On preventive maintenance, interviewee 3a mentioned: *"There is little priority given to periodic maintenance of equipment. Periodic and preventive maintenance of equipment, because they... It mostly has to do with money."* It is also mentioned by organization 3 that there are often requests for help, seeing that the client at that time might not have the money to repair their equipment, but still wants tips on how to solve a problem with the equipment. Monetary issues can also come up dependent upon the maintenance structure that a company implements with its equipment. Organization 4 states: *"So you usually have to have some expert trained in the capital city, which is expensive. They've got to then travel out and you know all of a sudden costs start adding on."* However, this is an approach taken by other organizations, and not an issue they have experienced themselves. Organization 5 does state that having to send personnel is an expensive endeavour, supporting herein the statement of organization 4 on money being an issue.

HUMAN

Human resources can pose as a problem when the correct executor for maintenance is not available. This notion of the correct executor can be seen as the unavailability of the personnel, or the lack of knowledge and skill within the personnel that is available. The latter is dependent upon knowledge needed to maintain the equipment, which in turn depends on the intricateness of the design. What can be seen in the strategies taken by the organizations, is that the organizations mostly train personnel on-site to be able to do the maintenance on their equipment. One problem arising with this however is, that companies acknowledge that it does happen that this trained personnel leaves. *"And so quite often, that was our experience with, that we heard about say up till 10 years ago with Biomedes as well. That you might get someone that's really good. You'd get them qualified, and then they would leave."* (interview transcript organization 1). *"And yeah, it can happen that you train them for a couple of years and they go somewhere else, but that is all in the game."* (interview transcript organization 3b).

5.4.2 INSTITUTIONAL

Another theme that can be identified in barriers impeding maintenance, is institutional barriers. This can either be restrictive formal institutions, like law or client organization policies, or informal institutions preventing maintenance from taking place. These informal institutions include trust between actors within the maintenance process and habits preventing change.

POLICY

Even with formal institutions not necessarily being in-scope for this research, some notions on policy were made. One policy restricting maintenance, is policy making it difficult for reverse logistics to be carried out by organizations wanting to fulfil their side of a warranty contract (interview transcript organization 5). This is the only explicit notion made within this research on policy having effects on the themes in scope. Implicitly however, every maintenance contract is bound by policy and regulation. How these contracts are thus designed might already propose formal policy barriers.

DISTRUST

An informal institution impeding maintenance, is a lack of trust between technical and medical personnel in client facilities. Organization 1 concludes this on the fact that biomedical engineers are not yet in their right to address issues that arise during repair (interview transcript organization 1). Interviewee 2 states: *"Being able to get diagnostic tools in these places is very difficult, because there is a distrust, in a lot of cases anyway, between the operators of the equipment and the technicians. So if it's slightly wrong, or slightly broken, they don't report it until it is completely defunct, non-functional."* This distrust can however also exist between client and company due to for example the non-existence of a relationship between the two.

Vignette: An example of distrust / policy – organization 1.

Organization 1 funded a program that looked at all oxygen plants in Malawi and assessed them physically with biomedical engineers. These engineers made a national report on what needed repairs, and what was to break soon. The actual repair of one plant was then funded by another donor. This donor paid for repairs made up in this report, however already new issues had arisen in the time that had passed. There was thus confusion on if the contract had been carried out right, and the involved parties did not seem to get a clear picture of what went wrong. Only when organization 1 stepped in and organized a phone call with all parties, the issue could be resolved. In their opinion, this call could have been avoided had the BMEs been trusted to be more of a middle man.

BREAKING HABITS

The last institutional barrier is the need for habits to be broken, e.g. the need for standard practice to be altered. For maintenance, this could either be the standard practice of a specific person, or an organisation as a whole. For example, the implemented checklist by organization 3 for their engineers asks them to establish a new routine, integrating this checklist (interview transcript company 3a). It could also be said that the current practice of running equipment until it is defunct is a habit of current end-users (interview transcript organization 2), that might need to be broken for maintenance to be done at an earlier stage. The breakage of habits requires active behaviour change, a notion that will be elaborately discussed in chapter 7.

5.4.3 COMMUNICATION

The last identified category within barriers for maintenance is communication. As can be seen in Figure 12, many lines of communication are sometimes necessary to be able to do maintenance. These lines might have been non-existent from the start of implementation, even with invitation of the company to keep in touch (interview transcript organization 1). What also happens is discontinuation of the relationship due to the established contact person leaving the client organization and as a consequence any check-ins from the company not coming through (interview transcript organization 2; 3).

A lack of communication might also be due to the end-user mishandling the equipment and causing it to break, but not wanting to admit this due to ego, or possibly thinking they might have to pay for repairs. A lack of communication can also be the cause of equipment being wrongly repaired. *"Sometimes we get somebody that sends us a picture of the machine that it's broken down. We're not sure what happened and then when I look at it you know the concentrator is in the machine backwards. And now that didn't just happen. You know somebody's fiddled with it."* (interview transcript organization 2).

5.5 CONCLUSION

This chapter aimed to answer the first sub-question of this research: *"What are maintenance implications to take into account for adoption of medical technology in Sub-Saharan Africa?"*. The implications found are a connection of the barriers uncovered through interviews with the characteristics of the implementation situations discussed within these interviews:

- **Time** is an implication for strategies in which an organization is dependent upon persons with high workloads, and due to this not finding time to fit in the maintenance regime dictated by implementing organizations. The maintenance regime herein also plays a role, if being too demanding time-wise, for example with most periodic maintenance schemes.
- **Money** is an implication for maintenance when costs of maintenance are too high for the client organization to be able to afford said maintenance. These costs can be heightened through a high need of maintenance as a whole, as well as the needs for materials to execute the maintenance tasks. This is then also directly dependent upon the budget a client organization has.
- **Human resources** can pose problems for maintenance due to the intended executor (e.g. the technical personnel with the needed skill and knowledge level) of maintenance not being available within a client organization. This is not only affected by the personnel available at implementation, but also dependent upon staff turnover rates within that client organization.
- **Policy** can be an implication for maintenance through restriction of actions necessary to execute maintenance. This policy can be country-wide, but also hospital-specific policy inhibiting maintenance actions.
- **Trust** is an implication for maintenance if a lack of trust inhibits the communication lines necessary for the correct and timely execution of maintenance. This trust encompasses trust within the client organization between technical and medical personnel, or the trust within the client / organization relationship.
- **Breaking habits** poses as an implication if the maintenance regime of the newly implementing equipment requires changes in routines of personnel. This is dependent upon current regimes, and on familiarity of the new equipment.
- **Communication** is an implication for maintenance because of the significant effects it has on maintenance being executed. If communication is lacking and breakage of equipment is unknown to the organization, foreseen help with maintenance cannot be given.

Moving on, the next chapters discusses the findings connected to the theme training.

CHAPTER 6. TRAINING

6.1 INTRODUCTION

Having identified the maintenance implications for adoption, the next theme in scope is discussed: training. Within section 6.2, the strategies of the organizations are summarized. Herein both user and maintenance training are included, since these are intertwined. Preconceptions informing these strategies are discussed in section 6.3 Then, barriers that have effects on training are discussed in section 6.4. The aim of this chapter is to find relations in organization characteristics described in chapter 4 and hardships within the field of training, posing as barriers to adoption. Also, any other implications within the field of training that are connected to other factors outside of the organization itself are discussed. This is concluded in section 6.5, providing an answer to the second sub-question of this research: *“What are training implications to take into account for adoption of medical technology in Sub-Saharan Africa?”*

6.2 IDENTIFIED STRATEGIES

Before discussing any successes and failures that the organizations have come across within the field of training, the strategies of the companies are described and compared. The main points of the strategy for each organization are firstly summarized in Table 17. Because of the differences between projects for organization 1 and 5, these notions are not necessarily strategy, but paths taken in examples given in research upon discussion of implementation of equipment. Both foundations have however also provided training without equipment implementation, of which findings are incorporated in this chapter. In the sections underneath this table, the strategies taken are further elaborated. Design is also discussed for its interrelations with training, it is however not taken into account within the table itself.

Nr.	User	Maintenance	Target personnel	Trainer	Methods	Materials
1.	X		Dependent upon project	BME	In-hospital training through BME if deemed necessary	Laminated quick guide, manual
		X	Dependent upon project	Company / Head trainer	Trainer on trainer model, resulting in peer-to-peer group WhatsApps	-
2.	X		Mainly anaesthetic nurses, other medical personnel dependent upon equipment	Company	Walkthrough after installation by company, online/on-site	Instructional videos, manuals
		X	Lower-level technicians	Company	Walkthrough during installation by company, online/on-site	Instructional videos, manuals
3.	X		Radiographers, laypersons	Company	On-Site and/or online by company, supporting peer-to-peer group WhatsApps	E-learning, instructional videos, manual, webinar

Nr.	User	Maintenance	Target personnel	Trainer	Methods	Materials
		X	Engineer	Company	On-Site during installation, preventive and corrective maintenance. Supported by peer-to-peer WhatsApps	Manuals, Instructional Videos, passbook
4.	X		Doctors, Nurses, Healthworkers	Company	Trainer-on-trainer model with 3 in-person visits from company	Manuals, slide-deck, cheat-cards
		X	Technician	Company	Training during initial installation on small maintenance tasks.	Manual
5.	X		Dependent upon project	Dependent upon project	Establishing baseline, do training and then measure KPI's	-
6.	X		Nurses, GP's	Company	Physical training by company employees	-

Table 17. Overview of training strategies.

Nr in this table stands for the organization number which was given to the organization in Table 9. *User* depicts if the organization at hand provides user training. *Maintenance* depicts if the organization at hand provides maintenance training. *Target personnel* states the to-be-trained, *trainer* states who is responsible for providing said training. *Methods* gives a short statement on the training methods the organization uses. *Materials* sums up the provided materials by the organizations to the client with the equipment.

6.2.1 DESIGN

As with maintenance, the design of the equipment already determines partially how much training is needed for adoption, or at least for implementation. The organizations developing their own equipment recognize this, and a design principle apparent for all their equipment is it being easy to use. This is also advertised in their brochures (sales brochures organization 2; 3; 4). It is however important to understand, that the defined easy to use in HIC is not necessarily the same as in LMIC. This is supported by mentions of organization 4: *"It's interesting because when you talk about something that's easy to use, well, easy to use for which culture?"* and organization 3b: *"What can be very logical from a Western point of view, can be viewed as very unclear from their perspective."*

6.2.2 USER TRAINING

To give further insights on user training and how exactly the strategies differ between organizations, the similarities and differences of these strategies are elaborated upon. Firstly, one must pay attention to the intended user of the equipment. The education that this user has, has direct effects on the training this user needs to be able to use the implemented equipment. This relation is directly reflected in training strategies. For example, organization 1 aims to donate equipment that is needed, but already familiar to the user and does not need too much training. Through their relationships with their partnered facilities, they can make the estimation if this familiarity is there, or else if training is still necessary (interview transcript organization 1). Organization 2's training is tailored towards the knowledge of its end-users, making for the main training materials to be in the form of videos and manuals, combined with a training at initial implementation and installation (interview transcript organization 2). Organization 3 acknowledges that their equipment's AI can be interpreted by a layperson if they receive the right training, and have adapted their training programme and materials accordingly (interview transcript organization 3a;3b).

Organization 3, 4 and 6 believe that user training must not only include training in the exact use of the equipment itself. This is based on the fact that organization 3 offers a training programme on the benefits of implementation of their equipment to radiologists, ensuring they do not feel the equipment is a threat to their work. They also mention that the people paying for the equipment should also receive some sort of training (interview transcript organization 3). Organization 4 offers a curriculum expanded on also the medical practice surrounding the use of the medical equipment itself (interview transcript organization 4). For organization 6, the broader applied training includes training their users on the importance of carrying out tests with their diagnostic equipment due to the financial demand of the leasing contract they have with the organization (interview transcript organization 6).

6.2.3 MAINTENANCE TRAINING

With the previous chapter in mind, the training for the implied maintenance executor is discussed. As with training for the end-user, the previous training of the executor is to be kept in mind when deciding upon the fitting approach. Also, needed training is to be adjusted to the maintenance needs the design of the equipment implies. This relation can be found in the strategies that the organizations adhere to. Organization 2 designs its equipment to “run and run” without needing too much maintenance. Its maintenance training is then thus also restricted to videos and manuals with a short walkthrough during installation, and helpdesk support of the organization if needed (interview transcript organization 2). Organization 4 mostly complies with this training approach, although they do include having a local technician trained for the basic maintenance tasks (interview transcript organization 4). Organization 3 hires, although freelance most times, engineers and trains them for installation and maintenance of their equipment. This training is done physically, ensuring tasks can be done by the newly hired engineer through a passbook to sign off certain installation and maintenance tasks (interview transcript organization 3a).

Vignette: WhatsApp groups after training.

Organization 1 did a donation in Mali in which ventilators were donated to the Ministry of Health for district hospitals. This donation included a five day training for the heads of biomedical departments for each region, applying a trainer-on-trainer model. These heads could in turn train responsible persons in their regions, eventually training down to facility level. This maintenance training thus cascaded down from engineer towards local electricians for example. One year later, there is still a WhatsApp group active in which peer-to-peer advice can be given on breakages of equipment.

Organization 3 also deploys WhatsApp groups after implementation and training to enable both easy peer-to-peer and company-to-client contact

6.2.4 TRAINING METHODS

The last subject to be elaborated through examples is training methods and materials. The biggest distinction to be made herein is if the training is done on-site and thus physically, or if the training is provided online. Most organizations preferred physical training before COVID-19, but since the pandemic has proven to most that training can also be provided from afar, organizations are starting to do more and more digitally (interview transcript organization 2; 3). Organizations 4 and 6 however do still prefer physical training, with the latter even stating that it is needed to do this even if it is “very human intensive.” (interview transcript organization 3).

Another element differing is the involvement of the organization itself during each training. Some organizations prefer to do training for each facility themselves, others prefer to use a trainer-on-trainer model. With the latter, the organization can provide a centralized training to so-called head-trainers for each of the facilities, or maybe districts, their equipment is to be implemented in. These head-trainers can then go on and train persons of interest in their own facility. This model has been used by organization 1 and 4. Organization 4 however does check in at each facility at a second visit to see if there is need for extra training provided by the organization itself.

6.3 PRECONCEPTIONS

As with strategy decisions made on maintenance, the training strategies were also built upon assumptions, some assumptions being supported by field research. These assumptions do not necessarily differ per company, but more per client organization. Some general notions however are on the overall educational level being quite low (organization 1; 2; 4; 6). Further preconceptions within this theme were not identified.

Vignette: Task-shifting through training

A preconception that was formulated in the geographical scope of Chapter 4, is the little availability of medically trained professionals. This preconception was used by both organization 1 as organization 5 to fund projects in which training is the complete project. Within this training, they teach midwives and nurses to use ultrasound to be able to detect abnormalities in pregnancies. Teaching the nurses and midwives to be able to do this, they are able to refer abnormal cases towards more highly trained professionals. This ensures the women that are referred towards hospitals are more likely to need the extra attention, lowering workloads in hospitals.

6.4 IDENTIFIED BARRIERS

With the strategies and preconceptions identified, barriers for training can be identified. Barriers in training are also classified as such, when it has an effect on training outcomes. Training barriers are barriers in adoption, due to incorrect use, or even un-use of the equipment as a whole. The barriers have been grouped into themes mostly adjacent to the themes identified within the maintenance barriers.

6.4.1 RESOURCES

Similarly to maintenance, a lack of resources poses as a barrier for training. This can either be time, money, human resources or materials. What should be stated beforehand, is that the direct benefits of training might be hard to measure, making it harder to make investment in it tangible in rewards.

TIME

Time can be a factor preventing training from taken place. *"There's best practice and then there is just some facilities who are too busy"* (interview transcript organization 1). Besides the client organization not having time, it can also be that the organization itself does not have the time to provide training, especially if it is a special request for extra training. *"I only allow it when he is not gone for a week, because they never want to pay."* (Interview transcript organization 3a). Organization 4 states that too large groups take up too much time, but also mention that for some user groups training would be a waste of time: *"Whereas these other doctors, that would just be a waste of their time."* Time thus has to be managed in both organization's and client's perspective.

Vignette: Becoming time efficient – Organization 4

Organization 4 trains their end-users using a trainer-on-trainer model, providing this training to a large range of medical personnel. They do not however train every level of medical personnel, ranging from health-worker to doctor, the same curriculum. At initial implementation during the first project, they found out that large groups and unknown basic knowledge of participants made the training too long. To make this process more efficient, they currently gauge the size of groups, and survey participants on current knowledge to ensure the training is tailored and thus time efficient.

MONEY

Since training is not always within contract with the buy of equipment, money can be a hindering factor. This is however not mentioned by the organizations included as an impeding factor for the initial trainings within their implementations. It is mentioned when asked on requests for extra training due to for example staff turnover. *"We do webinars, but we don't do the training, that is not included in the price of what we do."* (interview transcript organization 3a). *"We will go back as often as they want us to, the difference be would need them to pay for it at that point."* (interview transcript organization 4). What is also of importance to note is that integrating training into contracts of purchase of equipment, inherently makes the contract more expensive. This might affect either organization or client negatively if these costs were to be minimized on one of the sides, creating a trade-off in quality of training and costs of training.

HUMAN

The issue arising with maintenance personnel also exists for medical personnel. As an example hereof organization 1 states: *"It's a little bit like saying that analogy would be that you want an obstetrician for a rural hospital in Liberia. So you'd send the doctor to the UK to get the obstetrics training, they come back, and then they leave."* Also, persons involved in the trainer-on-trainer program might leave, like a master trainer, causing the method to come to a halt (interview transcript organization 4). Besides trained persons leaving, there is also mentioning of staff turnover affecting training, or training needs. *"You're gonna have staff turnover with user training anyway."* (interview transcript organization 1).

MATERIALS

The last resource related barrier that affects training are the training materials. They have to be good enough *"for people to understand the equipment."* (interview transcript organization 2). These materials should adhere to the correct language, to increase understandability (interview transcript organization 2). Most companies provide manuals and videos with their equipment, sometimes even so-called *"cheat-sheets"* or *"quick guides"* (interview transcript organization 1; 4). What should also be kept in mind with these materials, is their availability. For example, company 2 provides their videos on USB, while they are also available online (interview transcript organization 2).

Vignette: Fitting training materials – Organization 3

Organization 3 has a daughter company in Ghana since 2016. Using this company to gauge what should and should not be included in training materials through the availability of local knowledge and experience has proven to be very helpful for organization 3. This, combined with intensive testing of prototypes to see if usage is similar to expected use makes for tailored materials, starting with physical training, but also e-learnings, videos and yearly webinars.

6.4.2 COMMUNICATION

Since training is based upon the transfer of knowledge from organization to client, communication between the two is key. Factors possibly hindering communication are thus also be discussed.

LANGUAGE

Language is not necessarily mentioned as a hindering factor, though the theme of language has come up in the interviews. “*We’re finding using animations work extremely well. I don’t know if you looked at any on our website, but we got some good animations on there. Now a lot easier to do for if you’re gonna need to do translations or if you’re going to change anything you couldn’t, you can make those changes a bit easier than reshooting a new video.*” (interview transcript organization 2). Also, organization 4 mentions the need for a translator locally when doing online training (interview transcript organization 4).

METHODS

As mentioned above, the methods used to provide training have been through some rapid changes due to COVID19, and views on what is more successful differ. “*Online, with [equipment nr. 3] is something else, that’s a different challenge.*” (interview transcript organization 3a). “*The ideal is to be in person. It’s much more efficient.*” (interview transcript organization 4). The method chosen can thus herein pose a barrier, be it for the organization or the client.

Vignette: Online versus offline – Organization 4.

