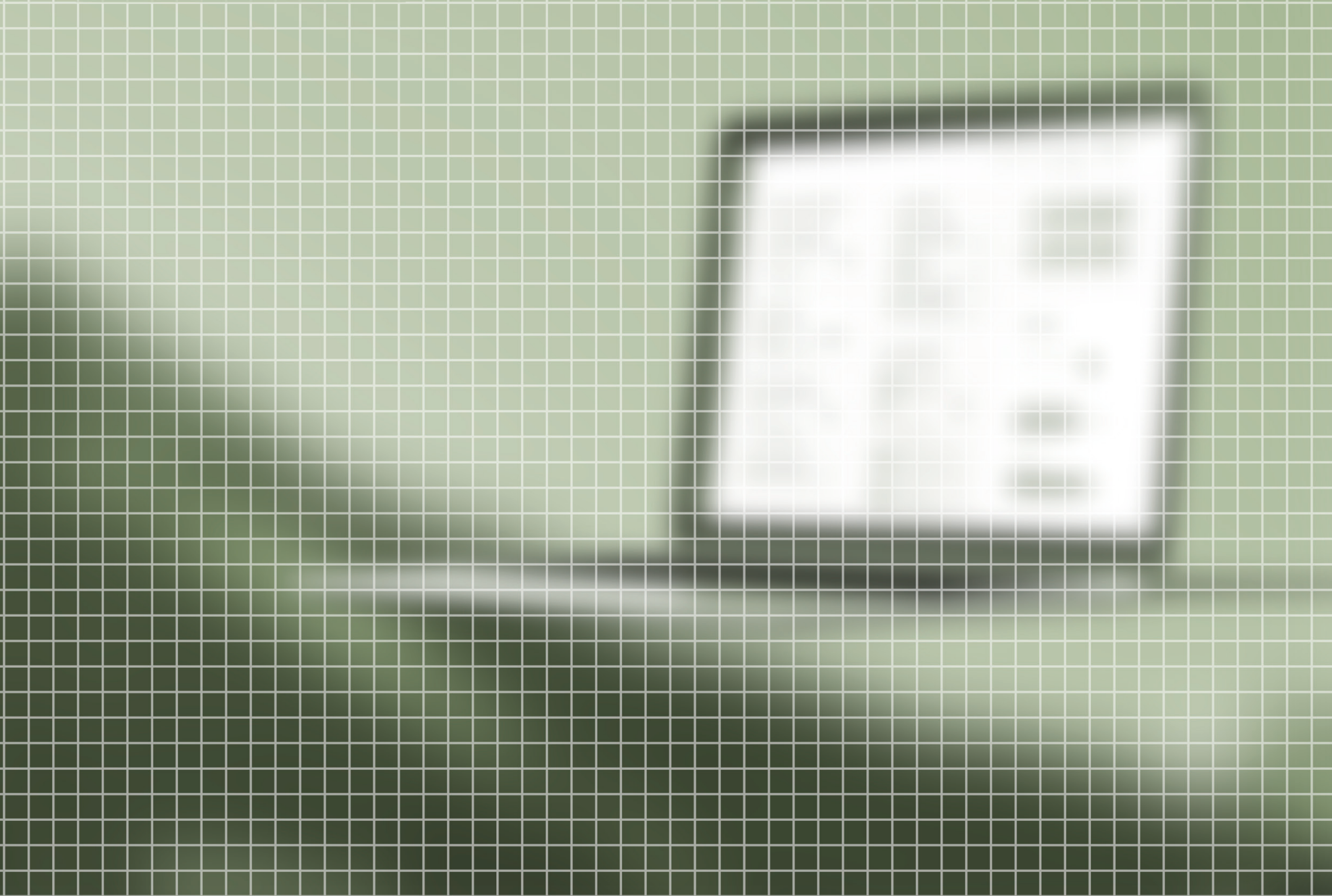
MASTER THESIS DESIGN FOR INTERACTION

A STEP TOWARDS AN INCLUSIVE MAINTENANCE MANAGEMENT SYSTEM IN HOSPITALS

ANNE MOONEN



21-09-2023

GRADUATION PROJECT

Master Design for Interaction
Delft University of Technology
Faculty of Industrial Design Engineering

AUTHOR

A.E. Moonen (Anne)

SUPERVISORY TEAM

Prof. Dr. Ir. Diehl, J.C.
Dr. Ir. Pasman, G.
Dr. Ir. Oosting, R.M.

DELFT UNIVERSITY OF TECHNOLOGY

Faculty of Industrial Design Engineering
Landbergstraat 15
2628 CE Delft
The Netherlands
www.tudelft.nl

A NEW INTERFACE DESIGN FOR NEPALESE HOSPITALS

A STEP TOWARDS AN INCLUSIVE MAINTENANCE MANAGEMENT SYSTEM IN HOSPITALS

EXECUTIVE SUMMARY

This project addresses the subject of integrating Computerized Maintenance Management Systems (CMMS) into low-to-middle income healthcare contexts, with a specific focus on Nepal. CMMS play a prominent role in enabling Biomedical Equipment Technicians (BMETs) to monitor and optimize the performance of medical equipment (WHO, 2012), streamline operational processes, and facilitate intra-hospital communication and decision-making (Basiony, 2013). However, existing CMMS solutions designed for high-income environments, often fail to seamlessly integrate into the unique workflows and needs of low-to-middle income settings (Cohen et al., 2023).

The central problem identified in the Nepalese context is a misalignment between the workflow of BMETs and the CMMS interface. An overwhelming amount of information and functionalities within the system, making it challenging for the BMETs to identify tasks. Reinforced by, that the Nepalese context places less value on data creation and tend to operate more in accordance with tasks that can be observed physically.

To identify and address this problem, a comparative study was conducted between a Dutch hospital and two Nepalese hospitals. Data was gathered using the context-mapping method (Vissers et al., 2005), and a comprehensive understanding of the system's interface was obtained through the streamlined cognitive walkthrough method (Spencer, 2000). The design goal was to create an inclusive interface for BMETs in Nepal through the visualization of medical device data. Norman and Draper's design steps (1986) were used to generate an iterative approach for designing an CMMS interface. A mixed-method approach, including the System Usability Scale (Brooke, 1996), was used to evaluate the iterative prototypes and the final interface design.

The results of this study showed, by visualizing medical device data, a transition from a data-centric system to a task-oriented system. BMETs in Nepal confirmed through evaluation that the final design represents an improvement on the systems towards a task-oriented interface that aligns more with their daily workflow.

The project serves an inspiration for future designers to illustrate the importance of a human-centered approach when adapting software from one context to another. By highlighting the importance of considering the needs and workflows of a setting. Furthermore, this project can be a resource for companies and NGOs seeking to develop CMMS solutions from a human-centered perspective.
In the Nepalese context, it provides building blocks for designing CMMS systems that better suit the work environment. In essence, this research represents a step towards a more inclusive CMMS system and the broader conversation on human-centered design in healthcare technology.

PREFACE

Before diving in on the contents of this report, I would like to share a glimpse of my personal experience during this project—an experience that has left an mark on me. Almost a year ago, I began to think about what I still wanted to explore in my master's program. The concept of human interaction with technology, with a commitment of placing humans at the core of a design project, has always motivated me. The energy I can get from user testing, interviews and observations gives me confirmation every time that this is what I really enjoy. At the faculty I felt that we were designing a lot for the same contexts. For my graduation project, I wanted to push myself to explore new limits and apply the methods I had learned in a context where intuition alone would not suffice.

I presented this question to my supervisory team, and as I stand here at the end of September, I can conclude that I definitely learned a lot about desigining in a different context and have gained a very special experience.

Therefore, I would like to thank my supervisory team. First of all, for thinking along with my predetermined learning goals from the start, the freedom to let me travel to Nepal with all confidence, bringing me back to the essence of my project and all the other wisdom that has come along in the past 6 months.

Nepal presented an entirely new environment, with challenges and a lot of new impressions. I would want to express my gratitude to the BMETs at United Mission Hospital Tansen and INF Green Pasture Hospital. Their willingness to share their time and their generosity in doing so were absolutely admirable. I am so grateful that I got to spend time with them both inside and outside of the hospital.

Closer to home, I wish to express my gratitude to the biomedical technologist in Amsterdam. Your introduction to the world of CMMS was really helpful. Your honesty and infectious enthusiasm provided a boost at the outset and, once again, as we reached the end of this project.

Thankyou, to all (former) TU Delft students who went on internships and conducted research on CMMS in Kenya, Suriname, and Nepal. Your willingness to share your findings and provide feedback on the prototypes helped me a lot in this project.

I am grateful to the employees at Samedis.care and PLAMAHS for their expertise and providing me with insights into the complexities of designing a CMMS system.

Finally, my friends and family, thank you. For brainstorming, testing, listening and reading through this entire project. Because of my enthusiasm, I could never tell about the project briefly so thankyou for your patience!

One lesson I hope to apply to my life after graduation is the importance of actually listening to one another and accepting diversity rather than pushing preconceived assumptions on design. Wherever my path takes me, I wish to have the opportunity of bridging the gap between humans and technology.

Anne

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INTRODUCTION

1.1 INTRODUCTION

In today's rapidly evolving technological world, User Experience (UX) design has emerged as an approach to understanding user needs. Its impact plays a prominent role in transforming how we interact with digital systems. In the realm of healthcare, where accessibility and efficiency is important, is using the potential of UX design a step forward. This thesis aims to bridge the gap between user expectations and technological solutions, with a specific focus on the context of Nepalese hospitals.

User experience design serves as a bridge, connecting user needs with innovative solutions. In a global context, where the pursuit of accessible healthcare (SDG 3) remains a priority, such innovations must be attuned to local nuances, encompassing social, cultural, environmental, and economic challenges. This project finds its context in the healthcare system of Nepal, a country where the convergence of technological innovation and healthcare accessibility can have a significant impact.

In hospitals Computerized Maintenance Management System (CMMS) plays an important role within healthcare service delivery. Challenges often arise due to inadequate management and maintenance of medical devices (Zamzam et al., 2021).As a result, a strong CMMS system represents a crucial tool for hospitals to use in equipment maintenance and upkeep. However, the core principles of a strong CMMS remain consistent across settings, implementing such systems in varied contexts poses challenges.

High-income settings and low-to-middle-income hospitals share the same core concept (WHO, 2012), but existing CMMS designed for high-income environments often fail to integrate seamlessly into low-to-middle income contexts (Cohen et al., 2023).

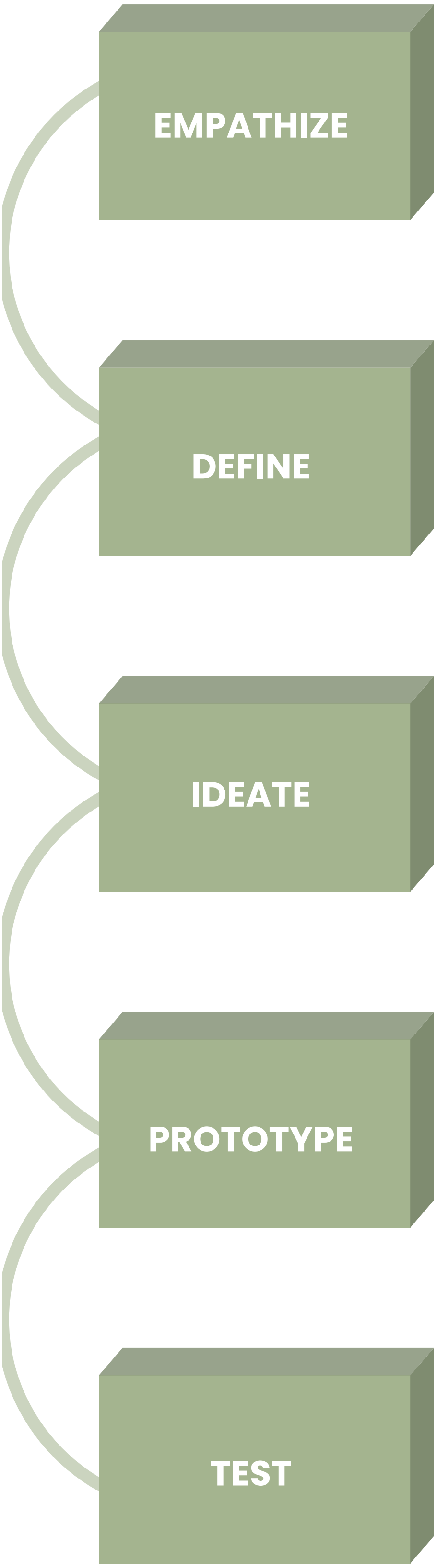
The objective of the project is to support the development of an inclusive global healthcare system. The project seeks to increase CMMS utilisation, promoting a healthcare environment that is a step closer to inclusivity on a global scale, by adapting the CMMS design to match the local workflow.