A physical training of organization 4 consists of teaching a medical curriculum as well as a walkthrough of the ventilator. During this training, asking questions is low-level, sparking open discussions. Online however, an interpreter with ventilator is sat on the client-side. On the company-side there is an employee with the ventilator. The employee walks through the machine, the translator repeating what is said to the client. It has been found that this makes it harder to ask questions.

6.5 CONCLUSION

This chapter aimed to answer the second sub-question of this research: “*What are training implications to take into account for adoption of medical technology in Sub-Saharan Africa?*”. The implications found are a connection of the barriers uncovered through interviews with the characteristics of the implementation situations discussed within these interviews:

- **Time** is an implication for training if there cannot be time found to perform the training needed for equipment implementation. A number of reasons were found implicating time: workload of both to-be-trained and trainer, the needed time to complete training (which in turn is dependent upon the needed incline in knowledge and skill level) but also dependent upon the knowledge on training needs beforehand to ensure time-efficiency.
- **Money** poses as a barrier for training if there is a need for the client organization to pay extra for training necessary to adopt the implemented technology. This payment might be for physical training, but also for extra training materials. The other way around, money can be an implication for training on the organization side if there is an ask for a per-diem to be paid for time of the to-be-trained.

- **Human resources** are an implication for training if the intended to-be-trained (e.g. the correct kind of medical personnel with the needed knowledge and skill-level to attend training) is not available within the client organization. Staff turnover poses herein the same issue as for maintenance, though it poses a more significant barrier for training during trainer-on-trainer schemes if the trainer leaves the client organization.
- **Materials** pose as an implication for training due to the dependence of a success of training on the fit of the training materials with the client organization. This fit can be expressed through online and offline availability of these materials for repetition of training and the level of knowledge needed to understand the materials.
- **Language** is a barrier for training due to the need for a common language to transfer knowledge from implementing organization to client organization. This has effects on both the training itself as the training materials.
- **Methods** is an implication for training dependent upon the preferred method of training by the organization, as well as the preferred and possible methods at the client organization and the possible (mis)match herein.

Moving on, the next chapter will compile the findings on the last theme in scope: organisational and behavioural change.

CHAPTER 7. BEHAVIOURAL AND ORGANISATIONAL CHANGES

7.1 INTRODUCTION

The last theme in scope covers the behavioural and organisational changes needed when implementing medical technology. To detail this, boundaries on this topic were determined after the literature review. Within the case study, strategies on consumables and spare parts management were discussed, as well as the needs for behaviour change alongside implementation. With some organizations certification was also discussed. The findings that fall within this scope are first summarized within section 7.2. Within this section the main elements of the strategies will also be explained. Then, any preconceptions that have informed these strategies are discussed in section 7.3. With the strategies and preconceptions known, uncovered barriers are discussed in section 7.4. Finally, implications are summarized in section 7.5, providing an answer to the third sub-question of this research: *“What are organisational and behavioural implications to take into account for adoption of medical technology in Sub-Saharan Africa?”*

7.2 IDENTIFIED STRATEGIES

Strategies were determined on the broad notion of organisational and behavioural changes that support the implementation of medical technology. Organisational changes were herein regarded as spare parts and consumables management, and if applicable certification of end-users. Behavioural change can concern anyone that is affected by the implementation of the equipment (e.g. end-users, maintenance personnel, management, etc.). Table 18 summarizes if the organization at hand has a strategy on these notions, and if so what the key points thereof are. The *Nr* depicts the number of the organization given in Table 9. For this theme, the interrelations with design will also be discussed. Further elaborations on this table can be found in the sections following Table 18.

Nr.	Consumables	Spare Parts	Certification	Behavioural Changes
1.	Donated equipment that has as little consumables as possible, if used then possibly with cleaning protocol.	Generally send spare parts, possibly via post after determining what is wrong	-	-
2.	Everything where it is possible is autoclavable, or at least re-processable through some sort of cleaning protocol	Provide spare parts after it is worked out what is wrong. Little changes made to equipment to ensure availability of spare parts.	-	-
3.	Very little consumables needed, is possible to run without.	Modular design, spare parts are to be bought if not included in contract.	Policy dictates that radiographers should be certified.	Incentive structures for engineers to fill in preventive checklists. Training of actors that might feel threatened by their equipment.
4.	High need, to be donated with the equipment donation.	To be bought when out of contract, company ensures availability.	Company-recognized certification after training.	Including charting training and materials with equipment implementation.

Nr.	Consumables	Spare Parts	Certification	Behavioural Changes
5.	Through partners, or supply via corporate.	Range of possible solutions, including 3D-printing, local manufacturing. Also using corporate 5.	-	Policy dictating double work, preventing change to single use of new intervention.
6.	Included with leasing contract.	-	-	Teaching clinicians on financial aspects, interpretation of outcomes to ensure they apply this in daily practice.

Table 18. Overview of strategies on organisational and behavioural changes.

7.2.1 DESIGN

As with the previous themes, some of these strategies are dependent upon the design of the equipment. The design dictates the need for consumables when using the equipment. As seen above, organization 2 states: *"Yeah, everything we can is autoclavable or at the very least sort of reprocessable, as far as some sort of cleaning protocol."* (interview transcript organization 2). Organization 4 however did not integrate this into their design, *"so with a ventilator you need a lot of accessories, so like a mask and tubes and all this."* (interview transcript organization 4). This shows the impact design has on management of consumables. Moving on to spare parts, the same basic relation arises. Equipment design dictates how to manage spare parts. For example, modularity of the design impacts the ease of replacement, and the amount advised to be kept in stock (interview transcript organization 3b). As for the impact design has on behaviour change, one must look at the likeliness that the new equipment asks for a change in routines. This dials back to the design principles applicable for training. Integrating "easy to use" in one's design, already dictating some form of familiarity for the user of the equipment.

7.2.2 ORGANISATIONAL CHANGE

Included on the notion of organisational change are thus consumables, spare parts and certification needs for trained personnel. These are things that require some form of organization from both company and client, to be able to keep the equipment running. Most organizations recognize that with consumables, it is unreasonable to expect client organizations to change them after one-use, which is typical in HIC (interview transcript organization 1; 2; 4). Organization 3 simply does not deal with a lot of consumables, and the foundations ensure that if they are to implement equipment that has high needs that there is a supplier nearby (interview transcript organization 1; 3; 5). With spare parts, it is mostly priority to ensure availability of spare parts, although not necessarily free of charge.

7.2.3 BEHAVIOUR CHANGE

Behaviour change is applicable when new medical equipment asks personnel at the client organization to change their behaviour to be able to integrate the equipment within their routines. An example of behaviour change needing support from the organization, is one of organization 4 when implementing their ventilators in Zambia. They expected there would not be behaviour change necessary. However: *"So it's, It's interesting, it does, but it shouldn't. So I'll explain what I mean by that. If you are a doctor, nurse, or respiratory therapist in a US Hospital or any European hospital, charting is normal. So as you are monitoring your patient, your charting well what's their CO2 levels, what's their O2 levels, what's their respiratory rate. You are charting that every hour. They don't do that. They should be doing it. That's like good medical practice, so it's not something that is unique to our ventilators."* (interview transcript organization 4).

7.3 PRECONCEPTIONS

Strategies surrounding organisational and behaviour changes are also built upon assumptions, some of which were field researched. The first preconception herein has already been discussed, namely that consumables are reused due to limited availability: *"Yeah, the consumables, you're not supposed to reuse those, but they do because they don't have new ones."* (interview transcript organization 4). *"It will always get reused, you have to accept that from the start, I think."* (interview transcript organization 2). For spare parts and behaviour changes there were little assumptions found within the case studies.

Vignette: Reuse of consumables

Consumables are goods that are to, in HIC settings, be used one-per-patient. This is however not the case in LMIC. Organization 2 designed their equipment in a way that most consumables are at least autoclavable. This means that these parts can be sterilized if necessary. Organization 4 did not do this, providing a problem: a need for a constant stream of consumables, due to risk of infection if the consumables at hand are reused. Organization 1 has a multitude of examples of in-house solutions for cleaning of consumables if the consumables itself are not at hand for replacement. There are thus many creative solutions to the consumables issues that are apparent in LMIC.

7.4 BARRIERS

The barriers found within this theme are interconnected with previous chapters. For spare parts and consumables, they can be further defined. However, for behaviour change it is difficult, since behaviour change is a goal in itself but also an outcome of for example the training done. Furthermore, behaviour change poses as a barrier for training and maintenance, e.g. breaking habits. There are thus few barriers uncovered that just inhabit behaviour change within this research.

7.4.1 RESOURCES

MONEY

One of the main barriers for consumables and spare parts is a lack of money hindering the client in gaining access to them. As mentioned on consumables: *"They won't be able to afford to replace it"* (interview transcript organization 2). With spare parts, the same issue arises. *"They can't find it, the money. Those devices then are set aside for a couple of months, as long as they cannot find the money."* (interview transcript organization 3b). Both are thus subject to money being available to be able to provide them. This can be on both organization and client side, dependent upon who the contract states the responsible party is.

MATERIALS

The material sense of lack of resources poses as a barrier when the client organization, even if money is available, cannot get the correct spare parts to be able to repair their machines. *"They don't have access to spare parts, because a lot of their equipment is donated."* (interview transcript organization 2). This can be because the type of machine donated is not manufactured anymore, or because they do not know the correct routes of acquiring specific spare parts. Another possible consequence of a lack of materials might be the inhibitive factor this has on behaviour change. As with the case of charting in Zambia, if the charts are not available, the behaviour change is impeded (interview transcript organization 4).

7.4.2 INSTITUTIONAL

POLICY

Lack of policy can be inhibiting an evenly distributed stream of consumables, for example the ventilator consumables of organization 4. Even with their wish to supply all receiving hospitals with consumables, the consumables seem to stagger at their point of entrance into the country, Lusaka (interview transcript organization 4). Policy can be an inhibiting factor for behaviour change aspects that are required for implementation. The new way of work might not be the way that is asked of personnel in policy, thus restricting them from adhering to new routines (interview transcript organization 5).

Vignette: Vicious cycle of consumable need versus policy – Organization 4

The ventilator developed by organization 4 has a high consumables need. This is, because of the NGO-structure of the organization, also delivered by the organization through funding. They noticed however that when wanting to send consumables to Zambia and have them be distributed to all hospitals in which their equipment is implemented, this was not as easy. The consumables currently get sucked up by the biggest hospitals in the capital city, where the ask is also the largest. This ask is this high however, because current needs cannot be served by smaller hospitals due to lack of functional equipment. This lack of functional equipment is however partially due to no consumables being delivered to these hospitals.

ACCEPTANCE

A barrier that could hinder the behaviour change needed to have personnel embed the equipment in their routines is the notion of acceptance of the newly implemented technology. To improve chances of this acceptance, organization 3 for example provides radiologists with information on the actual impact of their solutions to prevent them from actively bad-mouthing their equipment (interview transcript organization 3b). Organization 5 also mentions that when questioning behaviour change, one must first look at acceptance (interview transcript organization 5). Organization 6 however states: *“So it's very much, the adoption of technology happens, right? I mean, my grandma uses an iPhone. It took her years to do it, but finally people change and they can... You know they adapt. Or maybe they are scared in the beginning but then they adapt.”* Comprising this acceptance to it just being a matter of time.

7.5 CONCLUSION

This chapter aimed to answer the third sub-question of this research: *“What are organisational and behavioural implications to take into account for adoption of medical technology in Sub-Saharan Africa?”*. Organisational change is herein defined as spare parts and consumables management. The implications found are a connection of the barriers uncovered through interviews with the characteristics of the implementation situations discussed within these interviews:

- **Money** poses an implication for both spare parts and consumables management if the need of the equipment of either (or both) is too high to fit within the budget of the client organization. This is dependent upon the costs of the specific part, as well as the frequency the part needs replacement.
- **Materials** are an implication if the specific spare part or consumable needed is no longer in production, and thus unavailable even if the client organization is able to afford them.

- **Policy** can restrict both organisational and behavioural change through existent country and / or hospital policies dictating current practice and thus preventing change.
- **Acceptance** of the implemented equipment affects behavioural change. This acceptance in turn is dictated by the familiarity of the equipment, as well as if the implementation requires a high number of changes (e.g. a high amount of effort) in routines.

With the answer to the first three sub-questions, and thus the findings of the themes in scope compiled, these findings have to be discussed before being able to compile them into a framework. This discussion will be done in the next chapter, comparing findings to literature and discussing limitations and recommendations for research thus far.

CHAPTER 8. DISCUSSION

8.1 INTRODUCTION

Concluding the first phase of this research, the multiple-case study, the findings have to be discussed before moving on to integrating them into a framework. First the geographical setting is discussed in section 8.2. Then, the findings are enfolded with literature, comparing the findings of the multiple case study with the literature review in section 8.3. Also, limitations of the research thus far are discussed in section 8.4. Section 8.5 provides a synthesis of findings thus far, answering the first three sub-questions and subsequently providing a preliminary answer to the main research question. Section 8.6 justifies the need for a framework to further detail this answer to the main research question.

8.2 GEOGRAPHICAL CONTEXT

Before discussing the discovered barriers of this research, the implications of the geographical scope drawn in Chapter 4 are discussed. Firstly, the differences in shares in Health Expenditures when comparing HIC, LMIC and SSA. In comparison to HIC, SSA has large external share of health expenditure. This encompasses every financial flow in the healthcare system that comes from foreign sources. Currently, Malawi has the largest external share totalling 53,76% of current health expenditure (indexmundi, 2019). This indicates that there are large foreign influences within the healthcare systems in SSA, which might also dictate the kinds of equipment being procured. Another noticeable difference lies in domestic private expenditure shares. In HIC there is a low contribution of out-of-pocket spendings, this is significantly higher in LMIC and SSA. This could be an indication of differences in insurance systems, seeing that this share covers insurance payments. The larger contribution of out-of-pocket spendings in SSA might indicate that there are less people that actually pay a regular amount to insurance and thus cash flows are more uncertain than in HIC settings.

The differences in availability of medical personnel might also already be telling for the aforementioned share of non-functional equipment in LMIC. For example, if equipment was made to be handled by specialized physicians, it can simply be that adoption is made difficult due to this end-user not being present in SSA. And even if the specialized physician is not the direct end-user, but their knowledge is required within an organization to provide the surrounding medical care, this is an issue. It can thus be said that taking into account into detail what the availability of the different levels of medical staff is in each specific implementation situation is of importance when indicating which barriers are applicable.

8.3 ENFOLDING LITERATURE

The barriers found can be compared to the barriers that were found in the literature review, summarized in Table 7 in section 2.6. The barriers found were also compared to other literature not yet included in chapter 2, to put them into a literary context where necessary.

8.3.1 MAINTENANCE

The barriers found within the literature review were maintenance systems, financial resources and accessibility. Within the case studies, those barriers were also discussed. For one, the financial resource barrier was corroborated by the interviewees. This however not due to funding and investment issues as mentioned by Diaconu et al. (2017) and Marks et al. (2019), but more so due to the financial strain that maintenance has on the client. The funding and investment issues are however somewhat mentioned by the emphasis on designing your equipment to have low maintenance needs. This has a direct effect on the financial strain that the maintenance has on the client, although it might also make the equipment itself more expensive to manufacture.

Looking at the reason for accessibility being given as a barrier within the literature review, the lack of access to skilled persons to do the maintenance, this is corroborated by the findings of the case studies through the human resources barrier. This is in literature described as a problem specifically connected to the presence of biomedical engineers (Adams & Dobson, 2019; Marks et al., 2019; Oosting et al., 2019). And even though organization 1 does make statements of there being a large lack of biomedical engineers in SSA, the other organizations do not adhere to this being the issue. The problem lies in training someone on a high level, like biomedical engineer, with the risk of that person then leaving (organization 1; 2; 3). Accessibility as in rural-ness of a facility is not explicitly mentioned as a problem in providing maintenance.

For maintenance systems, the findings are a bit more complex. With maintenance systems, one could say this means the periodic maintenance actions undertaken by a client organization, also described as preventive maintenance in section 5.2.2. In literature there is an emphasis on the lack of existence of maintenance systems. Organizations included do not perceive this as a barrier, but as a given in client organizations in SSA. They do not expect periodic maintenance for their equipment, and design it as such. And if they do expect it, they give clear instructions and try to create incentive systems to support this periodic maintenance (organization 3). The difference in views might be due to organizations included with are mostly designing their equipment in-house, and the design-view is only described in 3 out of the 10 papers included on maintenance. Moyimane et al. (2017), discussing the design of maintenance systems surrounding the financial, physical and human resources available, corroborates with these design principles are the barriers found.

Barriers not yet discussed within the literature review, were the barriers in the institutional and communicational realm. For example, formal policy restricting reverse logistics and thus warranty contracts was not discussed in literature. There was no mention on warranty whatsoever. The distrust, breaking habits and communication barriers can somewhat be seen as parts of what would be a functioning maintenance system, which was found to be lacking within literature. One could also say that these kinds of barriers are in play when there is need for a client/organization relationship, which is not discussed in literature. This might be due to current research not being done from an organization perspective, causing these barriers to not appear in current literature.

8.3.2 TRAINING

Within training, some barriers were explicitly discussed in both literature and case studies. Firstly, the time barrier mentioned by E. T. Kim et al. (2018) is corroborated by the notion of organization 1 that time propose difficulties due to the high workload of end-users. The human resource barrier is also adhered to by this author and the case studies, with some of the organizations implementing a trainer-on-trainer model to overcome this barrier (organization 1; 2; 4). The cost-prohibitive barriers within literature, focussing on the prohibitive costs of materials is not adhered to by the organizations included (Burger et al., 2021). This might be due to the organizations providing materials with the purchase of the product, and thus taking away this barrier. The cost barrier is mentioned by organization 1 on training, stating that companies do not pay the per diem for the end-users for them to be able to participate in the training.

The materials barrier does come back in a different form in the multiple case study, with the statement that materials have to be proficient for persons to understand the equipment. Language also plays a role herein. Language is a phenomenon that is brought up in literature as a requirement to success by Gaziano et al. (2015) and Merali et al. (2020) for training, corroborated by organization 2 and 4. Language might thus be more of a factor of influence for training to succeed, than it being a barrier in itself. Another notion that can be integrated into these materials, is the mention in literature on the level of knowledge existent in client facilities posing as a barrier. This level of knowledge has direct effects on training time and materials, being a factor of influence instead of a barrier in itself.

The in literature mentioned context-specificity barrier is a barrier that has been detailed into a multitude of factors of influence within the multiple case study. Seeing the context-specificity as a precondition for trainings to be successful, requires for companies to have knowledge on characteristics of their client organization. The irregularity of training found as barrier by a large number of studies in the literature review, does not seem to come up in the case study. There is some mention for the need of a refresher training, for example the webinars provided yearly by organization 3, but it is not mentioned as a barrier for training not succeeding in itself. This might be due to the materials provided with purchase of the equipment being a replacement for this regularity of training, combined with an initial user-training during or after installation. Also, the client / organization relationship upheld by some of the organizations gives them clear indication for the need of the repeat of training which might also be why they do not perceive this irregularity as a barrier.

8.3.3 BEHAVIOURAL AND ORGANISATIONAL CHANGES

Comparing the findings in the last theme to literature is difficult, because of the lack of literature found. To be able to discuss this, the theme is split into spare parts / consumables management and behavioural change.

ORGANISATIONAL CHANGES

Organisational changes within this research were scoped to include notions on spare parts and consumables management. Of these, there was no mention of barriers within the included articles in the literature review. They are however recognized as problem areas by the organizations included, and the problems mentioned are seen within maintenance as a barrier in literature. For example, companies emphasize the fact that they have spare parts readily available (organization 2; 3; 4), and keep them available by leaving parts of the machines untouched to ensure this. This overcomes the barrier mentioned by Barkley et al. (2021), stating that there is an unavailability for spare parts due to the machines that are available in facilities are older models. That this still is an issue in SSA however, is not denied by any of the organizations included, which is why it is still included as a barrier concluding from the case studies. The other identified barriers within the case studies specifically for consumables and spare parts are financial resources and policy. These are barriers that have come up in the realm of maintenance, but through this case study are now also explicitly connected to consumables and spare parts management.