This thesis uses a methodology that emphasises human-centricity and was driven by the design thinking approach (see page 8). On-site context mapping, comparative analysis of work processes and CMMS utilization between a hospital in the Netherlands and 2 hospitals in Nepal were used in this research. All from the human-centred perspective of Biomedical Equipment Technicians (BMETs).

Grounded in the design thinking framework, this thesis unfolds through five iterative phases: Empathize, Define, Ideate, Prototype, and Test. Together, these stages direct the project and serve as the report's framework.

A thorough interface design for a CMMS system has been conceptualised and demonstrated as a result of this project. This design is in line with the needs and challenges faced by hospitals in Nepal, and it is hoped that it will serve as an example for those looking at developing a CMMS for the context of Nepal.

1.2 THESIS APPROACH



EMPATHIZE
In this phase, the research focused on understanding the local context of BMETs in Nepal. It made use of context mapping and involves conducting interviews, observations, and generative sessions to gather insights.

DEFINE
Based on the insights gained during the empathize phase, a problem statement, design goal and a list of requirements was formed. Which served as the basis of the design process.

IDEATE
The ideation phase aimed to generate creative solutions to address the identified problems. Through brainstorming sessions the project is developed new ideas and concepts.

PROTOTYPE
Building on the ideas generated during the ideation phase, prototypes were developed of CMMS user interfaces that reflect the specific needs and requirements of BMETs in Nepal. This phase involved iterative design processes and user evaluation. To refine and improve the usability of the CMMS user interface.

TEST
The final phase focused on testing and refining the prototypes. The feedback and insights gathered from these tests have guided iterative improvements to the user interface ensuring it’s usability and accessibility.

BACKGROUND

OVERVIEW

Within this chapter, a comprehension of the context is given. The definition and importance of a CMMS system are presented, underscoring its benefits for hospitals. An overview of Nepal's and the Dutch healthcare system is provided, including its utilization of CMMS. Moreover, the chapter delves into the approach for designing an effective system, emphasizing the aspects of usefulness.

SUMMARY

A CMMS serves as a vital software tool for BMETs, enabling them to monitor the status of medical equipment within hospitals. The significance of a CMMS in a hospital setting is evident through its contributions to improved decision-making, streamlined operational processes, enhanced equipment performance, and intra-hospital communication. Notably, Nepal's healthcare system is striving to implement a comprehensive nationwide CMMS, but the current landscape witnesses a coexistence of diverse CMMS systems across various hospitals. When creating a valuable software solution, utility and usability factors should be considered.

2.1 CMMS
THE SYSTEM

For all the physical equipment in a hospital, the specifications on how and when it is maintained and what occurs during device reparations are recorded by a CMMS.

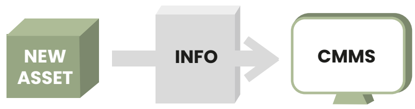
The system's complexity is determined by the size of the hospital, type of hospital, location, and resource management (WHO, 2012).

BASIC PROCESSES OF A CMMS

Using the cognitive walkthrough (see page 19) and internship reports of biomedical engineering students at TU Delft, a general overview was constructed for the phases of a CMMS system being: inventory, maintenance and repair. These phases serve as the foundational framework for comprehending the utilization of a CMMS system throughout the entirety of the project. A more detailed rendition of this outline can be accessed in Appendix B.1.

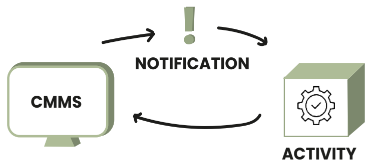
INVENTORY

Inventory is the process of fully incorporating a new/ donated medical device into the system.



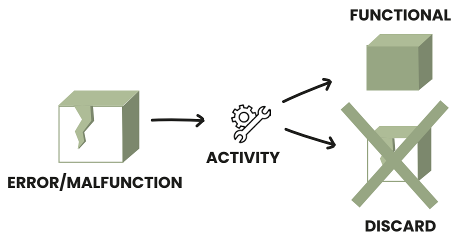
MAINTENANCE

Maintenance in this context pertains preventive maintenance. This involves systematically conducting maintenance activities on the system at regular time intervals.



REPAIR

Documenting an error or malfunction along with its subsequent resolution.



THE USER, BIOMEDICAL EQUIPMENT TECHNICIANS

There are various stakeholder within the system around the CMMS. These stakeholders (see Figure 1) either bring information into the system or extract information from it. The BMETs are a CMMS's fundamental users. They are the only ones interacting with the system in all three phases. The other stakeholders will only read the information. The hospital's medical equipment ought to be maintained and repaired by BMETs. The interaction between the interface and the user, in this case the BMET, is the primary emphasis of this project.

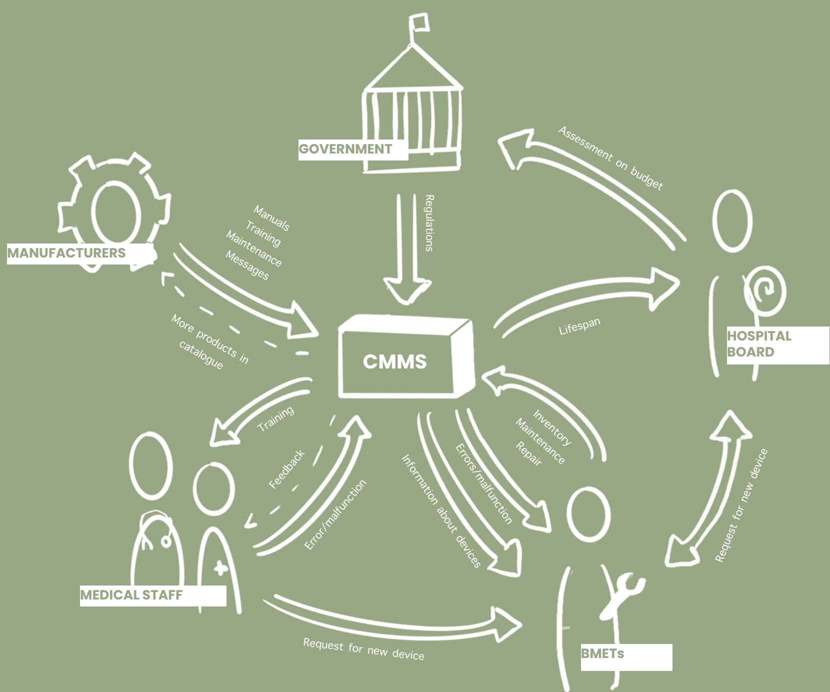


Figure 1: Overview of the stakeholders around a CMMS.