BEHAVIOURAL CHANGE

The notion of behaviour change is a more difficult one, being dependent upon the established routine and behaviour of persons within the client organization and the impact the to be implemented medical equipment has on this. Within literature, the notions of readiness and workload were found to be barriers impeding this.

This workload has been seen within the multiple case study as more of an influencing factor affecting the success of training and maintenance. The notion readiness can herein kind of be compared to the acceptance barrier found within the case studies. However, within the field of maintenance and training the barrier 'breaking habits' has been identified. This is a notion that is directly tied towards a need for behaviour change. Further barriers for behaviour change however seem to be missing within this research. Indicators and interventions of behaviour change are however widely described in other research, for example the COM-B model by Michie et al. (2011). This model describes the dependencies between capability, motivation, opportunity and behaviour. For this research, it was chosen to rely on the indications for the barrier breaking habits to indicate if behaviour change is necessary. The COM-B model can then be used for further investigation of the behaviour change necessary.

8.4 LIMITATIONS

The limitations within the multiple-case study part of this research are surrounding two themes: the fact that this research is a multiple-case study, and that this research is solely based upon qualitative sources and qualitative analysis methods. These will be discussed separately, elaborating why and how these are limitations having effects on the outcomes.

8.4.1 LIMITATIONS OF MULTIPLE-CASE STUDY RESEARCH

The multiple case study done has its limitations. As described by Eisenhardt (1989), the outcomes of a multiple case study can be hard to generalize towards theory. To prevent this, case selection is ought to be done through finding cases that are alike, applying the replication logic principle. However, within this multiple case study, the cases differed quite a lot. Besides the intended differences in medical equipment and size and scope, organizations also differed in type. The foundations included do not develop medical equipment in-house, giving way to differences in barriers that arise when implementing medical equipment in SSA. The amount of foundations and companies spoken to however are too limited to make harsh conclusions on these differences, not having the amount of corroborating data to know if these are outliers or recurring phenomena.

The validity of the findings of the multiple case study are also an issue due to this lack of generalizability. The differences in the cases might have been easier to overcome through an extension of the data sources per case study, providing more verification of the within-case analysis and thus strengthening the validity cross-case analysis. Because the cases already imply differences in outcomes and barriers per implementation situation (e.g. the interplay of the company, client and medical equipment during and after implementation), other perspectives could provide more validity to the indicators that are considered for each of the barriers. Besides the difference in organization types, the findings of the multiple case study and literature make it clear that even though SSA is generalized in theory, countries within SSA differ significantly. For one, looking at the differences in income classifications visualized in Figure 8 in section 4.2, it is clear that there are large differences in income. Statements made by the organizations included on examples within countries reflect this. It might thus also be that some barriers are country-specific, which not been explored enough within this research to include these geographical restrictions within the findings.

8.4.2 LIMITATIONS OF QUALITATIVE RESEARCH AND ANALYSIS

Other limitations of this case study research lie in the fact that the sources used and analysis done, are all qualitative. Qualitative research can be subject to the bias of the researcher, and ones assumptions on the subjects researched (Diefenbach, 2009). Also, there could be an issue of large volumes of data making analysis time consuming (Anderson, 2010). This creates a paradox for research that is subject to a shorter time frame. A bias might be overcome by gaining access to more sources of data, gaining more perspectives limiting one's own bias. This is restricted by the timeframe of this research, only having the possibility to analyse a limited number of cases and a limited amount of data. This is directly connected to another limitation. Having done only 1 interview per case might have given an incomplete view of the barriers existent within scope, although they do provide an organization perspective which is the goal of this research.

8.5 SYNTHESIS OF FINDINGS THUS FAR

This chapter provided a discussion of the findings of chapters 4 through 7. Comparing the findings to the initial setting of the scope within the literature review provided some rephrasing and integration of factors of influence and barriers. The discussion thus provides a final answer to the first three sub-questions, and subsequently enabling an answer to the main research question. These answers are summarized below.

SQ1: What are maintenance implications to take into account for adoption of medical technology in Sub-Saharan Africa?

For this, the theme maintenance has to be given a final definition. Within this research it is defined as: "Covering any notion of periodic and corrective maintenance (e.g. cleaning, repair, replacement) of the medical equipment implemented by the organization." Maintenance implications are regarded as barriers impeding maintenance from taking place (correctly). The final list of implications resulting from this discussion:

- **Time**, being influenced by *workload* of personnel and *time-needs* of an implemented maintenance scheme, is an implication for maintenance. Workload is herein an influencing factor, known for being high in both literature (Brooke-Sumner et al., 2019; Cowden et al., 2020), as in case-study findings (organization 1, 3). Time-needs chosen as the other influencing factor is supported by the emphasis of fitting maintenance schemes in literature (Moyimane et al., 2017), as well as the organizations' emphasis on the need for equipment with low maintenance needs (organization 1-6).
- **Money** poses an implications if high costs inhibit maintenance. Within this research this is expressed in costs for both *materials* (e.g. tools and spare parts) as *personnel*, chosen because of the emphasis of organizations that these are to be kept low in the design process (organization 2, 3, 4). This is also supported by the financial resource barrier resultant from the literature review (Ayah et al., 2020).
- **Human resources**, result of both *availability* of specific persons as *staff turnover*, are a third implication for maintenance. This notion of availability, expressed as accessibility in literature (Adams & Dobson, 2019; Marks et al., 2019; Oosting et al., 2019), was also expressed by organization 1-3. These organizations also stated staff turnover as indication issues within the realm of human resources.
- **Trust** describes the implication of *within client* and *client / organization relationships* affecting maintenance. This is not yet described in literature, but organization 2 stresses the effects of trust on maintenance. The importance of the client / organization relationship is supported by all organizations included.
- **Breaking habits** is directly connected to *familiarity* of new equipment to the client. This familiarity is connected to the easy-to-maintain design principle of organizations included. This is then used as an indication for behaviour change, further explained in sub-question 3. The assumption is that familiarity provides the capability, opportunity and motivation to maintain the equipment (Michie et al., 2011).
- **Communication**, influenced by the (non-)existence of a *client/organization relationship* as well as the *stance* an organization has herein, is the last implication for maintenance. Both factors were non-discussed in literature, but are seen in the case studies as the origin of certain issues for organizations, with the importance visualised in Figure 12.

SQ2: What are training implications to take into account for adoption of medical technology in Sub-Saharan Africa?

The theme training is through this research defined as "Covering any notion of training done on use and maintenance of the medical equipment implemented by the organization." Training implications are regarded as barriers impeding training from taking place, or training outcomes not deemed successful. The final list of implications resulting from this discussion:

- **Time**, being influenced by *workload*, chosen *method* and *level* needed to understand *materials*, forms an implication for training. Workload was already stated in literature (E. T. Kim et al., 2018), and further supported through notions within the multiple case study (organization 1). Methods dictate the match of client / organization preferred training, on which differing statements were made by organizations included (organization 2, 3, 4, 6). The level of knowledge needed is a notion supported both by literature (McDonald et al., 2019), as well as by the adaptability notion of organizations 3 and 4.

- **Money** poses an implication if high costs inhibit training (outcomes). This is expressed in *type, materials provided* and *trainer*. Both type and materials are described in literature as being prohibitive (Burger et al., 2021; Siddharthan et al., 2021). This materials notion is supported within findings, seeing that most organizations offer a range of materials within contract (organization 2, 3, 4, 6). Trainer is noted of importance by organization 1, mentioning costs of external trainers, as well as by Siddharthan et al. (2021).
- **Human resources**, result of both *availability* of specific persons as *staff turnover*, poses an implication for training. The availability issue of trainers was noted by Siddharthan et al. (2021). The availability issue for medical personnel was shown in the World Bank Data, as well as noted in case studies by organization 1, 2 and 3 alongside the effects of staff turnover also mentioned by organization 4.
- **Materials**, expressed in *amount, language* and *level* of knowledge, also are an implication for training. These factors are chosen to encompass the context-specificity importance expressed in literature (Gaziano et al., 2015; Makokha-Sandell et al., 2020; Opie & Huynh, 2021). The importance of language herein was also mentioned by organization 3 and 4.
- **Trust**, mirroring maintenance theme, originates in the relationship between *client and organization*, and is deemed to have similar effects on training as on maintenance.
- **Breaking habits**, expressed in *familiarity, similarity* and *novelty* of equipment in current *medical practice*. These notions dictate if there is a likely need for behaviour change. This is reflected in the easy-to-use design principles adhered to by organization 2-4. If these conditions are met, the assumption is personnel has the capability, opportunity and motivation to complete training successfully (Michie et al., 2011).
- **Communication** is a rephrase of the aforementioned *language* barrier. The latter being recognized in literature (Gaziano et al., 2015; Merali et al., 2020) and by organization 3 and 4, but integrated into this research as being of influence of the greater theme communication to fall in line with the theme maintenance.

SQ3: What are organisational and behavioural implications to take into account for adoption of medical technology in Sub-Saharan Africa?

This theme consists of two parts: organisational and behavioural change. The theme has in this research two definitions. Organisational change is defined as: "Covering any notion of spare parts and consumables and the management thereof needed by the medical equipment by the organization." Organisational implications are herein barriers from this management not keeping the equipment running, and can be seen as subject to the same factors of influence. The final list of implications resulting from discussion are:

- **Time**, expressed in *availability* of spare parts / consumables (e.g. if they are available within-country, or if import is necessary), poses as an implication for organisational change. This availability is emphasized by organization 2, 3 and 4. It is corroborated by Barkley et al. (2021) of the issue of untouched-machines, and thus a long time period of non-functionality, hindering adoption.
- **Money** poses an implication if high costs inhibit the purchase of spare parts / consumables. This is also dependent upon the aforementioned *availability*, but also the *needs* equipment has. The latter is mentioned by organizations as a design principle of keeping those needs low (organization 2, 3, 4, 6). The financial strain of spare parts is supported through maintenance literature (Ayah et al., 2020)
- **Materials**, dependent upon *availability* (e.g. if the materials are still in production) can pose a barrier to organisational change. This was mentioned in literature by Barkley et al. (2021) adhered to by notions on importance of ensuring this by organization 1-6.
- **Policy**, specifically policy influencing the *import* of spare parts / consumables are also an implication for organisational change. This is connected to the *availability*. This policy is mentioned in the case studies by organization 1 and 6.
- **Breaking habits** expresses the need for behaviour change, dependent upon *current regimes* for spare parts / consumables management and their *need*. This is reflected

in notions of organizations included on current management of these, especially notions on issues herein by organization 1 and 2. If there is no change asked from current to new regime, it is assumed that there is no behaviour change necessary.

- **Communication**, dependent upon *availability* and *client / organization relationship* is a last implication for organisational change. The two being interconnected, due to a need for a relationship if goods are to be imported. This being corroborated by the organizations included of which this is a requirement (organization 2, 3, 4, 6).

The implications of behaviour change are not defined by this table, but if the 'breaking habits' barrier is applicable, further investigation into this theme can be done through the COM-B model by Michie et al. (2011), taking capability, opportunity and motivation as barriers if comparing them to this research. Defining those as implications gives the following list:

- **Capability**, consisting of *physical* (e.g. balance and dexterity) and *psychological* (e.g. understanding and memory) capability to obtain and express the new behaviour;
- **Opportunity**, consisting of *physical* (e.g. financial and material resources) and *social* (e.g. culture and social norms) to obtain and express the new behaviour;
- **Motivation**, consisting of *reflective* (e.g. plans and evaluations) and *automatic* (e.g. desires and habits) to obtain and express the new behaviour (Michie et al., 2011).

Research thus far can already provide an answer the main research question of this research:

How can a medical technical organization overcome barriers in adoption of their medical technology in Sub-Saharan Africa?

For an organization to be able to overcome barriers in adoption, the organization must gain understanding of what influences adoption in the first place. Three specific themes influencing adoption were selected in this research: maintenance, training, organisational and behavioural change. Understanding their direct influence on adoption, and providing knowledge on how other steps in the implementation process affect the themes provides an organization with a better chance on overcoming possible barriers through their strategies.

This research points out that barriers can be categorized into three major categories: resources (e.g. time, money, human and/or materials), institutional barriers (e.g. policy, trust and/or breaking habits) and communication. The aforementioned answers of the first three sub-questions provide in-depth definitions and applicability conditions for the themes in-scope. To be able to overcome these barriers, an overview of current best practices for the uncovered barrier / theme combinations is given in Table 19.

Barrier	Maintenance	Training	Spare Parts	Consumables
Time	Design equipment to have low maintenance needs (o. 2, 3, 4), to be modular (o. 3), checklists to predict maintenance (o. 3).	Design equipment for low training needs (o. 1), quick guides on the spot (o. 1, 2, 3, 4), trainer-on-trainer model (o. 2, 4) and gage knowledge beforehand (o. 4).	Ensure spare parts are modularly replaceable (o.3), have local source of spare parts available (o. 5).	Low consumables need (o. 2, 3), have local supply (o. 5).
Money	Design equipment to have low maintenance needs (o. 2, 3, 4), provide suggested spare parts lists (o. 1, 3), maintenance can be done by low-level technician (o. 2, 4), peer-to-peer support through WhatsApp (o. 1, 3).	Trainer-on-trainer (o. 2, 4), integral part of purchase (o. 2, 4).	Lease machines including spare parts (o.6); buying spare parts at AliBaba (o.1).	Consumables are autoclavable (o.2), other sources of consumables (o. 1).

Barrier	Maintenance	Training	Spare Parts	Consumables
Human Resources	Representative does maintenance (o. 3), regular check-ins (o. 1), peer-to-peer sufficiency building (o. 1).	Trainer-on-trainer (o. 2, 4), refresher materials like e-learning and webinars (o. 3).		
Materials	Ensuring availability (o. 2, 3, 4), small changes/updates (o. 2, 3).	Quick guides (o. 1-6), manuals (o. 1-6), videos (o. 2, 3, 6), e-learning (o. 3), webinar (o. 3).	Ensuring availability (o. 2, 3, 4), modularity (o. 3), local availability (o. 5).	Ensuring availability (o. 6), autoclavable (o. 2), other sources (o.1), local availability (o. 5).
Policy			Local availability (o. 5), sold with equipment (o. 2, 3).	Local availability (o. 5, 6).
Trust	Regular physical check-ins (o. 6), regular phonecalls (o. 1), WhatsApp check-ins in group chats (o. 3), helpdesk available (o. 2, 3).	Regular physical check-ins (o. 6), regular phonecalls (o. 1).		
Breaking habits	Incentive system for maintenance checklists (o.3).	Training on clinical context (o.4, 6).	Lease of machines including spare parts (o.6)	Providing charts necessary for change (o.4)
Communication	Regular physical check-ins (o. 6), regular phonecalls (o. 1), WhatsApp check-ins in group chats (o. 3), helpdesk available (o. 2, 3).	Ensure correct language for materials (o. 2), translator available (o. 3, 4).	Contact info on equipment (o. 2), contact-person for orders (o. 2, 3).	Contact-person for orders (o. 2,3).

Table 19. Overview of mitigating strategies for barrier / theme combinations found in this research. The o. depicts which organizations propose the strategy.

8.6 JUSTIFICATION OF NEED FOR FRAMEWORK

To justify the findings of this research are to be integrated into a framework, the existent implementation frameworks are analysed alongside the discussed findings. As stated in the introduction, current frameworks in implementation research describing implementation of medical technology, like the Consolidated Framework of Implementation Research of Damschroder et al. (2009), describe adoption of the technology as an outcome of the implementation process. It however does not describe in detail which of its constructs contribute to the success of this adoption outcome. Specific barriers of adoption are thus also hard to conceive using this framework as sole evaluator for one's strategy. The CFIR framework constructs do portray similarities with the constructs found in this research, be it that this case study contains a higher level of detail for the constructs that overlap. It is interesting that the tools presented online supported by the CFIR to analyse strategies already integrate the notion of behaviour change theories to support implementation strategies.

The NASSS framework by Greenhalgh and Papoutsi (2019), a recent framework integrating Adoption as one of its main topics of interests, is still considered most wholesome after uncovering barriers specific to low-resource contexts, which seemed to be missing from that specific framework. Overlapping interrelations between constructs found in this research and the NASSS framework are for example the need for an evaluation of changes needed to routines of personnel to evaluate possible success of implementation leading to adoption. This can be viewed within this research as the barrier domain breaking habits. Knowledge needed to use the technology is also overlapping in this research and the NASSS framework, as well as surrounding legislation. It is however still apparent that some factors are not taken into account for this framework, being the processes of maintenance and training.

When comparing constructs found within the multiple case study to current implementation research, the notion of design of equipment appears in every theme of this research. Companies included designing equipment in-house stressed that this is integral. There should thus also be some dynamicity regarding implementation and design, viewing these processes as parallel and not sequential. This asks for a more actionable framework, viewing the barriers found within this research as preventable when integrated into an earlier step in the design and implementation process. Also, there is still a need for a framework designed specifically for problems that arise due to the LMIC context that are not found in these frameworks developed in HIC settings. This framework in turn can be used by organizations implementing medical technology in LMIC settings, specifically SSA, by building upon the experiences of other organizations compiled through that specific framework. Using the framework to determine blind spots in their strategy gives a better chance for adoption.

Moving on, the following chapter aims to show the interdependencies between the themes in scope, the barriers found and the applicability to specific implementation situations through the characteristics of the organization, client organization and equipment. This provides an actionable tool, the framework, integrating the knowledge uncovered through this research and making it practically applicable for organizations implementing medical technologies in SSA.

CHAPTER 9. FRAMEWORK

9.1 INTRODUCTION

With the implications of the themes in scope identified and discussed, a framework can be drawn. The goal of this framework is to connect known characteristics of a project in which it is the goal of an organization to implement medical technology, and have the framework give insights into what possible barriers they might come across hindering one of the themes in scope. This then gives the opportunity to analyse those barriers alongside current practices in the field. A first iteration framework is drawn within the first section, providing hypotheses on relations between characteristics and barriers in section 9.2. Section 9.3 tests these hypotheses by the in-depth case study, for which the framework was filled in for two implementation situations of company 2. The findings of the framework were tested on interviewees, resulting in possible alterations. Section 9.4 provides expert views on the framework. Finally, section 9.5 concludes this chapter with an answer to the fourth sub-question: *“How can these implications for adoption of medical technologies in Sub-Saharan Africa be integrated into a framework?”*

9.2 SHAPING HYPOTHESES

To be able to shape the framework, the implications and factors of influence are combined as discussed in the previous chapter. The results of this are portrayed in Table 20. To be able to fill in this table, tables of defined characteristics of influence of the company, client organization and medical equipment can be found in Appendix D. The possible values for each characteristic are also pre-defined within these tables.

To be able to reduce this table to indicators of barriers that might appear dependent upon the characteristics of the company, client organization and medical equipment, the following legend is made:

- **Red**: At least 2/3 of factors of influence propose a higher level for a problem, or at least all factors propose the lowest value for a problem.
- **Orange**: At least 2/3 of factors of influence propose the lowest value for a problem.
- **Yellow**: At least 1 of factors of influence proposes the lowest value for a problem.
- **Green**: Factors of influence are not proposing problems.
- NA: Factors of influence not applicable for this case.

To read this table, the following example is portrayed:

Time poses a **significant** barrier to *maintenance* due to the workload of the executor, a low-level-technician, being medium with no need for *preventive maintenance*, but a need for *corrective maintenance* once a month.