2.1 CMMS

VALUE OF A CMMS

The incorporation of a CMMS is significant in the context of healthcare services in areas of the global south. The following paragraphs outline the main advantages of using a CMMS system:

OPTIMIZED PERFORMANCE OF EQUIPMENT

A CMMS enhances the scheduling of preventive maintenance, thereby facilitating regular assessments and upkeep of medical equipment. This proactive strategy significantly diminishes the occurrence of unforeseen breakdowns and subsequently enhances the overall performance of the equipment. It is pertinent to note that, in the global south, approximately half of the medical devices suffer from inadequate maintenance, resulting in grave implications for healthcare provision (WHO, 2012). The implementation of a CMMS system offers a means to mitigate this concern by ensuring regular maintenance activities, curtailing equipment downtime and ultimately elevating the quality of patient care and safety.

Therefore the WHO is steering towards a collaboration between healthcare systems and local BMETs to develop data driven systems for the everyday use of a CMMS. (WHO, 2011).

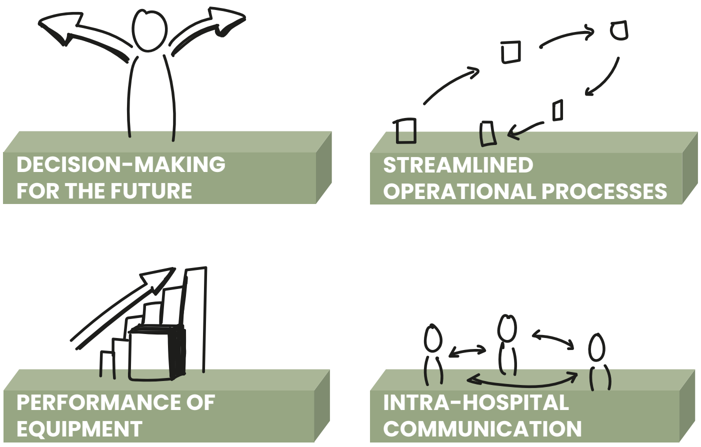


Figure 2: 4 values of using a CMMS system in a hospital context.

STREAMLINED OPERATIONAL PROCESSES

The CMMS eliminates the need for antiquated pen-and-paper procedures, reduces misunderstandings and removes the possibility of losing important records. The improvement of operational procedures is the result of this technical development, which speeds up failure analysis and makes it possible to prioritise repair operations streamlining the operational processes. (Basiony, 2013).

DECISION-MAKING FOR THE FUTURE

The CMMS is crucial in the documentation of data pertaining to maintenance (Cohen et al., 2023). According to the WHO (2011), a basic CMMS includes a database with details on medical equipment and a list of spare components. It also keeps track of previous maintenance, which is useful for guiding decision-making in the future. The CMMS's ability to centralise data integration, which provides useful insights into typical repair times and associated costs, is a key benefit. Therefore the CMMS facilitates effective decision-making and responsible budget distribution in healthcare systems by optimising hospital resources and financial allocations (Basiony, 2013).

INTRA-HOSPITAL COMMUNICATION

In accordance to Basiony's findings (2013), the CMMS serves to augment interdisciplinary and inter hospital communication. It establishes a platform through which diverse departments and multiple healthcare facilities can collaborate seamlessly, fostering improved coordination and resource allocation.

2.2 NEPALESE CONTEXT

OVERALL HEALTHCARE

The research focussed on the context of Nepal, a nation between the borders of India and China, renowned globally for the Himalayas mountain range. The country is home to approximately 30 million residents. During the span of 2021/22 (corresponding to Nepalese year 2078/79), Nepal accommodated 192 public hospitals and 2155 private hospitals within its healthcare infrastructure (Department of Health Services, 2022). Owing to the substandard quality and malfunctioning state of medical equipment within public hospitals across Nepal, the populace holds pessimistic views regarding the efficacy of the overall healthcare system. This sentiment currently constitutes a significant barrier, impeding the population's use of the healthcare services (Grainger, 2018).

BMETS IN NEPAL

Within the Nepalese context, there emerged a need for expertise in the maintenance of medical equipment, aimed at prolonging the lifespan of medical devices. Consequently, the National Health Training Centre (NHTC) under the purview of Nepal's Ministry of Health and Population (MoHP) formulated a training program, designed to equip Biomedical Equipment Technicians (BMETs) with skills tailored to the needs of rural hospitals in Nepal (Topham et al., 2008). In a study delving into the impact of BMET deployment within government hospitals in Nepal conducted by Thapa et al. (2021), the presence of BMETs exhibited a positive influence on the functionality of devices. The deployment had some additional advantages as well. From an economic standpoint, BMETs facilitated quicker and more cost-effective device repairs compared to external technicians. Moreover, the presence of BMETs bolstered the self-assurance of medical personnel, fostering a sense of reliance on the functionality of all medical equipment.

CMMS IN NEPAL

The period from 2011 to 2014 marked the inaugural introduction of the initial CMMS in Nepal, known as PLAMAHS. The pilot program spanning three years propelled the equipment's functionality from 64% to an impressive 99% in this hospitals. This transformative shift engendered a substantial change in Nepal's equipment maintenance practices. Subsequent to the pilot phase, the Nepalese government embarked on the implementation of a nationwide CMMS across the healthcare sector. As of August 2023, this full-scale implementation has not taken place yet, resulting in the coexistence of diverse CMMS systems across various hospitals. These systems range from internally developed solutions to those procured from Western nations.