Furthermore, barriers herein should be clarified as being a notation for a domain the barrier belongs to. Policy in itself for example is thus not the barrier, but a regulation falling in the broader category of policy might be. As for the classification of significance of each indication, the indication is built upon what is known within this research to be an estimate taking into account the probability (e.g. the amount of factors of influence proposing a possible problem) and the significance (e.g. the severity of the proposed problem within that specific factor of influence). Quantitative factors of influence, for example actual costs and duration of maintenance and training are herein disregarded due to there not being enough data to support such claims within this framework as is.

Barrier	Maintenance	Training	Spare Parts	Consumables
<i>Time</i>	1. Workload of executor: medium+ 2. Frequency - preventive: monthly+ 3. Frequency – corrective: monthly+	1. Workload to-be-trained: medium+ 2. Method: on-site 3. Materials level > level to-be-trained	1. Availability: Import	1. Availability: Import
<i>Money</i>	1. Executor: Expert 2. Need for spare parts: monthly or more 3. Tools available < tools needed	1. Training type: Paid 2. Materials: 1 or less 3. Trainer: external	1. Availability: Import 2. Need: Medium+	1. Availability: Import 2. Need: Medium+
<i>Human Resources</i>	1. Executor wanted (or higher) not available in CO 2. Staff turnover in executor: medium+	1. Staff turnover in intended user: medium+ 2. Intended user (or higher) not available in CO		
<i>Materials</i>	1. Tools available < tools needed	1. Materials: 1 or less 2. Materials level > level to-be-trained	1. Availability: unavailable	1. Availability: unavailable
<i>Policy</i>			1. Availability: import 2. Import policy: restrictive	1. Availability: import 2. Import policy: restrictive
<i>Trust</i>	1. Relationship: Not established 2. Skill level difference med/tech < 2	1. Relationship: Not established		
<i>Breaking habits</i>	1. Familiarity: No 2. Similar equipment available: No	1. Familiarity: No 2. Similar equipment available: No 3. Novelty / Behaviour change: significant 4. Medical Practice: unknown	1. Established spare parts regime: No 2. Need: medium+	1. Established consumables regime: No 2. Need: Medium+
<i>Communication</i>	1. Relationship: not established 2. Stance: reactive	1. Language training is not language CO	1. Availability: import 2. Relationship: not established	1. Availability: import 2. Relationship: not established

Table 20. Included barriers that are indicated by framework application.

9.3 TESTING HYPOTHESES

To demonstrate the framework, test-cases are used. These test-cases are further examined through interviews with other perspectives affected by the processes in the framework. For this, company 2 was used due to its comparability to GOAL3, being a for-profit company implementing their technology in hospitals. Firstly, the framework was filled in as far as possible, using information on the implementation situations given through the multiple case study and the in-depth interviewees. The filled in tables on these scenarios can be found in Appendix E, subsequently providing risk indications. The risk indications were then tested through open-ended questions with interviewees, trying to find corroborating and contradicting stories with the framework. The interviewees included for the in-depth case study were: an anaesthetic nurse, also responsible for maintenance tasks, from Somaliland (interviewee 2b), a NICU nurse from Zambia (interviewee 2c) and the sales and marketing coordinator from organization 2 (interviewee 2d), responsible for the training materials. The findings are discussed per theme. The risk-indications matrices of the implementation situations at the base of this discussion can be found in Figure 13 and Figure 14, shortly explained underneath.

Barrier	Maintenance	Training	Spare Parts	Consumables
Time				
Money				
Human Resources				
Materials				
Policy				
Trust				
Breaking habits				
Communication				

Figure 13. Risk indication matrix for client organization 2b.

Client organization 2b is a learning hospital based in Somaliland. The interviewee spoken with is a senior anaesthetic nurse. The equipment implemented by organization 2 regarded anaesthetic machines, of which similar types were already available within the facility. Due to the intended users being trained in that hospital on anaesthetics, the use of the machine is already integrated in this training. In this specific client organization, there is only one electrician available. This electrician and interviewee 2b were trained by organization 2 on maintenance tasks for the equipment of organization 2. The implemented equipment of was installed by interviewee 2, establishing a client / organization relationship at installation. During installation, a short maintenance and user training was done.

Barrier	Maintenance	Training	Spare Parts	Consumables
Time				
Money				
Human Resources				
Materials				
Policy				
Trust				
Breaking habits				
Communication				

Figure 14. Risk indication matrix for client organization 2c.

Client organization 2c is a district hospital based in rural Zambia. Interviewee 2c works here as a NICU nurse, all the while also taking on organisational tasks for this NICU. The implemented equipment was a bubble CPAP, bought through a distribution centre based in Zambia. This equipment was installed without user- and maintenance training. Initially, there was no client / organization relationship established with organization 2. This only came to be when interviewee 2b gaged a user training was necessary, and reached out to organization 2 for this training. After this training, a relationship was established, easing the supply of consumables and spare parts which were an issue before this was established. Maintenance in this organization is provided by a Zambian network of biomedical engineers.

The figures visualise the indicated risks through the use of the framework from Table 20. It shows that it is expected that client organization 2c would have had more issues regarding themes in scope, which affecting adoption of the medical technology implemented by organization 2. It would thus be expected that when asked questions, interviewee 2c has experienced more problems in each of the themes in scope. The barrier / theme combination that differ in colour are discussed through examples underneath, showing what nuances are currently missing from the framework as is.

9.3.1 MAINTENANCE

For maintenance, the difference in established relationships with the organization seems to be the key to the differences in the statements made by interviewee 2b and 2c. 2b mentions an open line of communication, and this easing up the maintenance tasks at hand. 2b states that even with him being an anaesthetic nurse, he is the one trained for maintenance tasks for equipment of organization 2. This would make that the executor used within the characteristics can be extended to an end-user being capable of corrective maintenance tasks. This might however be specific to the equipment of 2b, which is, in the opinion of all interviewees, very robust in itself and easy to maintain and use. 2c got the equipment through a distributor, and did not immediately establish a relationship with the organization. This not happening made for a while client organization 2c not using the in-place support that organization 2 provides with its equipment, and thus lead to problems with maintenance. However, after establishment of the relationship, those problems with maintenance were mitigated.

Within general remarks on maintenance on the hospitals in which interviewee 2b and 2c are active, one specific situation stood out. A focus within this research has been uncover why preventive maintenance is not being done within SSA. Within the multiple-case study findings, it seems like the barriers were time and money.

Through the in-depth case study, it was found that a lack of available equipment is also a barrier. The available equipment is always in-use, and thus taking the equipment away for servicing is very difficult. As for efforts taken by organization 2 to mitigate barriers that were beneficial, the manufacturing of the equipment is deemed exceptional by the interviewees. Most maintenance actions are well-supported by the animated videos on USBs, together with comprehensible manuals. Furthermore, contact information can be found on each piece of equipment to stimulate to search support directly from organization 2.

9.3.2 TRAINING

For training, one can see that the risk indicated by the framework is significantly higher for 2c than 2b. This is once again partially due to the unestablished client / organization relationship at the moment of implementation. With client organization 2c having to ask for training, and thus also having to pay for this, a financial barrier was indicated. This is however not standard practice, with interviewee 2d explaining that this happens if the equipment is purchased or donated through another organization than organization 2 itself. The training materials that are supplied with the equipment are then also enough to be able to operate the equipment, this is corroborated by both 2b and 2c. Additional training is however beneficial for making sure that the equipment is used and maintained in the best way possible. For the case of 2b, risk indicators were also less due to the anaesthetic equipment being familiar to the end-users within the facility, while the CPAP was not yet introduced in facility 2c.

Furthermore, in the framework 'knowledge and skill' is used as an indicator to be able to compare the baseline of this available in the client organization with what is needed to participate in training, and what is needed to be able to use the equipment to be implemented by an organization. However, the gaging of this level can be quite a delicate task. It is difficult to do this before the execution of any training, due to the chance of being viewed as either arrogant or ignorant by asking questions on this before knowing the client organization on a relational level (interviewee 2d).

Organization 2 has gone through some adjustments with COVID-19, switching from physical installations and training to doing this online. Doing training online has significantly reduced costs for extra training, due to persons not needing to be flown to SSA (interviewee 2d). One last notion on training is time being a barrier for training. Both 2b and 2c state that doing training is always considered beneficial, even with high workloads, due to equipment reducing this workload through efficient use, which can be achieved through training.

9.3.3 SPARE PARTS AND CONSUMABLES

For spare parts, the differences in risk indication also come from the belated relationship, leading to hardships of locating spare parts and consumables for client organization 2c. 2c hereby mentioned that the distributor through which they bought their equipment is no longer active in Zambia. This made it difficult for interviewee 2c to import spare parts and consumables directly to their facility, due to import policies. 2b made no mention on policy, stating that spare parts were, if ordered, at his facility within 2 weeks. 2c spoke of 6 weeks. These shipment times could be integrated into the framework, since it has a significant impact on the downtime of machines.

9.3.4 BEHAVIOUR CHANGE

For behaviour change, it was indicated that the implementation situation at facility 2 asked for more habitual actions than situation 2a. This can be allocated to the fact that the implemented CPAP machines were not yet familiar to the end-users present in facility 2b, while the equipment implemented in 2a was already familiar. The training done, classifying through the COM-B model as an intervention improving capability, at a later stage at 2b, helped the client organization overcome this barrier.

9.3.5 POSSIBLE FRAMEWORK ALTERATIONS

Concluding from the findings in the sections above, framework alterations are proposed. For one, there should be additional factors of influence dictating if there is a risk indication for consumables and spare parts, due to the indications being too harsh for what the actual situation turned out to be. An indicator could be the shipping time, and the inventory at the facility might also need to be taken into account for a more correct indication of barriers. Also, even though interviewee 2a and 2b demonstrate that knowledge and skill levels are of importance to be taken into account for training and materials, it is stated by 2c that gaging this before implementation is not easy or nice to do. Thus, it might be of more importance to have these indicators be integrated into it being a risk if the training is not adaptable towards multiple skill and knowledge levels, than trying to gage these levels beforehand to indicate risks.

9.4 EXPERT VIEWS ON THE FRAMEWORK

The final validation step within for the framework consisted of interviews with two experts providing their perspectives. The first, giving a design-perspective, is a TU professor at the faculty of Industrial Design (E1). The second, giving a procurement perspective, is a UNops project manager, overseeing projects in the medical field in LMIC (E2).

Presenting the framework to E1, it was made apparent that the framework in itself is extensive. The amount of knowledge needed to apply the tool as is makes it hard for a designer to be able to prioritize from the indication table alone. The characteristics tables ask for levels of detail of knowledge on the client organization, while all this detail might at that time not yet be necessary. For a designer, gaining this knowledge might not be worth the time at the point of framework implementation. E1 views the framework would thus benefit from having it be layered, indicating what actions are at what stage important. Because of a lack of evidence however, this layering cannot yet be done. The integrated themes of the framework are however viewed of importance from a design perspective. Integrating knowledge and possibly thus prioritization on these themes in the design process when developing medical equipment for LMIC can make for a better fitting design. A suggestion was to introduce a discussion with an organization before showing the framework, to already start the thinking process of the organization on adoption, and possible inhibiting factors uncovered in this research. This start might also make it easier to fill in the characteristics tables as presented. The comparison of the initial discussion with the indications made by the framework might give some sort of prioritization that is lacking from the framework itself. Furthermore, E1 advised testing on different uses of the framework to discover its potential on application within the design process.

E2 was interviewed for a view on the framework from a perspective of an expert working in LMIC settings in a multitude of projects covering procurement and implementation of medical equipment. Looking at the framework, the most important notion E2 made is that the root-cause of non-adoption can be found in steps that are pre-implementation. In his experience, medical equipment that is being procured and sold does not meet low-resource context needs in the first place. Looking at the themes included, these themes are points that are pain-points in this not meeting needs. Medical equipment being sold in high-end settings sometimes require extensive maintenance and thus maintenance systems, while these are not present in LMIC. This is portrayed in the framework through taking into account within the client organization characteristics how much technical personnel is present at a facility, and if the facility is already implementing a periodic maintenance regime.

E2 did however state on this point that it is not necessarily a requirement for facilities to even have any maintenance personnel at all, which could implicate that this characteristics could be reduced to a mere: is there technical personnel present. A specific notion on this maintenance made was also the growth of digital interventions, and the non-existence of IT personnel at facilities. This is could then be a maintenance personnel function that could be added into the framework to shine a specific light on this problem. On both maintenance and training, E2 also stated that it is not always taken into account in the procurement process that maintenance and training are procured with the equipment. Currently, the preference in some projects still remains the amount of machines to be procured, not procuring with machines maintenance and training to ensure a longer use of the equipment. E2 does however recognize that both are needed for this sustainable implementation, and thus adoption. Another problem arises in his experience though when procuring training programmes alongside equipment: the procuring party, in most cases of experience of E2 Ministries, recognize that the offering of training comes with the risk of personnel leaving after receiving this training. Another issue that is not yet integrated into the framework that has direct effects on adoption is the policy changes needed for equipment to be integrated into daily practice, and the difficulty of achieving that those changes be made in experience of E2.

9.5 CONCLUSION

This chapter aimed to answer the fourth sub-question of this research: *“How can these implications for adoption of medical technologies in Sub-Saharan Africa be integrated into a framework?”*. Through a sequence of validating interviews, the drafted framework of the discussed barriers in the previous chapter was finalized. The final framework, and the guide on how to apply this framework to specific implementation situations is provided in Appendix F. Moving on, the last chapter provides a conclusion to this research, elaborating on the answer of the main research question given in previous chapter.

CHAPTER 10. CONCLUSION

10.1 INTRODUCTION

Within chapter 10, the answer to the main research question for this research is detailed to be applicable to specific implementation situations. This is done through a short summarization of how the findings of the sub-questions and subsequently the built of the framework lead to an answer to this main research question in section 10.2. Section 10.3 explores the limitations specifically for the framework, as well as the recommendations for further research. Lastly, section 10.4 summarizes the academic contribution of this thesis.

10.2 OVERCOMING ADOPTION BARRIERS

This research aimed to discover current barriers affecting adoption of medical technology in Sub-Saharan Africa, specifically in the fields of maintenance, training, organisational and behavioural change. Through the uncovering of the barriers through qualitative research, implications in these themes in scope could be formulated. With these findings formulated and discussed, a framework was drawn to give an overview of these barriers and their implications. This framework can be used to answer the main research question:

“How can a medical technical organization overcome barriers in adoption of medical technology in Sub-Saharan Africa?”

To be able to answer this question, the main findings of this study ought to be summarized. Firstly, barriers within this research were confined to be in one of the following themes:

- *Maintenance*: Covering any notion of periodic and corrective maintenance (e.g. cleaning, repair, replacement) of the medical equipment implemented by the organization.
- *Training*: Covering any notion of training done on use and maintenance of the medical equipment implemented by the organization.
- *Organisational Change*: Covering any notion of spare parts and consumables and the management thereof needed by the medical equipment by the organization.
- *Behavioural Change*: Covering any notion of the need for behaviour change to support the adoption of medical equipment implemented by the organization.

This research creates understanding that factors impeding either one or a multitude of these themes have a direct effect on the adoption of the medical equipment. Secondly, impeding factors, in this research defined as barriers and their subsequent implications, were uncovered through an extensive literature review and multiple-case study. The implications found were *time* (e.g. the organization or client not having enough time to perform tasks dictated within one or more themes), *money* (e.g. the organization or client being inhibited by money), *human resources* (e.g. the client not having the (correct) personnel to perform tasks dictated within one or more themes), *materials* (e.g. unavailability of materials inhibiting one or more themes in scope), *policy* (e.g. formal rules of a region or facility inhibiting the client), *trust* (e.g. trust within the client organization, or between client and implementing organization preventing needs for themes in scope from being carried out), *breaking habits* (e.g. an indication for significant behaviour change needed for one or more of the themes in scope) and *communication* (e.g. a lacking in the client / organization relationship inhibiting one or more of the themes in scope).

Thirdly, given the lack of guidance in overcoming these barriers in literature, current mitigating strategies were provided through the multiple case study. These strategies focus on lowering costs en effort for the client organization through designing equipment fit for LMIC settings, requiring low maintenance, training, spare parts and consumables. Providing the surrounding support within the needs that remain in the themes is the other focus point of these mitigating strategies. This also builds upon the upkeep of a healthy and proactive client / organization relationship, to enable the organization to troubleshoot if necessary. The understanding of the interrelations of the implementation process, the themes affecting adoption and the barriers uncovered through this research already provides better opportunities to overcome the barriers in adoption analysing these subsequent to the mitigating strategies in current practice.

Finally, given the lack of a framework integrating this knowledge in current literature, this answer, already provided in Chapter 8, is extended through the framework drawn in Chapter 9, providing a valorisation of this research through an actionable tool for organizations to analyse their implementation situations on possible occurrence of barriers. This in turn provides the opportunity for the general findings of this research into insights in barriers for specific implementation situations. A visualisation of the effects of these insights is visualized in the simplified implementation processes in Figure 15, in which the framework can inform the design, and Figure 16, in which the design of equipment is already final.

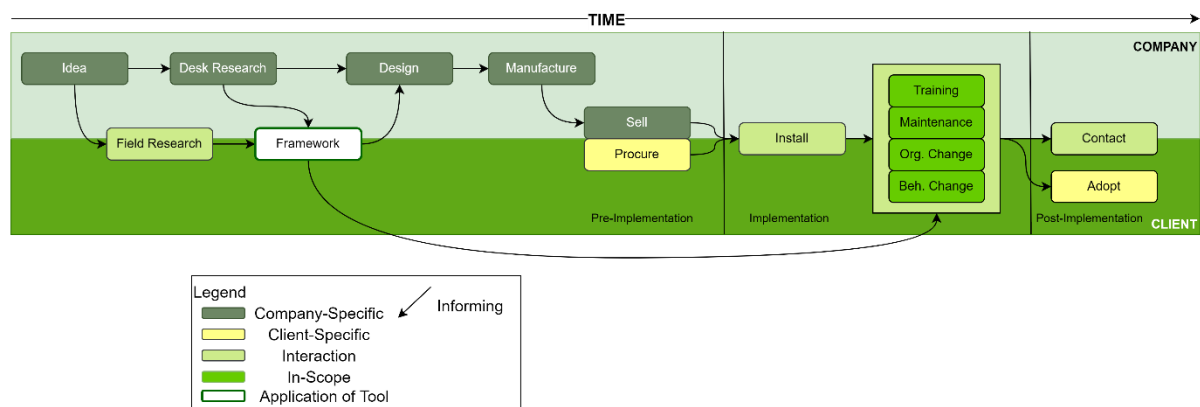


Figure 15. Proposed timeline including use of framework within implementation if design can still be altered.

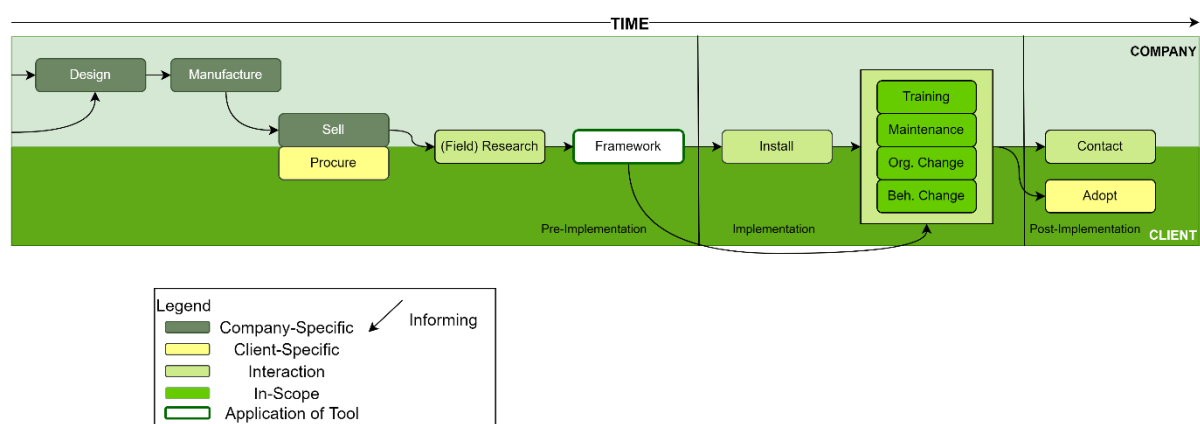


Figure 16. Proposed timeline including use of framework within implementation if design is a given.