> This has caused a real paradigm shift - a turnaround in the way equipment is maintained in Nepal. It is building the government's capacity in terms of partnerships and private sector engagement, managing multi-year contracts and developing the biomedical engineering market in the country - Mr Shanker Pandey - Head of Office at kfW Nepal on the implementation of PLAMAHS (Grainger, 2018)

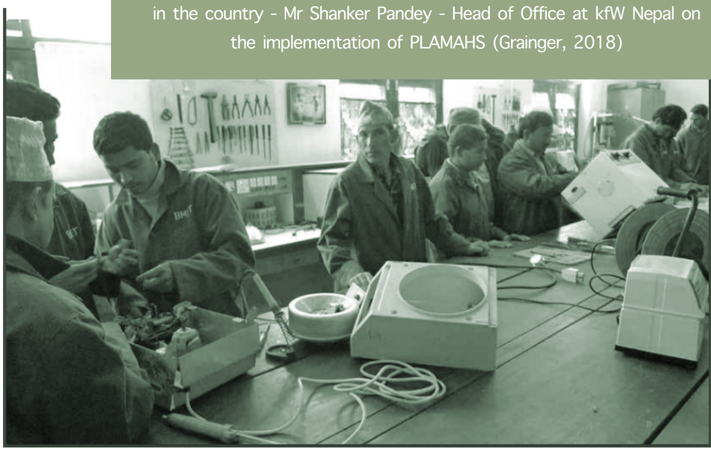


Figure 4: Picture of BMETs in training by the National Health training Centre et al., (2010)

Figure 3: Map of Nepal.

30.000.000	**RESIDENTS**
192	**PUBLIC HOSPITALS**
2155	**PRIVATE HOSPITALS**

2.3 DUTCH CONTEXT

OVERALL HEALTHCARE

In this study a comparison between a Dutch hospital and 2 hospitals in Nepal is made to get a better understanding of which operations are context specific and which are function specific. Therefore, it is important to have background information of the Nepal and the Dutch healthcare system. Currently, the Netherlands has 98 General hospitals, 8 academic hospitals and 7 children's hospitals (Ziekenhuiszorg | aanbod | Instellingen, 2023). These hospitals provide care to the Dutch population of 17 900 000 residents in September 2023.

BMETS IN THE NETHERLANDS

There has been a biomedical technician education in the Netherlands for a long time. This is offered both as an HBO (higher professional eduction) and as a WO (university education) study. At WO level, this study has been taught since 1997 but only since 2007 has the profession really been present in hospitals and seen as the bridge between technology, healthcare and management. (Geschiedenis – BMTZ, n.d.).

CMMS IN THE NETHERLANDS

In the Netherlands, one of the most widely used CMMS system is Ultimo. This is an asset management system that has been around for decades in the healthcare sector. The use of asset management systems is actually already a standard in health care management in Dutch hospitals and is used to comply with the Medical Covenant of Technology in the Netherlands.

17.900.000	RESIDENTS
98	GENERAL HOSPITALS
8	ACADEMIC HOSPITALS
7	CHILDREN'S HOSPITALS

Figure 5: Map of the Netherlands.

2.4 DESIGNING AN INTERFACE

USEFULNESS OF A SOFTWARE SYSTEM

A CMMS should first and foremost be easy for users to use. How well the system helps the user accomplish their desired goal determines how usable the system is. Grudin (1992) asserts that a system's usefulness is made up of its utility and usability. In utility, the question of whether a system consist of the functionalities for achieving the desired goal is the main concern. Usability places a greater emphasis on the user and their capacity to recognize and utilize the system's features.

USABILITY

Usability is crucial when creating a software interface because the user and system interaction is the main focus of designing an interface.
Five different characteristics can be used to explain usability (Nielsen, 1993):

LEARNABILITY:
The ease with which a system can be learned and the speed which an user can carry out first operations.

EFFICIENCY:
The system should increase the user's productivity if the user is comfortable in using the system.

MEMORABILITY:
A user should not have to spend much time learning the system the next time he uses it, therefore it must be easily recognizable.

ERRORS:
Errors should be minimal during user interactions with the system. If these mistakes do happen, the user should be able to fix them right away.

SATISFACTION:
Using the system should be a pleasant experience for the user.

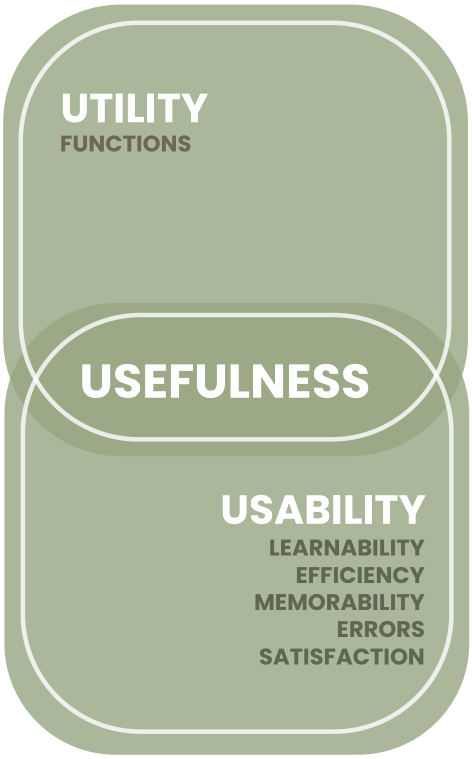


Figure 6: Schematic overview on usefulness.

EMPATHIZE

OVERVIEW

This chapter delves into an exploration of the context and work process through a comparative analyses of a Dutch and two Nepalese hospitals. Resulting in a process analysis, equipment journey and a value analysis. The outcome of these analyses will be forming a problem statement and design requirements that will be explained in more detail in the next chapter.

SUMMARY

Through the application of context mapping techniques, a difference between real-life workflow and the CMMS workflow was uncovered. This discrepancy stems from the overwhelming volume of information and potential actions within the system, a problem heightened by the fact that Nepalese BMETs tend to prioritize physical tasks and activities over data-based activities more than Dutch BMETs.

3.1 METHOD

CONTEXTMAPPING

To find out how we can improve the usability of the CMMS an exploratory study was conducted. Aimed at comprehending the context around the use of CMMS within a specific local setting. Employing the context mapping methodology, the data was collected through a combination of interviews, observations, and generative sessions, as outlined by Vissers et al. in 2005 to get information on a deeper level. Information regarding the materials utilized in this sessions can be found in Appendix B.2.