In conclusion, an organization implementing medical technology in Sub Saharan Africa can overcome barriers in adoption through gaining insights into barriers (e.g. time, money human resources, materials, policy, trust, breaking habits and / or communication) applicable to them expressed in the themes maintenance, training, spare parts / consumables management and behaviour change, through analysing those barriers with current mitigating strategies. Specific insights into applicable barriers within proposed timelines for implementation situations can be created through application of the framework. This provides an opportunity for guided analysis of weak spots using the aforementioned current mitigating strategies. These can then be integrated into the design and / or implementation approach taken by the implementing organization. The integration of insights into adoption barriers in strategies, helps the implementing organization to overcome barriers in adoption. In Appendix G, an application example of this is given with the case of GOAL3.

10.3 FRAMEWORK LIMITATIONS AND FURTHER RESEARCH

The limitations of the findings used to construct the framework have already been discussed within chapter 8. However, the concluding framework and final answer to the main research question also have to be discussed. Through this, further limitations can be defined, as well as further research into both framework development and application.

10.2.1 LIMITATIONS

The framework produced by this research has limitations. Due to the limited timeframe in which the barriers were collected through the multiple-case study, the framework is not yet complete. Even with the validation steps taken through the in-depth case study, perspectives are still too limited to ensure completeness. Also, the amount of interviewees used for the in-depth case study were limited. The perspectives missing, procurement and maintenance, were however included in another way. Firstly, the maintenance perspective was discussed with interviewee 2b, since this interviewee was actually responsible for organization 2's maintenance. The procurement perspective was gained through expert interviewee E2. However, to validate the framework further, more perspectives interviewed would have been beneficial to gauge if the framework as is makes correct risk indications.

This notion of validation is also applicable towards the generalizability issue that arises in multiple-case study research. The extension of the case study of organization 2 gave that case in itself more validity than the other case studies on which the framework was based. It was apparent that these extra interviewees altered and detailed the notions by organization 2, so it could be stated that this would be the same if all case studies were to be extended and thus validated through interviews with other perspectives. By providing a greater validity of the study as a whole, the framework could also be more applicable to a broader spectrum of implementation situations with possibly not needing as much detailed characteristics included as of now.

The framework itself is extensive, which makes it difficult to apply for companies in early stages of development. The knowledge needed for this framework was derived from organizations that have already gone through the complete design and implementation process, so applying this now at an early stage could not be as easy as prescribed. This was reflected in the application example of GOAL3. Other limits exist in not all contextual factors being included in the framework, due to research on these factors not being done within this thesis. For example, organizations spoke on examples of policy in certain countries, but this was not included due to the limited examples per region available and the extended research needed to support such notions within the framework itself not being done. The region was thus kept as SSA as a whole, but as stated in the previous discussion chapter, the differences between countries in SSA are significant and could thus make for altering indications if taken into account.

Lastly, the burden of costs for companies has not been taken into account for the application of this framework. The appointed barriers might be the consequence of having to keep the costs low enough for the equipment to be purchasable by the client organizations, because of the target client being located in LMIC. There is thus a trade-off to be made in the lowering of these adoption barriers while keeping costs reasonably low.

10.2.2 RECOMMENDATIONS FOR FURTHER RESEARCH

For this thesis as a whole, research recommendations are drawn for both the multiple-case study and the framework. For one, to counteract the limitations connected to both the scoping of the multiple case study, but also to overgo the limited data issue, the research should be expanded to include both more cases but also more perspectives per case to uncover the validity of findings. Also, more barriers might be uncovered doing this.

Making the current multiple case study be more in-depth could uncover more preconditions and factors of influence for those barriers. The extension of the multiple case study could also solve the issue of generalizability, having more replicated characteristics of organizations to draw conclusions on. Furthermore, adding perspectives to current cases improves the validity of both the cases in itself as the validity of the multiple case study as a whole.

Besides recommendations specifically for the multiple case study, there are also recommendations for further research for the framework. Firstly, the application of the framework. The proposed application has not been tested to see if end-users would be able to apply it without help from the researcher. The ambiguity of the framework is herein thus also not yet researched fully. The framework as is could benefit from layering, guiding the user in the prioritization of certain barriers instead of giving information of all what was uncovered in this research at once. It is also recommended that the use of this framework be further explored through more quantifiable research methods, gaining large amounts of data that can be explored on significance of influence. This could be done through for example extensive surveying on the specifics uncovered in this research. As for the broadness of the framework, the framework should be further extended. A useful addition would be research into the other steps within the implementation process. Gaining more insights into the design process for example, can give a more clear indication of barriers one might overcome within this design.

Furthermore, the formal institutional perspective should be further researched. The influence of formal policy in hospitals, regions and countries have direct effects on steps in the implementation process, and within this framework this influence is only taken into account on the surface. An extensive analysis on the policies that frame a certain project would herein be useful to uncover further barriers. The financial perspective that guides an implementation process should also be included from the companies perspective. Currently, the framework does not consider the budget a company has to design and implement their equipment. This does however limit the possibilities of incorporating strategies to overcome each and every barrier uncovered by this framework.

Also, not all proposed changes from the in-depth case study were integrated into the final framework. The alteration on the knowledge and skill level was not made, due to its conflict with the findings from the multiple-case study. These alterations could however still be beneficial, if they could be researched further on their validity. Lastly, because of the actionable nature of this framework, it would be advisable to integrate this framework into a tool rather than tables of characteristics. One could implement these tables into an excel-file, creating a list for companies to fill in rather than having to look through all the tables to find what is applicable. The aforementioned layering would herein also be beneficial, having the file be interactive such that not applicable factors are automatically left unseen for the company making the framework as a whole more comprehensible and thus useable for a wider public.

10.4 ACADEMIC CONTRIBUTION

This thesis comprises multiple academic contributions. The academic contributions will hereunder be stated and elucidated.

Synthesising of existent knowledge on adoption barriers from the fields of medicine, biomedical engineering and health policy.

Through the literature review in Chapter 2, an academic contribution is already made. With the first search strings having only 1 useful result, a knowledge gap was already pointed out. This gap has been filled by the synthesis of the searches on separate themes that are present in this research. Compiling the current barriers that exist in maintenance, training and organisational/behavioural change for medical technology combines knowledge a multitude of research fields. Extending this synthesis with barriers currently encountered by organizations implementing their medical equipment in SSA, gives a further contribution to current academic knowledge.

Identification of gaps in design and procurement processes of medical equipment for low-resource settings.

This research points out that there are still steps to be taken outside of the themes in scope that directly influence the themes in scope. Two major fields herein are design and procurement. Design because of the possibilities to already overcome adoption issues during the design process. Procurement due to the client organization's (lack of) responsibility and possibly also responsibility in the occurrence of barriers in the implementation process. It shines a new light on the need for more research into these fields and how they influence each other.

Introducing a new cross-over of implementation and design science.

The final contribution of this research lies in the cross-over the framework proposes from design science towards implementation science. The integrated nature of the two regarding effects on adoption are enlightened through this research. Further research is however recommended to explore this cross over to its full extent. It is however already apparent in a systematic review covering implementation frameworks within the medical field that design is herein not yet a topic that is integrated (Moullin, Sabater-Hernández, Fernandez-Llimos, & Benrimoj, 2015).

CHAPTER 11. REFERENCES

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APPENDIX A. INTERVIEW PROTOCOL

Interview Protocol – [Company Name]

INTRODUCTION

This study is meant to shine a light on the different barriers that exist when trying to achieve long-term adoption of a newly introduced medical technology in hospitals in Sub Saharan Africa. To be able to gain more knowledge on this subject, a multiple case study is done. This interview is part of/serves as main input for one of the case studies.

To do before interview: preliminary research on the technology that the company has implemented. Also, as much as is known through open publication on the implementation process of the technology. E.g. when did they start, when did they get CE/FDA approval, in which countries and what order did they become active, what is their target audience (nurses, doctors, GPs, volunteers). Try to gain a comprehensive view on company structure. Introduce this overview that I have in the protocol to be sent to the company itself. Try to have the NASSS questions answered or at least categorized beforehand.

GENERAL INFORMATION

Evaluate with interviewee if information gathered is correct thus far. Then:

1. Can you shortly introduce your company for me?
 - a. What medical technology
 - b. What is the intended use/intended users
 - c. In how many countries active
 - d. Since when are you active
 - e. Nr of persons active
 - f. Nr of offices
 2. What do you do within the company?
 - a. Role within company
 - b. Field experience in LMIC
-

MAINTENANCE

One of the areas of interest within this research is the subject of maintenance of the implemented medical technology. For this I would like to discuss with you what you foresaw as being your strategy for maintenance, and how this panned out in the first trials and first months of extensive use of your materials. *Put emphasis on after-purchase strategy.*

3. What was your strategy for maintenance regarding your technology? And how has this changed over time?
 - a. Design
 - b. Preventive
 - c. Training
 - d. Manuals
4. How did you decide on this strategy?
 - a. Did you know of other implemented technologies?

5. *What were your experiences in the field when testing and using your technology, regarding maintenance? Ask for concrete experiences if they were not yet discussed.*

TRAINING

Another area of interest when wanting to achieve long-term adoption of a medical technology is the training you give staff for this technology. Hereby I am specifically talking about the user training.

6. What was your strategy on training the intended users, and how has this changed over time?
7. How did you decide on this strategy?
8. *What were your experiences in the field when testing and using your technology, regarding user training? Ask for concrete experiences if they were not yet discussed.*

ORGANISATIONAL CHANGE

To gain a full picture of the changes needed within a hospital that might be guided by your implementation process, the next topic I want to touch upon are some factors needed surrounding the organisational change supporting long-term adoption of medical technology. These factors are not widely described in literature, as are maintenance and training.

9. Does your product influence the daily practices of hospital staff? If so, did you support this and how?
 - a. *Behaviours*
 - b. *Routines*
 - c. *Organisational processes*
10. How did you account for supporting organisational features that ensure proper and long-term use of your products? Think of the following topics:
 - a. Consumables
 - b. Spare parts
 - c. Regulatory alterations
 - i. Within hospital
 - ii. Outside hospital environment

APPENDIX B. CASE STUDY MATERIALS

All materials used for the case studies are summarized on the nature of the materials. Materials are however not made available due to the anonymous nature of the multiple case study.

Organization Nr.	Material
1.	Website Interview Transcript
2.	Website Youtube Videos Sales Brochures Paper on CE certification Manuals
3.	Website Interview transcript NL Interview transcript Ghana Sales Brochures Manuals
4.	Website Interview transcript Sales brochures
5.	Website Interview transcript
6.	Website Interview transcript

Table 21. Overview of materials used within multiple case study.

APPENDIX C. ORGANIZATION PROFILES

Within this appendix, the more in-depth profiles of the included organizations are drawn.

B.1 ORGANIZATION 1

The first organization is a foundation based in Australia, founded in 2010. The foundation focusses on three areas: eyesight restoration, women's health and essential medical equipment (website organization 1). Focussing on this third area in scope, the foundation has focus on donating equipment with direct outputs. *"We always have our eye on what development is, but as a small foundation we think that we have impact in being agile and doing things now rather than working on things that the multilaterals and bilateral funding works on, in terms of broader development."* (interview transcript organization 1).

B.1.1 STRUCTURE AND GEOGRAPHICAL SCOPE

Organization 1 is a small organization, consisting of in total 6 persons, *"not all paid, even though they're all working full time, really."* (interview transcript organization 1). As a foundation, they search for projects with a direct impact. The foundation is based upon private ancillary funds. What this entails, is that private donations are redistributed through the foundation towards projects in low-resource settings. The projects have to be registered charities. To locate the projects that get donations, organization 1 partners with Rotary International to identify gaps that can be fulfilled by donating specific types of equipment. Then, the Rotary buys that equipment. This is done through an importing and distribution organization that is also run by the persons involved by organization 1. This way the best bulk deals can be made. They are *"currently funding projects in over 25 countries in the developing world."* (website organization 1).

B.1.2 MEDICAL EQUIPMENT

The aim of organization 1 is to only donate equipment that is robust, and does not need too much training to be implemented. *"We've found a range of things that we can see will increase the efficiency of certain of our partner facilities that we come across, without too much training... And that's kind of our formula to slot equipment that we know is as robust and as suitable for context as you can get without being overly expensive."* Technologies mentioned within the interview include pulse oximeters, portable ultrasound, oxygenators. The kinds of technologies organization 1 tends to steer away from are all kinds of laboratory equipment, due to its high demand in consumables, and interventions that are meant to interface on a tablet of some sorts. The latter is because of issues found when involved in a trial with such equipment, portraying problems with ownership of the tablet in question and needing too much training in getting used to the interface.

B.1.3 TARGET CLIENT / USER

To be able to adhere to the aim of the organization to have direct outputs while implementing medical equipment with little training, the user in mind has to have had some training. This means the target user is in most cases at least a health worker. The preferred client organization is health programs, due to their similar focus on outputs.

B.1.4 CLIENT / ORGANIZATION RELATIONSHIP

Once the equipment is donated, the foundation tries to stay actively in touch with the recipient. They invite their partners ask questions when they check in, giving the foundation the option to troubleshoot if there are any problems with the donated equipment. Through the building of this relationship, the organization is also able to determine if a location needs user-training for the equipment. This is then done through a partnership with a biomedical engineering network, with these engineers possibly providing this training. They have also found that troubleshooting in some situations asks for a simple solution: *"I know this is not sexy, it's not what you are looking for, but the best way to resolve it is classic communication and have a phone call."* (interview transcript organization 1).

B.1.5 OTHER FINDINGS

An interesting focus of this case study was the partnerships and focus on the role of biomedical engineers within the themes in scope for this research. The foundation has been wanting to work in the biomedical space for some time, wanting to grow the number and also the knowledge and skills of biomedical engineers in low-resource settings. They have found however that this is a very difficult thing to do, due to the little amount of biomedical engineers that are there, and then if you qualify one yourself that there is a chance of them leaving. This has then resulted in the choice of the partnership with the biomedical engineering network, achieving the same goal in some measure, but this is only practical in private, not for profit situations. They have however achieved some self-sufficiency in one of their maintenance programs, with it resulting in a tiered WhatsApp group for peer-to-peer advice. *"I could have paid for the training, just to get the WhatsApp group, because that is the capacity building that we haven't been able to do formally through like a formal program with government, but it did come about as an offshoot of a covert program."* In the belief of organization 1, if this biomedical capacity was grown together with a growing of the responsibilities could be a solution to problems with adoption. *"Well, it's all interconnected. I mean, and it's yeah the biomedes that should be in touch with clinicians. So it's a biomed should be involved in the lifespan of the equipment and they should be ensuring that that works and updating user training and responsive to the users. And the users should be, seeing the biomedes also as care provider. And so that's why I see that they're very integrated and that's the other thing to see the tool as well as helping to provide care."* (interview transcript organization 1).

B.2 ORGANIZATION 2

Organization 2 is a British organization, founded in 2003. The organization was founded with a focus on the development of anaesthetic equipment for low-resource settings. It has now been extended towards anaesthesiology and respiratory solutions, still focused solely on low-resource settings. The long standing expertise in the field allows the organization to develop and manufacture sustainable equipment, though still being affordable for LMIC. This combined with proper education and training ensures sustainable solutions not only in the use of their equipment, but in the medical practice surrounding their equipment as well. Working together with in-country partners helps them achieve the level of knowledge and resources they wish for their customers. They offer guidance and support for their products around the clock, for the lifespan of the equipment itself (website organization 2).

B.2.1 STRUCTURE AND GEOGRAPHICAL SCOPE

Organization 2 is a for-profit, commercial enterprise. They however work from a humanitarian perspective, which is why the focus is on the low-resource market. The very fact that the organization is a commercial enterprise is said to ensure the sustainability of their work (website of organization 2). Within the organization, 8 employees are active. The organization is active in about 80 countries worldwide, of which last known in 41 countries within Sub-Saharan Africa. Hereby one must mention the interviewees notion that this *“depends on which ones you actually recognize as a country”*, with this statement portraying one of the difficulties of business in LMIC (interview transcript organization 2). The organization has one office, based in the UK.

B.2.2 MEDICAL EQUIPMENT

The medical equipment of organization 2 is a wide range, with a focus on, as mentioned before, anaesthesiology and respiratory equipment. Their technologies can be subdivided into five categories: anaesthesia, intensive care and pain management, oxygen therapy, neonatal care and monitoring. Their entire market is based in LMIC.

“We do not make equipment for high income countries at all. I think to try and do both, you end up making compromises in both directions, and I think that's not a good thing.”

The equipment is built to last, minimizing the amount of maintenance that has to be done through appropriate engineering. All machines are engineered and manufactured in the UK, to enable the organization to keep an eye on the quality of its products. They do work with suppliers, but only for components and not for subcontract parts (interview transcript organization 2). Within their product range, robustness and being easy to use seem to be design principles of utmost importance. Cost-effectiveness is advertised, making the equipment of organization 2 assets and not costs for the client (sales brochures organization 2). The equipment that is on-market, is kept generic to ensure the prolonged availability of spare parts. These spare parts are under warranty with around the clock dedicated support of biomedical engineers for two years. After that, they can still be bought and helped with replacement, enabling the lifelong support coming with the buy of a product of the organization (website of organization 2; interview transcript organization 2).

B.2.3 TARGET CLIENT / USER

The medical user of the equipment of organization 2 can be regarded as the end-user of their products. In the case of organization 2, this entails *“the majority of equipment is used by anesthetic nurses, or anesthetic clinical officers so their training may be a little limited.”* (interview transcript organization 2). Another mentionable thing on the prospective end-user for organization 2, is the opinion of the interviewee regarding their expertise: *“What they know and what they do, they do very well. So much quicker than Western doctors do. I've spent quite a lot of time in the hospital in the UK, and when you go to Africa things are so much quicker. There's a lot less fuss, which can be a good thing and sometimes a bad thing.”*

But the anesthetic, I know lots of anesthetic nurses in Africa, the time it would be happy to give me an anesthetic and I know quite a few doctors in the UK I would not like to give me an anesthetic.

The targeted persons to do the maintenance on the equipment of organization 2 are not necessarily always high-level, such as biomedical engineers. Through experience, they know they need to provide materials for lower-level technicians to be able to understand the equipment, enabling them to do the general maintenance of the equipment. Their experience with training them to the level of biomedical engineer will actually up the chances of that specific person leaving (interview transcript organization 2). They do however state on their website that *“our biomedical engineers have also spent the last ten years training clinicians and biomedical engineers directly”* implying that there is still ongoing biomedical engineering training alongside their training of clinicians (website of organization 2).

B.2.4 CLIENT / ORGANIZATION RELATIONSHIP

Organization 2 has a great focus on customer commitment, providing lifelong support alongside their products. This aftersales support goes through email, telephone and WhatsApp for as long as the client has the equipment. The website is equipped with instructional and explanatory videos on each technology (website of organization 2). Since most of the dealings of organization 2 are directly with the end-user, they use these lines of communication to ensure access of client to organization. The interviewees reasoning for this is:

“Yeah, I think if they've got access to us, then they're more likely to come to us to help them find the problem, then go looking for it themselves and do something wrong.”

The aforementioned target client and user also depicts partially the relationships organization 2 has with its clients. The years of experience, going to the clients directly and providing training and education in the field as a leading expert, makes for a high level of trust both ways.

B.2.5 OTHER FINDINGS

Because of the open structure of the interview, the topics were not restricted to solely themes in scope. One discussion included within this interview specifically, was the mismatch that exists within the guidelines that exist for CE-marked equipment and the equipment that is actually functional within low-resource settings. The guidelines that are HIC centric do not fit companies that are producing equipment for LMIC. Quoting from a draft paper written by the interviewee on this matter: *“The often quoted and misquoted estimates from WHO are that up to 80% of medical equipment in many sub-Saharan African countries is donated or funded by foreign sources, and 70-90% of donated equipment is never operationalised. Some equipment is nonfunctional before it is donated, effectively it is dumping of waste or end of life equipment to avoid disposal costs. It is clear that there is a mismatch between medical equipment designed, certified and meeting current international standards and appropriate medical devices suitable to function and last in Sub-Saharan Africa and many other low-income settings which do not have the infrastructure standard of high-income areas.”* (paper written by the interviewee of organization 2). The interviewee also proposes the main differences between HIC and LMIC that could be at the core of this problem. The problematic issue with this right now is however, that tenders in LMIC mostly have a precondition that the device in question should be CE marked, making it hard to change this problem (interview transcript organization 2).

B.3 ORGANIZATION 3

Organization 3 was founded in 2003 with a focus on developing specific diagnostic solutions for a disease burdening over 10 million people a year. With the vision of improving people's quality of life through access to modern care in LMIC, focussing on adequate diagnoses so that this can be followed by proper treatment. Because of the initial focus on one disease, the organization is very strong in a niche market. Their strength lies in the development of artificial intelligence, that can be used to identify the disease. The results of their AI are currently better in identifying the disease than radiologists themselves (interview transcript organization 3b). Currently they stand at a total of 9.6 million screenings on the disease, involved in 164 projects and 1049 installations of equipment (website of organization 3). For this organization, two persons were interviewed. One of the main office in Den Bosch regarded as interviewee 3b and subsequently organization 3b if the notion is specific to that office. The other interviewee is regarded as 3a, subsequently organization 3a, and is based in an office in Ghana.

B.3.1 STRUCTURE AND GEOGRAPHICAL SCOPE

Organization 3 was founded in 2003. It is as a for-profit organization, though their main goal being impact and not profit. This is then also the reason for being active solely in low-resource settings (transcript of organization 3b). The organization is active in 74 LMIC (website of organization 3). Of these 74, about 40 of the 52 countries within Africa are dealing with organization 3b (interview transcript of organization 3b). Of these, about 16-20 have dealt with the local presence of organization 3a for installation and service support (interview transcript of organization 3a). To explain this structure a little further, the set-up of the Ghana office should be elaborated. Through a grand project in Ghana, covering the installation of 55 X-Ray apparatus and having to transfer the operation and maintenance of this equipment towards Ghanese persons over 5 years, organization 3 found out that the expertise of these Ghanese engineers was above expected. Organization 3b then decided to expand towards a Ghanese office, including those engineers and having them included in both installation and maintenance within other projects. This evolved to organization 3a now being responsible for the helpdesk for all equipment of organization 3b (transcript of organization 3a; transcript of organization 3b).

B.3.2 MEDICAL EQUIPMENT

Organization 3 offers a multitude of X-Ray solutions, combined with artificial intelligence solutions for initially one disease. It has since its founding been expanded towards other diseases, applying their expertise in other medical fields. The X-Ray solutions are also offered in the form of fully equipped clinical busses, or even clinics as a whole. The extension of the X-Ray solutions with AI enable more persons to be screened than in a normal radiologist context (interview transcript organization 3a). Their philosophy within the designing of their solutions is to built equipment that lasts. To give more depth to this, interviewee 3b mentioned this on the development of an additional ultrasound solution for their organization:

"We are currently working on the development of an ultrasound device, and an employee has been in Sierra Leone for three months already to see how it is used. And we already come across so many problems of which we think it is clear, but they don't understand it at all. And through this we have done many adjustments. So keep it simple, and everything you do should be of top quality. You better invest in the front, than constantly have problems in the field."

The technologies are adapted to be functional in low-resource settings, having factors like solar-power, being portable through the light weightiness, being multifunctional and through design having the X-Ray be non-damaging (brochures of organization 3). The key to these designs being success lying in the simplicity of the designs, having only functions incorporated

that are of importance, and not things that are just nice to have (interview transcript of organization 3b).

The equipment has a standard 2 year warranty, with service and spare parts arrangements after that period being dependent upon the project (transcript of organization 3a).

B.3.3 TARGET CLIENT / USER

The targeted client for organization 3 consists mainly of country health programs focused on the disease that organization 3 is specialized in. The scope of these programs can be either small or large, and even outside of these programs organization 3 has clients. The acquisition of customers is herein done by organization 3b. The intended user for the X-Ray devices are radiographers, that receive extended training by organization 3 to be able to use these specific X-Ray devices and take photos with them. The software however, might also be learned to previously untrained personnel, that receive training on how to use the software (transcript interview organization 3a;3b). As for the target technical employees needed to enable the long-term functioning of the equipment, this is dependent upon the scope and size of the project at hand. For any of the larger projects, a local engineer is put under contract, though mostly freelance, of organization 3 for both the installation and maintenance tasks of the equipment. Smaller projects are done through the use of hospital engineers (transcript of organization 3a).

B.3.4 CLIENT / ORGANIZATION RELATIONSHIP

Because of the intricateness of the equipment developed by organization 3, seeing it involves radiation, installation of equipment is done on-site using a combination of organization-own engineers and local engineers. This combination creates a knowledge transfer, enabling the local engineer to perform the next installation. This knowledge transfer from organization to client is also done during the maintenance tasks (transcript organization 3a). To further enable communication between organization and client, the organization focusses on establishing WhatsApp groups that enable peer-to-peer advice. This is for both the engineering as the medical side of the client. There is also proactiveness in the relationship from organization 3 towards its technical users, asking them to fill-in checklists on the equipment to be able to foresee problems and act on them (transcript of organization 3a). Furthermore, the client / organization relationship was mentioned by interviewee 3b as an important factor of their way of work, ensuring they can alter their equipment if needed.

"So we are very focused on the total package, so that the service also is continuously good. For us it is a very unpleasant idea that they buy something and after two years they don't use it anymore because some spare parts are not available."

B.4 ORGANIZATION 4

Organization 4 is an NGO based in the United States. It was founded in 2018 with the aim of designing, manufacturing and implementing respiratory solutions in LMIC. The reason for this being the high mortality rate under neonates due to birth asphyxia, a condition that is preventable if supplied with the right equipment and training. And even though they recognize that there are already ventilators and CPAP machines present in LMIC, think of the solutions of organization 2, their view on the matter is that most of these machines do not fit the context and fall into the aforementioned 70% of medical equipment that is deemed non-functional in LMIC (website of organization 4; interview transcript of organization 4). In the words of interviewee 4:

"Uh, and that's not the case in Africa and other developing markets. So that's our focus when we look at the markets, there is not a problem with the technology as far as, ventilators don't exist. They do exist, but if you go to a lot of these low resource settings, you'll see the hospitals have ventilators and, the statistics change and vary that I've seen, upwards of 70% of all medical devices in low resource settings are not used. Either they're broken or they're, you know, they can't get training to be able to know how to use the equipment."

B.4.1 STRUCTURE AND GEOGRAPHICAL SCOPE

Since the organization was only founded a couple of years ago, the organization has only managed to take on a handful of projects. The complete projects done, meaning both equipment implementation and a broad training programme, were in Cambodia, Madagascar and Zambia. They do however also have, or almost have, equipment implemented in Uganda, Zimbabwe and Mozambique. The training programme has not been done however, due to COVID-19 restrictions. Within the organization, 9 persons are active in the capacity of either full-time, part-time or volunteer. The organization started out as a for-profit, but after a while deemed it more useful to proceed as an NGO. This decision was based upon the notion that in the US, companies are to give a certain amount of money towards charities each year. This gives organization 4 a more sustainable business model, using these donations to operate in LMIC, than having the clients in LMIC pay for their equipment themselves (conversation with interviewee 4).

B.4.2 MEDICAL EQUIPMENT

Organization 4 offers two types of ventilators that are also able to provide CPAP. The ventilators are either made for a neonate or for an adult. The design philosophy for building these ventilators was to ensure ease of use, while also being affordable and easy to maintain. These requirements were all thought out having LMIC specifically in mind, seeing that ease of use can be defined differently when comparing them with HIC. For this equipment, this means that *"if you open up our ventilator, what you see inside is a bunch of knobs, a bunch of tubes you see a lot of mechanical devices that are in there, so physical devices that are making the ventilation and the CPAP work."* (transcript interview organization 4). The components within the device are made with automobile standards, which should ensure durability for a prolonged period of time. The warranty on the equipment is for 1 year, but the organization does promise ongoing maintenance and support for the life of the product. Noteworthy is that the adult ventilator has an emergency FDA approval, while the neonatal ventilator is still awaiting FDA approval (brochures of organization 4).

B.4.3 TARGET CLIENT / USER

One of the selling points of organization 4 is the integrated training programme, also including respiratory therapy. This supports their prefer of larger projects, taking on whole countries if possible through collaboration with a Ministry of Health. Smaller projects are however also taken on. The intended user varies, since a multitude of employees within a hospital can be trained for various uses of the ventilators.

In the words of the interviewee: *"It would be doctors, nurses and then a more limited usage of the equipment with midwives and community healthworkers. So we would not train a midwife or community health worker to do some more advanced things that you can do with the ventilators because they need other training to be able to do this, the training that we would provide."*

B.4.4 CLIENT / ORGANIZATION RELATIONSHIP

Because of the preferred larger scope of projects, the dealings of organization 4 seem to be limited towards the higher levels of organizations. They do however succeed in working together well with said higher levels, for example the Ministry of Health in Zambia. *"I have quotes from the Minister of Health in Zambia saying. Uh, I had a lot. I had multiple long conversations with him where he said one of the reasons we like what you guys do is because you don't come in with a training, that's like a couple hours on how to push buttons on the device you actually train respiratory therapy like patient intervention and protocols. Even training beyond the device, and so that's what they're... That's what they need."*

Further relational dealings of organization 4 with its direct end-user facilities is done through multiple channels. The contact when there are problems with equipment go through locally trained engineers. The organization does however prefer in-person visits when carrying out the training programme provided with their equipment. *"And we're able to really create a rapport, and to answer, I think more in depth questions. A virtual training works, but it's not ideal."*

B.5 ORGANIZATION 5

Organization 5 is a foundation that was founded in 2014. The foundation was formed in an effort to structure the social responsibility of a corporate organization. The foundation was founded in an effort to be better, more effective, more transparent and to share learnings of what before the founding of the foundation were loose projects done in the markets in which the corporate was active (interview transcript organization 5). The foundation focuses on SDG 3, ensure healthy lives and promote well-being for all at all ages, and SDG 17, revitalize the global partnership for sustainable development (website of organization 5). They do this through the use of the corporates resources in three ways: their technology, their expertise and their money.

B.5.1 STRUCTURE AND GEOGRAPHICAL SCOPE

The foundation works with an executive board that consists 7 persons responsible for the strategy, policies, performance and operations of the foundation. They hereby oversee the work of a management team of 5 people, overseeing the daily activities. Furthermore, many employees of the corporate organization are active in the foundation on a project basis (website of organization 5). Geographically, the foundation is widely active. The foundation does not have a sole focus on LMIC, they broaden their scope by also supporting disadvantaged communities within HIC (website of organization 5). Since the start of the foundation, over 250 projects have gotten support from the foundation (annual report 2020 of organization 5). On the question in which Sub-Saharan African countries the foundation is really active: *"I can name a couple of countries, so for example South-Africa, Kenya, Uganda, Ethiopia... We are there, South-Sudan, Somalia and so there are also a couple of countries where we are active at this moment. In the past also countries like Côte d'Ivoire and... So yeah, that varies."*

Besides support in projects, the organization has also set-up an incubator as a part of the foundation. This incubator is to, besides the kinds of support that already originate within the foundation, also provide loans to businesses that have a sustainable business model and impact in these disadvantaged communities. *"So we are committed to for example the providing of loans. So conventional loans, convertible loans or even equity and then in that way we look at how we can support them. And so we do this alongside the technology and access to expertise."*

B.5.2 MEDICAL EQUIPMENT

Since organization 5 is a foundation, they do not have any in-house development of medical equipment. They do however implement equipment of the corporate, whose sole focus is medical technology, and they partner with organizations in development of equipment and also the development of programmes aimed at bettering the quality or access to care. This is thus a widespread application of the notion of medical technology.

"Yes, it's also broad what you see as medical technology. Is it hardware, is it software and sometimes... Yeah sometimes, then I would take it even broader under innovation, and then even business model innovation becomes a part of it. Yeah, so that's all aspects and sometimes there are other elements within the technology, dependent upon the problem you are solving."

B.5.3 TARGET CLIENT / USER

The target client of the foundation is not necessarily the end-user of the implemented technologies. The target clients are based in the kinds of projects they provide their support. These projects can mostly be categorized in one of the following three:

1. Humanitarian aid.
2. Partnerships with NGOs.
3. Collaboration with social entrepreneurs.

The first consists of acts within emergency response, and all activities that can be supported by a health technology foundation. NGOs are preferred over Ministries by organization 5, due to their belief it is not beneficiary to invest in the government. The NGOs they prefer have local presence, but are able to go cross-border so that learnings can be applied from one country to another. The latter is the currently preferred way of working for organization 5, supporting social entrepreneurs that are focused on impact more than revenue, or profit. The reason for the shift of focus from NGOs towards social entrepreneurs is the sustainability that these businesses can bring over NGOs (interview transcript organization 5).

B.5.4 CLIENT / ORGANIZATION RELATIONSHIP

One of the key points within the foundation is the belief that innovation and collaboration can make a real impact by solving some of the world's toughest challenges (website of organization 5). This notion of collaboration makes for client / organization relationships to be outed mostly in partnering with the aforementioned NGOs and social entrepreneurs. The small managerial team of the organization is the one responsible for the relationships with these partners, and the relationship with the corporate of the organization. The organization also has partners on-ground to stay in touch with the projects that they are involved in.

"To have a strong market surveillance, post-market surveillance is very important, so when you implement stuff, feedback gets collected. So that is then actually the quality, and the safety notices that get delivered on time. This is very important for healthcare equipment, and healthcare technology and to make sure that the link with the customer, the customer relationship, really is well substantiated and that it is well kept, is maintained. This is important for winning or losing."

B.5.5 OTHER FINDINGS

Another aspect talked about within the interview, was the importance of the notion of ownership when talking about adoption for medical technologies. This ownership comes with the relevance of the local presence. To work within the realm of critical care, it is important to have strong local presence, or you ought to have a local partner there to be able to measure KPI's. *"So it is important to map those KPI's, this can be through the use of the technology by for example its availability, the uptime, the consumables... The auditing, the check, lesson or whatever, so you always need ownership on multiple sides. On the business side, this can be GOAL3 or another venture, but also by for example on the nurses side, the head nurse or whomever at the health facility."* (interview transcript organization 5). The KPI's should be checked regularly, and thus is this ownership something to be taken into account when implementing medical technology.

B.6 ORGANIZATION 6

The final organization included in the case study was founded in 2019 with the goal of making diagnostics accessible throughout small healthcare providers in Sub-Saharan Africa. Through leasing their equipment instead of the traditional financing, they solve this problem of accessibility (website of organization 6). To frame the market where the organization is active: *"We are in markets which are very very fragmented, from a healthcare perspective. So I mean, think, imagine if you're not in the Netherlands, or if the Netherlands would have 20.000 small GP practices instead of having 5000 or 2000, right. And then, all of them would be too small, too poor, too little, not enough patients. No education of the clinicians and no access to medical devices. That's kind of the picture, right? So, in that scene, you know most of the emerging markets function in the same way where basically you have massive fragmentation in primary care."*

B.6.1 STRUCTURE AND GEOGRAPHICAL SCOPE

The organization started in Kenya, with now over 800 partnered clinics, 5 organization-operated labs that have in total done over 100k tests (website of organization 6). They have started to expand their project into South Africa, starting in Cape Town. The organization has 6 teams and semi-offices. These are based in Nairobi, 4 other cities in Kenya and an office in Cape Town. In total the employees of organization 6 round up to about 130 persons. The specific business model, built upon leasing diagnostic devices was especially developed for Kenya, where the primary care system is very fragmented. Having primary care without access to laboratories makes for a large number of misdiagnosis in Kenya. This combined with persons paying out of pocket in their primary care clinics, makes for a gap in the market where organization 6 could start with a viable business model of leasing those smart diagnostic devices (interview transcript organization 6).

B.6.2 MEDICAL EQUIPMENT

Organization 6 itself has not developed any of the diagnostic equipment that are being offered by the organization. They have however *"built kind of an IoT platform to connect those devices together into one system, into one middleware, and we lease them."* This is in addition an *"in house electronic medical records and billing platform."* (interview transcript organization 6). The devices in question are innovative devices, able to detect one or two markers for a disease. These devices are produced by companies all over the world, scouted by organization 6 as fit for purpose. Most of the devices are purely digital, and able to give lab results in a short amount of time. This is then also the value proposition of the organization (interview transcript organization 6). Because of the interconnectedness of these digital devices to the platform organization 6 has built, one of its future endeavours will encompass the use of the gathered data to develop AI add-ons to the platform to further benefit diagnostics (interview transcript organization 6).

Currently the organization offers a total of 9 devices that can be leased. For all available devices, the return of investment can be calculated using a tool that is available on the organization's website (website of organization 6).

B.6.3 TARGET CLIENT / USER

As explained above, the focus of organization 6 is solely on primary care. More specified, *"Usually those practices are run by nurses, not by doctors, because there are not enough doctors, right? So there is no problem of access to care as such. You step out of your place, and you have, you know, ten small clinics and all of them are the same. A nurse maybe studied some kind of nursing school 10 years ago, she doesn't know much. She's going to look at you and say Nienke, let me give you some antibiotic and goodbye."* The client and end-user are thus in a sense the same for organization 6, namely primary care clinics run by nurses.

B.6.4 CLIENT / ORGANIZATION RELATIONSHIP

The client / organization relationship is of great importance for the success of the leasing contracts implemented by organization 6. The way they approach this is human intensive, doing most of their contact physically. *"We have 70 people going in the field every day."* (interview transcript organization 6. This physical contact is important, to build the relationship necessary. *"And also, a lot of countries who are kind of, face to face contact is very very important in the relationship and you need to be face to face."* This is also seen on the website, which is very focused directly towards the end-user, inviting them to be part of a partnership more so than trying to advertise their equipment (website organization 6). Another noticeable thing is that the organization actively is searching for clinics to help, not always having clinics pre-identified before going to the field. If the clinic is pre-identified they might be contacted by phone first.

B.6.5 OTHER FINDINGS

Since this organization is the only organization providing a service with leasing contracts, and the only one being based in Sub Saharan Africa, their takes on certain strategies seem to differ from the other 5 companies that have been spoken to. For once, the non-existent focus on digitalization of contact and training. This might however be due to the fact that all other companies have had to adapt to the COVID-19 restrictions, actively restricting travel from employees towards SSA. Since organization 6 is based in Kenya and has most of its clinics there, travel restrictions might not have been pushing them towards online solutions and thus keep them favouring the offline option.

APPENDIX D. PRELIMINARY FRAMEWORK

Needed characteristics to fill in framework. The notation of these characteristics are already decided upon by giving suggested values for each characteristic. One should fill in this framework pre-implementation, giving an indication for the risks that could be mitigated during implementation for adoption.