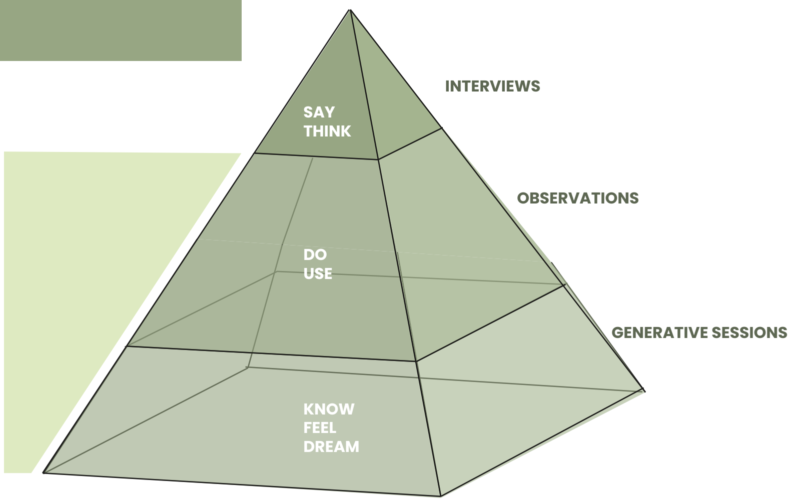


Figure 7: Infographic on techniques used during context mapping.

To gain a more profound insight into the nuances of the Nepalese context, a comparative analysis between multiple healthcare facilities was performed. Specifically, a hospital located in Amsterdam, the Netherlands and two hospitals situated in Nepal were compared which resulted in a process, equipment and value analysis. The participating hospitals that constitute the focal points of this study include:

THE HOSPITALS

HOSPITAL IN THE NETHERLANDS, AMSTERDAM

Situated in Amsterdam the Netherlands, The hospital plays a pivotal role in delivering healthcare services. With a total of 330 beds, the hospital maintains an independent procurement approach for all its supplies. The BMETs at this hospital utilize a software called Ultimo as their chosen CMMS. The hospital is a smaller hospital in the Netherlands which makes it better to compare with Nepalese hospitals.

INF GREEN PASTURE HOSPITAL AND REHABILITATION CENTRE, POKHARA

Nestled in Pokhara, Nepal, INF Green Pasture Hospital has served the local population for six decades. Pokhara, the second-largest city in Nepal with around 265,000 residents, was initially established to cater primarily to leprosy patients. Over the years, the hospital has expanded its scope to encompass spinal cord injury rehabilitation, reconstructive procedures, palliative care, and has a specialized ear centre. With 40 beds, the hospital attends to approximately 11,000 patients annually. The hospital's medical supplies are a mix of both purchases from Nepalese providers and donations.

UNITED MISSION HOSPITAL TANSEN

Located in Tansen, the United Mission Hospital serves not only the town's approximate 32,000 inhabitants but also a far-reaching area that extends its services to nearly one million people. The hospital handles 11,000 inpatient admissions and 89,000 outpatient visits each year. Having 169 beds, the medical facility provides an array of services, including surgical procedures, maternity care, dental services, counselling, and comprehensive testing and treatment for conditions such as TB, HIV, and leprosy.

United Mission Hospital Tansen is in the process of transitioning to self-procurement for medical equipment, although a significant portion of their inventory is still comprised of donated items. The hospital's biomedical team, consisting of four individuals with distinct specialties, employs a custom-made system referred to as "the dashboard" to facilitate their operations.

Figure 8: Map of the world with research sites indicated.

3.2 ANALYSIS ON THE SYSTEM

COGNITIVE WALKTHROUGH

To get an basic understanding about a CMMS the streamlined cognitive walkthrough method (Spencer, 2000) was executed on both the software used in the INF Green Pasture Hospital and the dashboard (an in-house software used at United Mission Hospital Tansen). Specifically, the cognitive walkthrough technique was employed to evaluate the CMMS. This approach enabled designers to perceive the system from the users perspective. Initially, three user scenarios were employed, focusing on the points where existing information clashed with required information, particularly in relation to how end users engage with the system.

The user scenarios were as follows:

1. INVENTORY	Entering a new device into the system.
2. MAINTENANCE	Performing maintenance on the device introduced in scenario 1.
3. REPAIR:	Reporting errors or malfunctions.

The insights garnered from this analysis were then utilized to formulate a basic understanding and assumptions on the use of the system. The assumptions were tested in actual in the on-site research.

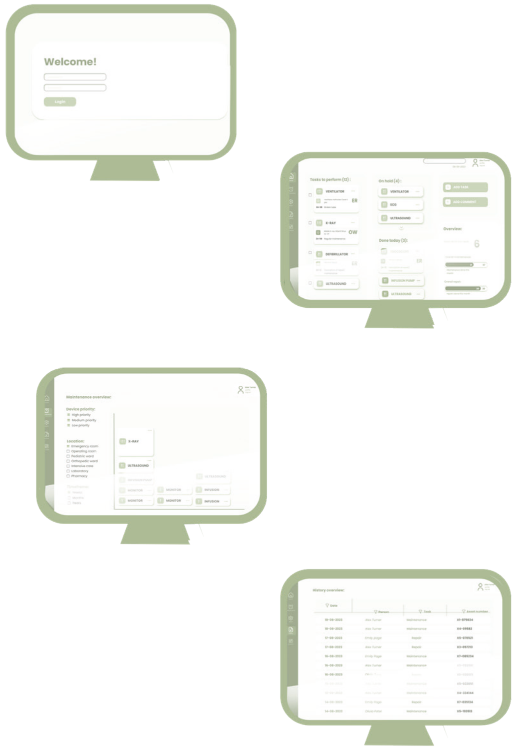


Figure 9: Illustration step by step of a cognitive walkthrough.

3.3 ANALYSIS ON THE CONTEXT

The context analysis consists of a process journey, equipment journey and a value analyses made by conducting research on site both in the Netherlands and Nepal. Together, they formed the basis for finding out what obstacles the BMETs encountered in using CMMS.

Figure 10: Picture of the author conducting interviews in Nepal.

3.3 ANALYSIS ON THE CONTEXT

PROCESS ANALYSIS

In this analysis the inventory, maintenance, and repair phases, as perceived from the perspective of BMETs, were systematically outlined. Within this framework, the assumptions made during the cognitive walkthrough were compared with the actual workflow. Each process was examined within its specific context, focusing on the steps performed, information collected, and utilization of the CMMS within each phase. Subsequently, a comparative analysis of the three contexts across the various phases was conducted. This results in an overview of the similarities and differences between the 3 contexts. For a detailed breakdown of the process analyses, see Appendix B.3.