C.1 TABLES OF CHARACTERISTICS

Category	Subcategory	Characteristic	Definition	Value
Organization	-	Age	The number of years the organization has been active.	[0 – 3 years / 5 – 10 years / 10+ years]
	-	Employees	The number of employees under contract of the organization.	Numeric
	-	Local network	If the organization in question has a local network of employees, thus dependent upon the project the framework is filled in for.	[yes / no]
	-	Development of Equipment	If the implemented equipment by the organization was also developed by the organization itself.	[Internal / External]
	-	Presence in SSA	The amount of countries the organization has presence in within Sub Saharan Africa.	[0 – 5 countries / 6 – 15 countries / 15+ countries]
	-	Target client organization type	The preferred organization type the organization targets, or does business with.	[Ministry / Health Program / Hospital / Clinic / Public / Private]+
	-	Stance in communication	Describes the preferred client / organization relationship the organization takes.	[None / Proactive / Reactive / Online / Physical]+
Client Organization	-	Type	Type of client organization in which the equipment is to be implemented.	[Ministry / Health Program / Hospital / Clinic / Public / Private]+
	Employees*	Knowledge and Skill base	Describes the existent skill and knowledge level of the employee that is being described.	[None / Low / Sufficient / Good / Excellent]
		Workload	The workload of the employee that is being described.	[Low / Medium / High / Extreme]
		Staff Turnover	The amount of staff, leaving or changing within the organization.	[None / Low / Medium / High / Extreme]
	-	Operating Conditions	Conditions like humidity, power requirements, etc.	[Unknown / Known]
	Equipment	Similar Equipment available	If there is equipment alike to the to be implemented equipment within the organisation.	[Yes / No]
	Routines	Medical Practice	Knowledge on the medical practice surrounding the to be implemented equipment.	[Unknown / Known]
		Spare parts handling	There is an existent scheme for the handling of spare parts.	[Yes / No]
		Consumables handling	There is an existent scheme for the handling of consumables.	[Yes / No]
	Policy	Medical Practice	The existence of policy dictating medical practice.	[Yes / No]
		Import	The existence of policy dictating import of materials.	[Yes / No]

	-	Relationship with organization	Describes when the relationship with organization is established.	[None / to-be-established / established]
Medical Equipment	-	Intended User	The medical end-user the equipment is designed for.	[Layperson / Healthworker / Nurse / Doctor]+
	Technological Context	Required routines	Knowledge on the medical practice suitable after equipment implementation, and if it matches with current medical practice.	[Similar / Different]
		Required operating conditions	Knowledge on the operating conditions the equipment functions in, and if it thus will function in client organization.	[Functional / Non-functional]
	Maintenance*	Executor	Describes what person is to be in charge of the maintenance described.	[End-User / Lower-Level Technical Employee / Higher-Level Technical Employee / Expert]
		Frequency	Describes how often the maintenance usually takes place.	[Daily / Weekly / Monthly / Quarterly / Yearly]
		Tools	Describes the need for tools within the maintenance described.	[None / Low / Medium / High / Extreme]
	Organisational Change*	Need	Describes the need of the equipment.	[None / Low / Medium / High / Extreme]
		Average costs	The average costs of the equipment.	Numeric
		Availability	Describes the availability for the equipment.	[Import / Local / Unavailable]
	Novelty	Familiarity	Describes the familiarity of the equipment to the client organization.	[Yes / No]
		Behaviour Change*	Describes the amount of changes required to established routines	[None / Few / Significant / Radical]
	Training*	Type	Describes the type of training given with the equipment, if there is any.	[Included / Paid / On-Site / Online / Offline Materials]+
		Materials	Describes the type of materials that are delivered with or as training.	[Manual / Videos / Quick Guide / E-Learning]+
		Level	Level of knowledge and skill needed to understand and participate in the training.	[None / Low / Sufficient / Good / Excellent]
		Trainer	Describes which person is to give the training	[organization / external / trainer-on-trainer / None]

Table 22. Descriptive characteristics of organization, client organization and equipment used in framework.

*These subcategories can be further specified into smaller subcategories.

Subcategory		
Employee	Technical	Lower-Level
	Medical	Higher-Level
		Doctor
Maintenance		Nurse
	Preventive	Healthworker
	Corrective	
Training	Technical	Layperson
		Lower-Level
		Higher-Level
	Medical	Layperson
		Healthworker
		Nurse
Behaviour Change		Doctor
	Medical Practice	
	Spare Parts	
Organisational change	Consumables	
	Spare parts	
	Consumables	

Table 23. Further specification of subcategories employee and maintenance.

C.2 COM-B MODEL

If the proposed framework indicates risks for behaviour change, the COM-B model comes into play. Because of the broad field of behaviour change research, it was chosen to use this already established method to analyze if the preconditions for behaviour change are within the strategy and materials of the organization and client organization, and if-not what the organization can do to ensure they are there. Firstly, to analyze if the capability, motivation and opportunity are there, the following questions can be asked:

1. Capability

- Is there physical capability (e.g. balance and dexterity) for the person to obtain and express the new behaviour?
- Is there psychological capability (e.g. understanding and memory) for the person to obtain and express the new behaviour?

2. Motivation

- Does the person have reflective motivation (e.g. plans and evaluations) to obtain and express the new behaviour?
- Does the person have automatic motivation (e.g. desires and habits) to obtain and express the new behaviour?

3. Opportunity

- Is there physical opportunity (e.g. financial and material resources) for the person to obtain and express the new behaviour?
- Is there social opportunity (e.g. culture and social norms) for the person to obtain and express the new behaviour?

With the sources that could possibly block the behaviour identified through this set of question, a possible intervention can be designed. For this, one could look at the behaviour change wheel by Michie et al. (2011) to look at possibilities. To be able to interpret this wheel, the table with definitions taken from the article by Michie et al. (2011) is given in Table 24, however the examples have been altered to examples of interventions and policies altered towards the adoption of medical technology. The examples are, if possible, taken from the case studies. If the example cannot be taken from the case studies, an example inspired by one of the case studies is given.

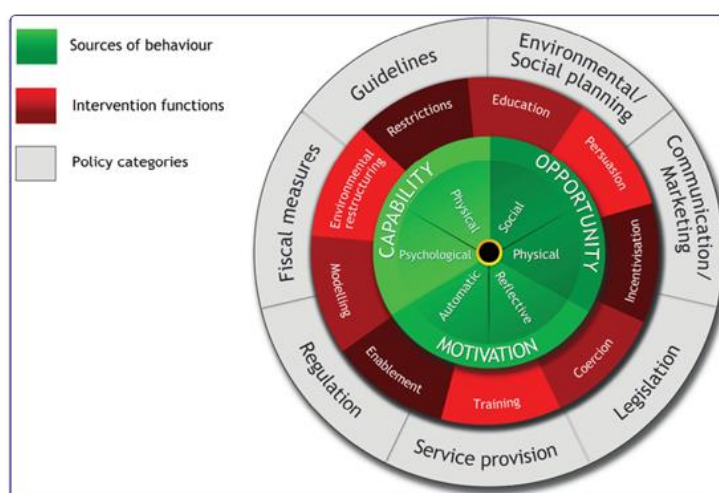


Figure 17. Behaviour change wheel copied from Michie et al. (2011).

	Category	Definition	Example
Interventions	Education	Increasing knowledge or understanding.	Education on the health benefits of doing the diagnostic tests. (c. 6)
	Persuasion	Using communication to induce positive or negative feelings or stimulate action.	Doing a symposium on the beneficial factors of the equipment, teaching radiologists there is not threat. (c. 3)
	Incentivisation	Creating expectation or reward.	Rewarding engineers filling in the checklists. (c. 3)
	Coercion	Creating expectation of punishment or cost.	Financial strain of not using the diagnostic devices. (c.6)
	Training	Imparting skills.	Training anaesthetic nurses on how to use the anaesthetic equipment. (c.2)
	Restriction	Using rules to reduce the opportunity to engage in the target behaviour (or to increase the target behaviour by reducing the opportunity to engage in competing behaviours)	Prohibiting the reuse of consumables.
	Environmental restructuring	Changing the physical or social context.	Providing charts to do the charting. (c. 4)
	Modelling	Providing an example for people to aspire or to imitate.	Organization engineers teaching local engineers with a passbook. (c. 3)
	Enablement	Increasing means/reducing barriers to increase capability or opportunity*	
Policies	Communication / Marketing	Using print, electronic, telephonic, or broadcast media.	Mass media campaigns on disease detection.
	Guidelines	Creating documents that recommend or mandate practice. This includes all changes to service provision.	Inserting equipment use in the treatment protocols.
	Fiscal	Using the tax system to reduce or increase the financial cost.	The import of consumables through Zambian policies. (c. 2c)
	Regulation	Establishing rules or principles of behaviour of practice.	Hospital policy dictating use of equipment.
	Legislation	Making or changing laws.	Legislation to improve import of consumables.
	Environmental / Social planning Service proposition	Designing and/or controlling the physical and social environment. Delivering a service.	Designing infrastructure to support transportation of consumables. The lease of diagnostic devices. (c. 6)

* Capability beyond education and training; opportunity beyond environmental restructuring

Table 24. Definitions of interventions and policies, taken from the research by Michie et al. (2011).

APPENDIX E. MOCK-UP FRAMEWORK ORGANIZATION 2

D.1 ORGANIZATION CHARACTERISTICS

Characteristic	Value
Age	10+ years
Employees	8
Local network	Yes
Development of Equipment	Internal
Presence in SSA	15+ countries
Target client organization type	Hospital
Stance in communication	Reactive, Online, Physical

Table 25. General characteristics organization 2.

D.2 CLIENT / EQUIPMENT

Because the medical persons spoken with are from different client organizations, and also spoke on differing types of equipment implemented, the characteristics per example are drawn. Then, a risk indication is made per example. Budgets are herein disregarded due to the confidential nature and thus no knowledge on exact numbers. The frameworks are filled in for the initial implementation situation.

D.2.1 SOMALILAND / ANAESTHETIC EQUIPMENT

Category	Subcategory	Sub subcategory	Characteristic	Value
Client Organization	-		Type	Hospital
	Employees*	Technical – Lower Level	Knowledge and Skill base	Low
			Workload	High
			Staff Turnover	Medium
		Medical – Nurse	Knowledge and Skill base	Sufficient
			Workload	High
			Staff Turnover	Medium
	-		Operating Conditions	Known
			Similar Equipment available	Yes
			Medical Practice	Known
	Routines		Spare parts handling	No
			Consumables handling	Yes
			Medical practice	No
	Policy		Import	No

			Relationship with organization	Established
Medical Equipment	-		Intended User	Nurse
	Technological Context		Required routines	Similar
			Required operating conditions	Functional
	Maintenance*	Corrective	Executor	Lower-Level technical employee
			Frequency	Low
			Tools	Low
	Organisational Change	Spare Parts	Need	Low
			Availability	Import
		Consumables	Need	Low
			Availability	Import
	Novelty		Familiarity	Yes
		Behaviour Change	Medical practice	Few
			Spare Parts	None
			Consumables	None
	Training*		Type	Included, Online, Offline Materials
			Materials	Manual, Videos
			Level	None
			Trainer	Trainer-on-trainer

Table 26. Client organization / equipment characteristics for Somaliland and anaesthetic equipment.

RISK INDICATION

Barrier	Maintenance	Training	Spare Parts	Consumables
Time				
Money				
Human Resources				
Materials				
Policy				
Trust				
Breaking habits				
Communication				

Figure 18. Risk indication for adoption barriers for Somaliland / Anaesthetic equipment.

D.2.2 ZAMBIA / CPAP

Category	Subcategory	Sub subcategory	Characteristic	Value
Client Organization	-		Type	Hospital
	Employees*	Technical – Lower Level	Knowledge and Skill base	Low
			Workload	High
			Staff Turnover	Medium
		Medical – Nurse	Knowledge and Skill base	Sufficient
			Workload	High
			Staff Turnover	Medium
	Equipment		Operating Conditions	Known
	Routines		Similar Equipment available	Yes
			Medical Practice	Known
			Spare parts handling	No
	Policy		Consumables handling	Yes
			Medical practice	No
			Import	No
	-	-	Relationship with Organization	None
Medical Equipment	-		Intended User	Nurse
	Technological Context		Required routines	Similar
			Required operating	Functional

		conditions	
Maintenance*	Corrective	Executor	Lower-Level technical employee
		Frequency	Low
		Tools	Low
Organisational Change	Spare Parts	Need	Low
		Availability	Import
	Consumables	Need	Low
		Availability	Import
Novelty		Familiarity	Yes
	Behaviour Change	Medical practice	Few
		Spare Parts	None
		Consumables	None
Training*		Type	Included, Online, Offline Materials
		Materials	Manual, Videos
		Level	None
		Trainer	Trainer-on-trainer

Table 27. Client organization / equipment characteristics for Zambia and CPAP.

RISK INDICATION

Barrier	Maintenance	Training	Spare Parts	Consumables
Time				
Money				
Human Resources				
Materials				
Policy				
Trust				
Breaking habits				
Communication				

Figure 19. Risk indication for adoption barriers for Zambia / CPAP.

APPENDIX F. FRAMEWORK GUIDE

This guide gives a step-by-step application approach to identify and analyse barriers in adoption applicable to an implementation situation. Implementation situation is herein defined as a medical equipment (ME) being implemented by an organization (O) in a client organization (CO).

STEP 1: IS THE DESIGN FINAL?

Firstly, the organization is to determine which one of the following paths is applicable to their implementation situation. Herein there are two options:

1. Use of the framework to inform both design and implementation strategy: Figure 20

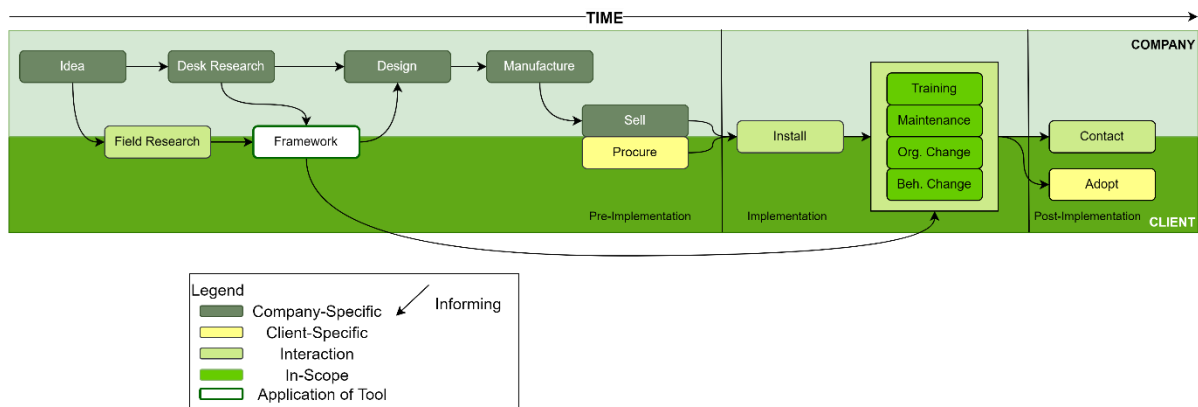


Figure 20. Simplified implementation process showing where the framework could be applied to inform both design and implementation strategy.

2. Use of the framework when design is already final, and thus only to inform implementation strategy: Figure 21

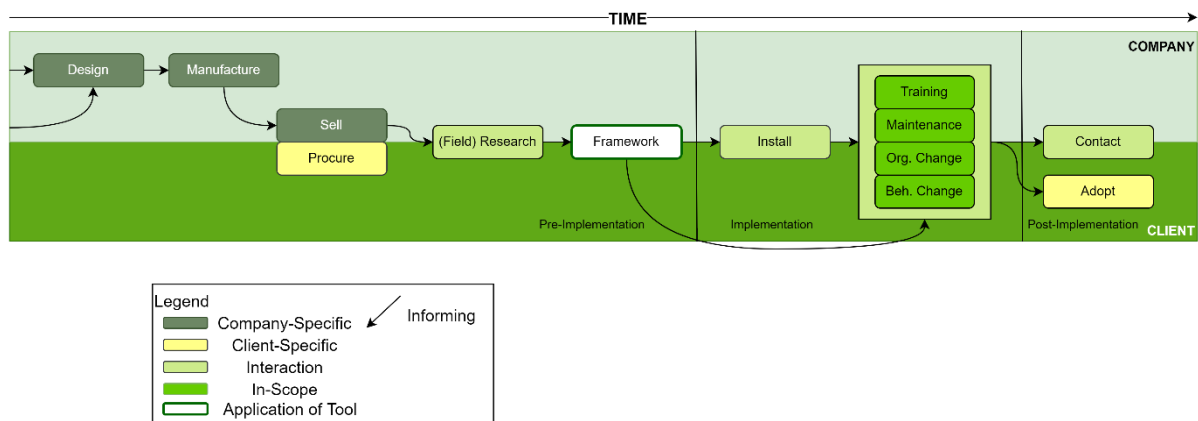


Figure 21. Simplified implementation process showing where the framework could be applied to inform solely the implementation strategy

STEP 2: RANK MAINTENANCE, TRAINING, ORGANISATIONAL AND BEHAVIOUR CHANGE.

Looking at the definition of these themes:

- *Maintenance*: Covering any notion of periodic and corrective maintenance (e.g. cleaning, repair, replacement) of the medical equipment implemented by the organization.
- *Training*: Covering any notion of training done on use and maintenance of the medical equipment implemented by the organization.
- *Organisational Change*: Covering any notion of spare parts and consumables and the management thereof needed by the medical equipment by the organization.
- *Behavioural Change*: Covering any notion of the need for behaviour change to support the adoption of medical equipment implemented by the organization.

Rank them on importance for the implementation situation at hand. The most important theme is herein the theme that you think you would have most problems with.

1. _____
2. _____
3. _____
4. _____

STEP 3: RANK BARRIERS ON POSSIBILITY OF OCCURRENCE.

The barriers that could be of influence in each of the steps and hereby having an effect of one of the themes in scope are summarized in Table 28. This table also depicts in which of the themes in scope the effect can be noticeable denoted with X's, and thus which of these themes in turn is affecting the outcome adoption of the technology. In this, *M* stands for maintenance, *T* for training, *SP* for spare parts and *C* for consumables.

Barrier	Definition	M	T	SP	C
<i>Time</i>	If time, be it a lack thereof or an action taking up too much time, being an inhibiting factor for the theme.	X	X	X	X
<i>Money</i>	If money is a constrictive factor for either the organization or client side of the theme.	X	X	X	X
<i>Human Resources</i>	If a theme is affected by staffing issues, be it in a lack of staff in general or the correct staff not being available.	X	X		
<i>Materials</i>	If a theme is affecting by materials not being available, while this not being due to costs or delivery times.	X	X	X	X
<i>Policy</i>	If a theme is affected by policy, with the notion of policy encompassing both client-specific but also region-specific policy.		X	X	X
<i>Trust</i>	If a theme is affected by trust, be it between client and organization, or within the client organization itself.	X	X		
<i>Breaking habits</i>	If there is an ask within the theme in scope for a party to alter their current routines and behaviours.	X	X	X	X
<i>Communication</i>	If communication between client and organization, be it lack thereof or communication not fitting with client/organization relationship, is an inhibiting factor for a theme.	X	X	X	X

Table 28. Overview of the barriers and their definitions, depicting on which of the themes in scope they could have effects.

Keeping this in mind, rank the barriers applicable to the themes at hand in order of severity for your organization. Taking maintenance as an example:

The applicable barriers for maintenance are: time, money, human resources, materials, trust, breaking habits and communication. Put them in an order of 1 – 7, with 1 being the most severe barrier for your organization. Do this for every theme.

Then, colour these barriers:

- **Red**: Theme ranks 1 / 2 and barrier ranks 1 / 2;
- **Orange**: Theme ranks 1 / 2 and barrier ranks 3 / 4 or theme ranks 3 / 4 and barrier ranks 1 / 2;
- **Yellow**: Theme ranks 1 / 2 and barrier ranks 5 / 6 or theme ranks 3 / 4 and barrier ranks 3 / 4;
- **Green**: Others;
- **NA**: Theme and / or barrier are deemed not applicable for the implementation situation.

STEP 4: FILL IN CHARACTERISTICS TABLES FOR FRAMEWORK

The to be filled out framework needs information on your organization, the to be implemented medical equipment and the client organization(s). To have a step-by-step guide on where to get this information, a flowchart was created in Figure 22. The to be gathered information is structured in the following tables:

- Organization (O) characteristics: Table 29
- Client Organization (CO) characteristics: Table 30
- Medical Equipment (ME) characteristics: Table 31

Note: The framework is to be used per implementation situation. This means that if there are different types of ME that are being implemented / the ME is to be implemented in different CO types that the tables are to be filled in per type.

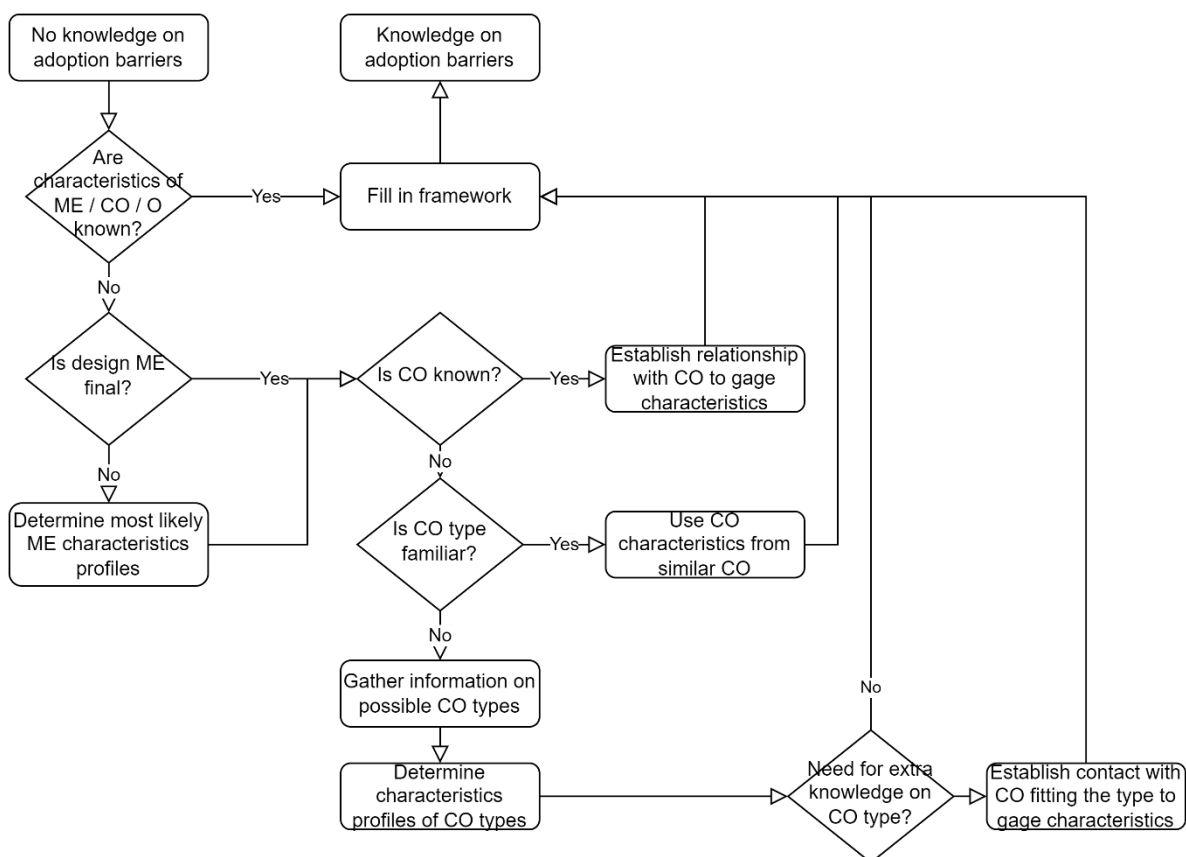


Figure 22. Flowchart on information sources needed to fill in framework. Note that if there is spoken of types/profiles, the framework could possibly be filled in per profile/type. Within this tree, ME stands for Medical Equipment, CO for Client Organization and C for Organization.

Subcategory	Characteristic	Definition	Value
-	Age	The number of years the organization has been active.	[0 – 3 years / 5 – 10 years / 10+ years]
-	Employees	The number of employees under contract of the organization.	Numeric
-	Local network	If the organization in question has a local network of employees, thus dependent upon the project the framework is filled in for.	[yes / no]
-	Development of Equipment	If the implemented equipment by the organization was also developed by the organization itself.	[Internal / External]
-	Presence in SSA	The amount of countries the organization has presence in within Sub Saharan Africa.	[0 – 5 countries / 6 – 15 countries / 15+ countries]
-	Target client organization type	The preferred organization type the organization targets, or does business with.	[Ministry / Health Program / Hospital / Clinic / Public / Private]+
-	Stance in communication	Describes the preferred client / organization relationship the organization takes.	[None / Proactive / Reactive / Online / Physical]+

Table 29. Characteristics table for Organization characteristics.

Subcategory	Characteristic	Definition	Value
-	Type	Type of client organization in which the equipment is to be implemented.	[Ministry / Health Program / Hospital / Clinic / Public / Private]+
-	Region	Defines the characteristics of the region where the CO is based and hereby partially its reachability.	[City / Rural]
Employees*	Knowledge and Skill base	Describes the existent skill and knowledge level of the employee that is being described.	[None / Low / Sufficient / Good / Excellent]
-	Workload	The workload of the employee that is being described.	[Low / Medium / High / Extreme]
-	Staff Turnover	The amount of staff, leaving or changing within the organization.	[None / Low / Medium / High / Extreme]
-	Operating Conditions	Conditions like humidity, power requirements, etc.	[Unknown / Known]
Equipment	Similar Equipment available	If there is equipment alike to the to be implemented equipment within the organisation.	[Yes / No]
Routines	Medical Practice	Knowledge on the medical practice surrounding the to be implemented equipment.	[Unknown / Known]
-	Spare parts handling	There is an existent scheme for the handling of spare parts.	[Yes / No]
-	Consumables handling	There is an existent scheme for the handling of consumables.	[Yes / No]
Policy	Medical Practice	The existence of policy dictating medical practice.	[Yes / No]
-	Import	The existence of policy dictating import of materials.	[Yes / No]
-	Relationship with organization	Describes when the relationship with organization is established.	[None / to-be-established / established]

Table 30. Characteristics table for Client Organization characteristics.

Subcategory	Characteristic	Definition	Value
-	Intended User	The medical end-user the equipment is designed for.	[Layperson / Healthworker / Nurse / Doctor]+
Technological Context	Required routines	Knowledge on the medical practice suitable after equipment implementation, and if it matches with current medical practice.	[Similar / Different]
	Required operating conditions	Knowledge on the operating conditions the equipment functions in, and if it thus will function in client organization.	[Functional / Non-functional]
Maintenance*	Executor	Describes what person is to be in charge of the maintenance described.	[End-User / Lower-Level Technical Employee / Higher-Level Technical Employee / Expert]
	Frequency	Describes how often the maintenance usually takes place.	[Daily / Weekly / Monthly / Quarterly / Yearly]
Organisational Change*	Tools	Describes the need for tools within the maintenance described.	[None / Low / Medium / High / Extreme]
	Need	Describes the need of the equipment.	[None / Low / Medium / High / Extreme]
	Average costs	The average costs of the equipment.	Numeric
	Availability	Describes the availability for the equipment.	[Import / Local / Unavailable]
Novelty	Familiarity	Describes the familiarity of the equipment to the client organization.	[Yes / No]
	Behaviour Change*	Describes the amount of changes required to established routines	[None / Few / Significant / Radical]
Training*	Type	Describes the type of training given with the equipment, if there is any.	[Included / Paid / On-Site / Online / Offline Materials]+
	Materials	Describes the type of materials that are delivered with or as training.	[Manual / Videos / Quick Guide / E-Learning]+
	Level	Level of knowledge and skill needed to understand and participate in the training.	[None / Low / Sufficient / Good / Excellent]
	Trainer	Describes which person is to give the training	[organization / external / trainer-on-trainer / None]

Table 31. Characteristics table for Medical Equipment characteristics.

*These subcategories can be further specified into smaller subcategories.

Subcategory			Subcategory		
Employee	Technical	Lower-Level	Training	Medical	Layperson
		Higher-Level			Healthworker
	Medical	Doctor			Nurse
Maintenance		Nurse	Behaviour Change	Medical Practice	Doctor
		Healthworker		Spare Parts	
	Preventive			Consumables	
Training	Corrective		Organisational change	Spare parts	
	Technical	Layperson			
		Lower-Level		Consumables	
		Higher-Level			

STEP 5: FILL IN FRAMEWORK

Barrier	Maintenance	Training	Spare Parts	Consumables
Time	1. Workload of executor: medium+ 2. Frequency - preventive: monthly+ 3. Frequency – corrective: monthly+	1. Workload to-be-trained: medium+ 2. Method: on-site 3. Trainer: external 4. Materials level > level to-be-trained	1. Availability: Import 2. Region: Rural	1. Availability: Import 2. Region: Rural
Money	1. Executor: Expert 2. Need for spare parts: monthly or more 3. Tools available < tools needed	1. Training type: Paid 2. Materials: 1 or less 3. Trainee: per-diem pay needed 4. Trainer: external	1. Availability: Import 2. Need: Medium+	1. Availability: Import 2. Need: Medium+
Human Resources	1. Executor wanted (or higher) not available in CO 2. Staff turnover in executor: medium+	1. Staff turnover in intended user: medium+ 2. Intended user (or higher) not available in CO		
Materials	1. Tools available < tools needed	1. Materials: 1 or less 2. Materials level > level to-be-trained	1. Availability: unavailable	1. Availability: unavailable
Policy			1. Availability: import 2. Import policy: restrictive	1. Availability: import 2. Import policy: restrictive
Trust	1. Relationship: Not established 2. Medical / technical relationship	1. Relationship: Not established		
Breaking habits	1. Familiarity: No 2. Similar equipment available: No	1. Familiarity: No 2. Similar equipment available: No 3. Novelty / Behaviour change: significant 4. Medical Practice: unknown	1. Established spare parts regime: No 2. Need: medium+	1. Established consumables regime: No 2. Need: Medium+
Communication	1. Relationship: not established 2. Stance: reactive	1. Language training is not language CO	1. Availability: import 2. Relationship: not established	1. Availability: import 2. Relationship: not established

Table 32. Final version of risk-indicative framework.

To be able to reduce this table to risk indicators, the following legend is made:

- **Red**: At least 2/3 of factors of influence propose a higher level for a problem, or at least all factors propose the lowest value for a problem.
- **Orange**: At least 2/3 of factors of influence propose the lowest value for a problem.
- **Yellow**: At least 1 of factors of influence proposes the lowest value for a problem.
- **Green**: Factors of influence are not proposing problems.
- **NA**: Factors of influence not applicable for this case.

To read this table, the following example is portrayed:

Time poses a **significant** barrier to *maintenance* due to the workload of the executor, a low-level-technician, being medium with no need for *preventive maintenance*, but a need for *corrective maintenance* once a month.

If there is an indication (meaning yellow or higher) for the 'breaking habits' barrier, the organization should take a look at the altered COM-B model, asking the following questions:

1. **Capability**

- a. Is there physical capability (e.g. balance and dexterity) for the person to obtain and express the new behaviour?
- b. Is there psychological capability (e.g. understanding and memory) for the person to obtain and express the new behaviour?

2. **Motivation**

- a. Does the person have reflective motivation (e.g. plans and evaluations) to obtain and express the new behaviour?
- b. Does the person have automatic motivation (e.g. desires and habits) to obtain and express the new behaviour?

3. **Opportunity**

- a. Is there physical opportunity (e.g. financial and material resources) for the person to obtain and express the new behaviour?
- b. Is there social opportunity (e.g. culture and social norms) for the person to obtain and express the new behaviour?

STEP 6: COMPARE FRAMEWORK INDICATIONS TO INITIAL RANKINGS

To gain insights from the framework and the initial rankings, the two have to be prepared. A flow chart was made to guide this analysis. The notion 'blind spots' is defined as any indications that are severe but were not highly ranked by the organization in the initial steps of this framework application.

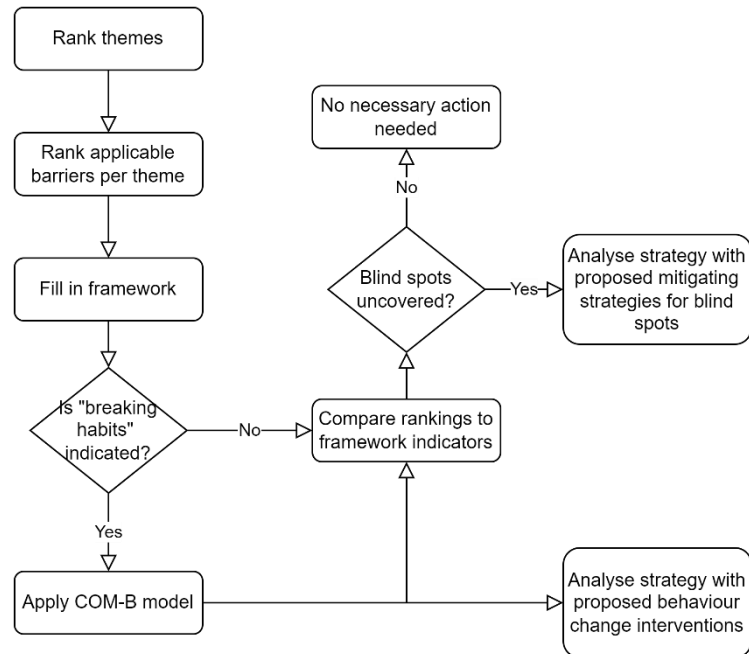


Figure 23. Flowchart guiding the analysis and interpretation of framework indicators.

STEP 7: DISCUSS FINDINGS ALONGSIDE BEST PRACTICES

Barrier	Maintenance	Training	Spare Parts	Consumables
Time	Design equipment to have low maintenance needs (o. 2, 3, 4), to be modular (o. 3), checklists to predict maintenance (o. 3).	Design equipment for low training needs (o. 1), quick guides on the spot (o. 1, 2, 3, 4), trainer-on-trainer model (o. 2, 4) and gage knowledge beforehand (o. 4).	Ensure spare parts are modularly replaceable (o.3), have local source of spare parts available (o. 5).	Low consumables need (o. 2, 3), have local supply (o. 5).
Money	Design equipment to have low maintenance needs (o. 2, 3, 4), provide suggested spare parts lists (o. 1, 3), maintenance can be done by low-level technician (o. 2, 4), peer-to-peer support through WhatsApp (o. 1, 3).	Trainer-on-trainer (o. 2, 4), integral part of purchase (o. 2, 4).	Lease machines including spare parts (o.6); buying spare parts at AliBaba (o.1).	Consumables are autoclavable (o.2), other sources of consumables (o. 1).
Human Resources	Representative does maintenance (o. 3), regular check-ins (o. 1), peer-to-peer sufficiency building (o. 1).	Trainer-on-trainer (o. 2, 4), refresher materials like e-learning and webinars (o. 3).		
Materials	Ensuring availability (o. 2, 3, 4), small changes/updates (o. 2, 3).	Quick guides (o. 1-6), manuals (o. 1-6), videos (o. 2, 3, 6), e-learning (o. 3), webinar (o. 3).	Ensuring availability (o. 2, 3, 4), modularity (o. 3), local availability (o. 5).	Ensuring availability (o. 6), autoclavable (o. 2), other sources (o.1), local availability (o. 5).
Policy			Local availability (o. 5), sold with equipment (o. 2, 3).	Local availability (o. 5, 6).
Trust	Regular physical check-ins (o. 6), regular phonecalls (o. 1), WhatsApp check-ins in group chats (o. 3), helpdesk available (o. 2, 3).	Regular physical check-ins (o. 6), regular phonecalls (o. 1).		
Breaking habits	Incentive system for maintenance checklists (o.3).	Training on clinical context (o.4, 6).	Lease of machines including spare parts (o.6)	Providing charts necessary for change (o.4)
Communication	Regular physical check-ins (o. 6), regular phonecalls (o. 1), WhatsApp check-ins in group chats (o. 3), helpdesk available (o. 2, 3).	Ensure correct language for materials (o. 2), translator available (o. 3, 4).	Contact info on equipment (o. 2), contact-person for orders (o. 2, 3).	Contact-person for orders (o. 2,3).

Table 33. Framework filled with possible mitigation strategies for each barrier / failure mechanism duo.

	Category	Definition	Example
Interventions	Education	Increasing knowledge or understanding.	Education on the health benefits of doing the diagnostic tests. (c. 6)
	Persuasion	Using communication to induce positive or negative feelings or stimulate action.	Doing a symposium on the beneficial factors of the equipment, teaching radiologists there is not threat. (c. 3)
	Incentivisation	Creating expectation or reward.	Rewarding engineers filling in the checklists. (c. 3)
	Coercion	Creating expectation of punishment or cost.	Financial strain of not using the diagnostic devices. (c.6)
	Training	Imparting skills.	Training anaesthetic nurses on how to use the anaesthetic equipment. (c.2)
	Restriction	Using rules to reduce the opportunity to engage in the target behaviour (or to increase the target behaviour by reducing the opportunity to engage in competing behaviours)	Prohibiting the reuse of consumables.
	Environmental restructuring	Changing the physical or social context.	Providing charts to do the charting. (c. 4)
	Modelling	Providing an example for people to aspire or to imitate.	Organization engineers teaching local engineers with a passbook. (c. 3)
	Enablement	Increasing means/reducing barriers to increase capability or opportunity*	
Policies	Communication / Marketing	Using print, electronic, telephonic, or broadcast media.	Mass media campaigns on disease detection.
	Guidelines	Creating documents that recommend or mandate practice. This includes all changes to service provision.	Inserting equipment use in the treatment protocols.
	Fiscal	Using the tax system to reduce or increase the financial cost.	The import of consumables through Zambian policies. (c. 2c)
	Regulation	Establishing rules or principles of behaviour of practice.	Hospital policy dictating use of equipment.
	Legislation	Making or changing laws.	Legislation to improve import of consumables.
	Environmental / Social planning	Designing and/or controlling the physical and social environment.	Designing infrastructure to support transportation of consumables.
	Service proposition	Delivering a service.	The lease of diagnostic devices. (c. 6)

Table 34. Possible mitigating strategies and interventions enabling behaviour change.

These tables can be used to guide discussion on the uncovered blind spots in the strategies of an organization for an implementation situation.

APPENDIX G. APPLICATION EXAMPLE – GOAL3

To test the applicability of the framework as an actionable tool, the framework was used for the case of GOAL3. The initial discussion was mostly surrounding the theme of training, because of the foreseen risks and needs for training that the implementation of the smart monitoring system has. Behaviour change is likely to be necessary, due to the changes of the equipment integration to medical practice. Initial ideas for mitigation are mostly surrounding the establishment of a baseline for the training needs in preparing for a pilot study.

Looking at indicators of the framework, it was hard to actually fill it in as is due to most characteristics not being determined yet. Due to this non-determination of the characteristics, it is hard to indicate risks because of most barriers seemingly being integrated in an idea of a mitigating strategy. The strategies for the failure mechanisms seem to be encompassing most factors of influence, or at least most determined factors of influence within this research seem to be thought about. Using the framework as a guide for topics to discuss on factors influencing the failure mechanisms was however interesting. For further analysis, GOAL3 is advised to compare their strategies to current best practices, as proposed in the framework guide, after gaining more insights into the characteristics of possible client organizations to have the framework provide better indications.