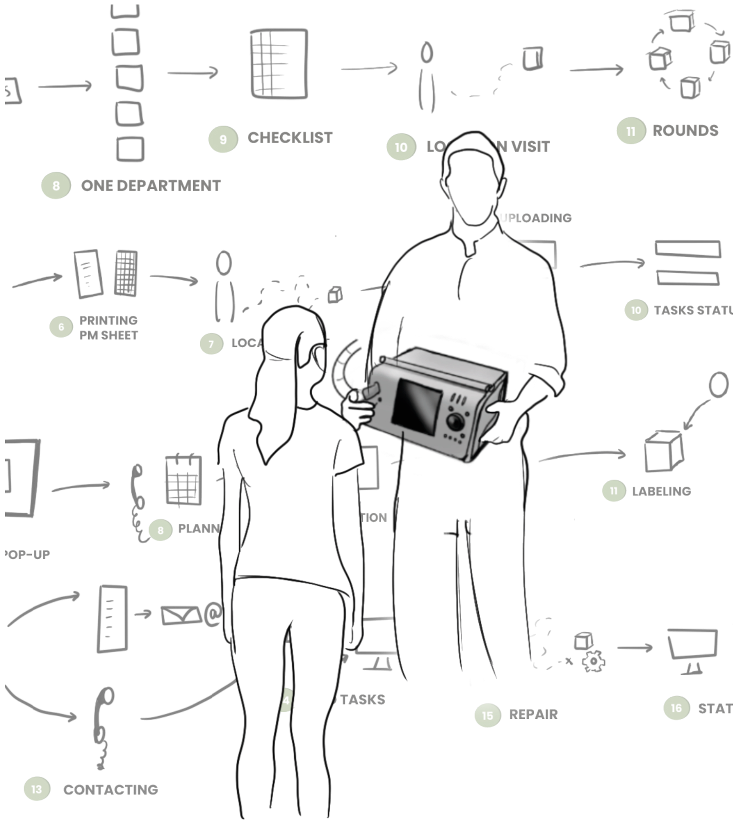


Figure 11: Illustration of process analysis (Appendix B.3).

EQUIPMENT JOURNEY

The process analysis was conducted from the perspective of a Biomedical Equipment Technician (BMET). In this equipment-centric approach, we examined the same processes but through the lens of the equipment itself. To facilitate a comparative analysis, we mapped out two distinct equipment pathways, aiming to identify knowledge gaps and concerns. These pathways were designed to offer a clearer understanding of when interactions with the CMMS occur or do not occur throughout the lifecycle of a medical device. The selected devices were chosen from those readily available in a Nepalese hospital, with variations in terms of usage, complexity, patient safety implications, and acquisition methods. The identified knowledge gaps and concerns were factored into the formulation of our main insights. The complete equipment journey is detailed in Appendix B.4 and was undertaken with two specific devices:

- ▶ Mobile X-Ray machine: Hitachi Sirius 130HP
  - Use: Used for diagnostics
  - Complexity: Complex device
  - Patient safety: Non-life-threatening
  - Acquired: Purchased

- ▶ Ventilator: Hoffrichter CARAT II Pro
  - Use: Used for treatment
  - Complexity: Simple device
  - Patient safety: Life-threatening
  - Acquired: Donated

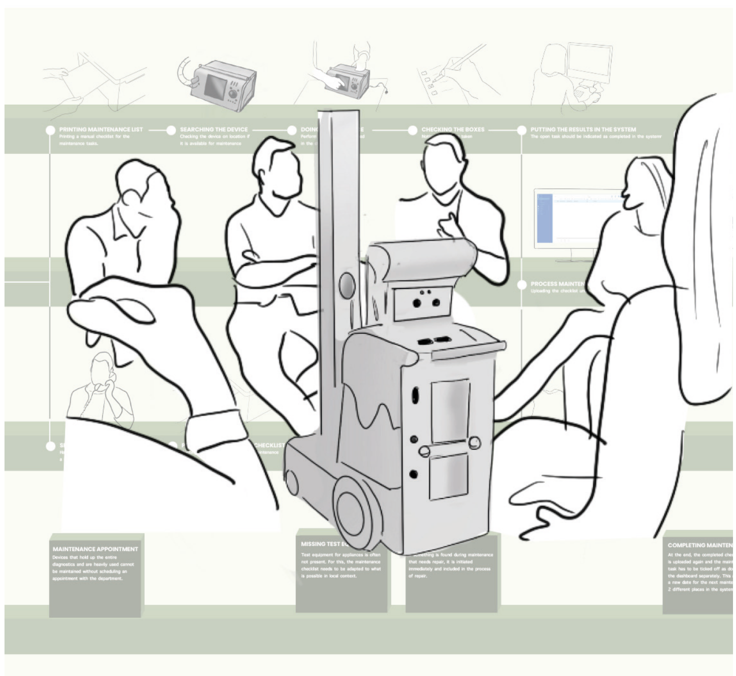


Figure 12: Illustration of equipment journey (Appendix B.4).

3.3 ANALYSIS ON THE CONTEXT

VALUE ANALYSIS

In addition to the insights gathered in the process and equipment journey, specific values in the work culture have surfaced through observations during the utilization of the system. These values can be integrated into the design by converting them into design requirements for the CMMS, using the approach outlined by Van der Poel (2013). The chosen values are drawn from the collection of 19 values delineated in Schwarz's Refined Theory (2012).

An example is Conformity-interpersonal. You can see this reflected, for example, in the fact that in daily practice a lot of time is set aside for colleagues who come in with a question. To accommodate this aspect, a design requirement should be incorporated into the design stating that the system must have seamless intermittent saving capabilities. The entire list of values can be found in Appendix B.5 and are integrated in the design requirements on page 30.

VALUE
Confirmatory-interpersonal (Schwarz, 2000)

NORM
Making time for incoming colleagues.

DESIGN REQUIREMENT
The system should be saved in between tasks.

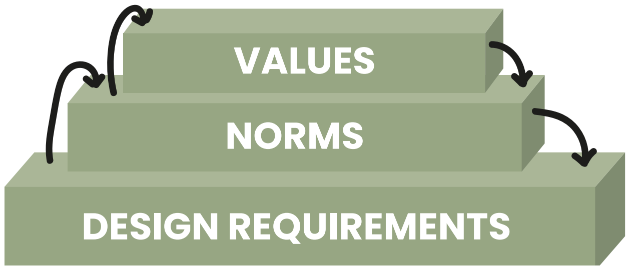


Figure 13: Steps from van der Poel (2013) from values to design requirements.

Figure 14: Office and workshop in a hospital in Nepal.

3.4 MAIN INSIGHTS

MISMATCH BETWEEN REAL WORLD AND CMMS

The exploratory study provided insights into the work processes of BMETs combined with the utilization of the CMMS. Upon reviewing both the process and equipment journeys, an observation was the notable difference between real-life workflow and the system's workflow aligning with one of the usability heuristics outlined by Nielsen (1994. This lack of synchronization led to either underutilization or non-utilization of the system, resulting in an inability to realize the benefits described on page 13.

This problem mostly results from the excessive amount of information and possible actions within the system provided, which makes it difficult for users to immediately identify their upcoming tasks. Instead of providing users with a simplified picture of device statuses and tasks ahead.

Figure 15 illustrates this occurrence. It's not always true that more details will give you a clearer image of the item you are interested in. The top metro map has a lot more information about possible routes but is less clear than the bottom map with only the essential information about the metro lines. An excessive amount of alternatives or extensive information may overwhelm the user and complicate the use. In fact, displaying less specific information might increase readability and overview recognizing what you are looking at.

So when designing an interface for a CMMS, a clear choice must be made on what information and how it is displayed to avoid the overload of information making it unclear which task needs to be performed.

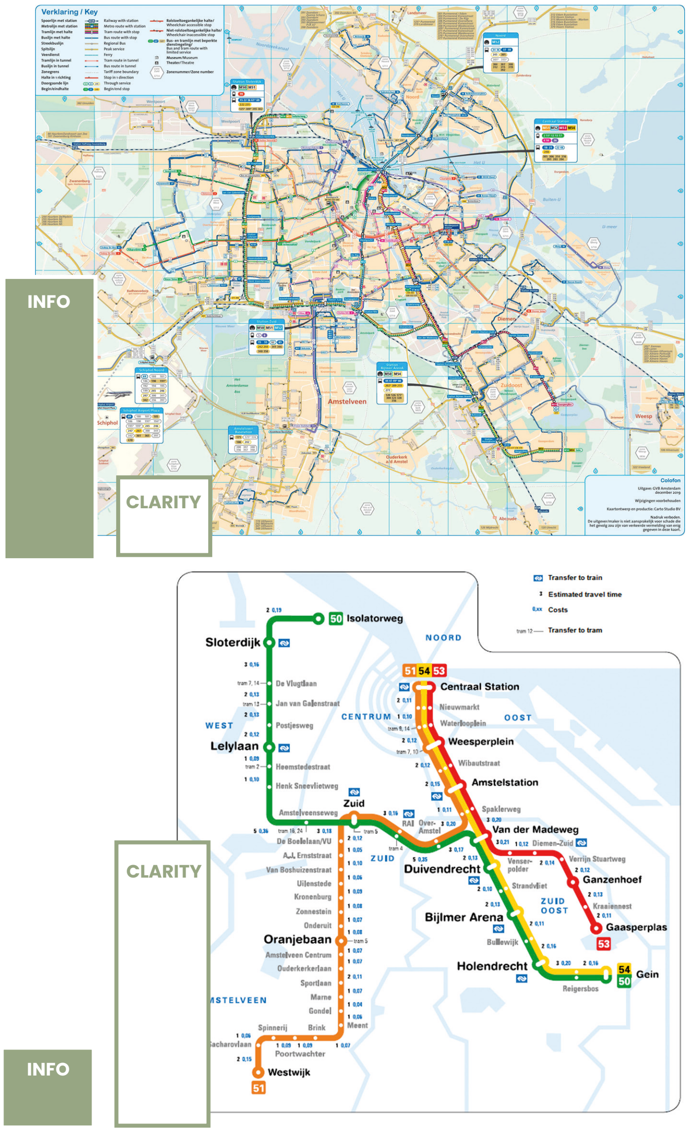


Figure 15 : Metaphor for creating confusion by providing more information.

Top map (Amsterdam Public Transport Map - n.d.)
Bottom map (Kaarten Voor Openbaar Vervoer (OV-kaarten) | Maps Maps Maps, 2017)

3.4 MAIN INSIGHTS

MORE TASK-BASED THEN DATA-BASED

The information overload and possible actions are reinforced by the fact that, compared to Dutch context, there is less value placed on the activity of creating data in the Nepalese context. The value analysis shows that the Netherlands' working style places a greater emphasis on ensuring that all the data is in the system. Therefore, a BMET in the Netherlands spends a large portion of his or her day in front of a computer. As opposed to Nepal, where BMETs tend to operate more in accordance with tasks that can be observed physically or that are given to them by a co-worker. A CMMS should therefore be a secondary activity or supported asset and not take up much time from the actual activity of maintaining or repairing medical equipment in order to fit the workflow in Nepal.

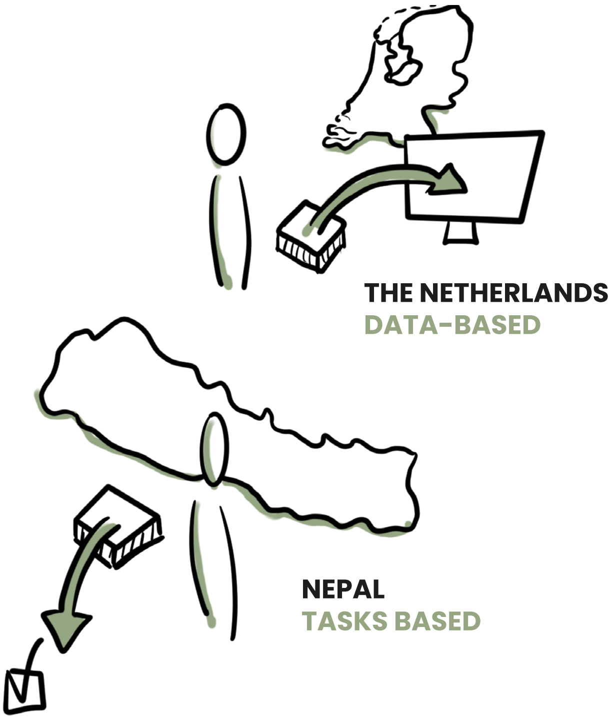


Figure 16: Illustration data-based and tasks based.

ZOOMING IN

ZOOMING IN ON THE WORKFLOW

At a higher-level perspective, these are the primary insights. However, when we delve into the specific work processes outlined in chapter 2.1, namely inventory, maintenance, and repair, we see notable disparities between the real-life workflow and the operation of the CMMS. The overarching goal of the projects is to synchronize the CMMS with the actual processes in practice and increase usability. To illustrate the approach, the following section outlines the intended steps to achieve this alignment.

The numbers in brackets [1] in the text refer to the numbers indicated in the image.

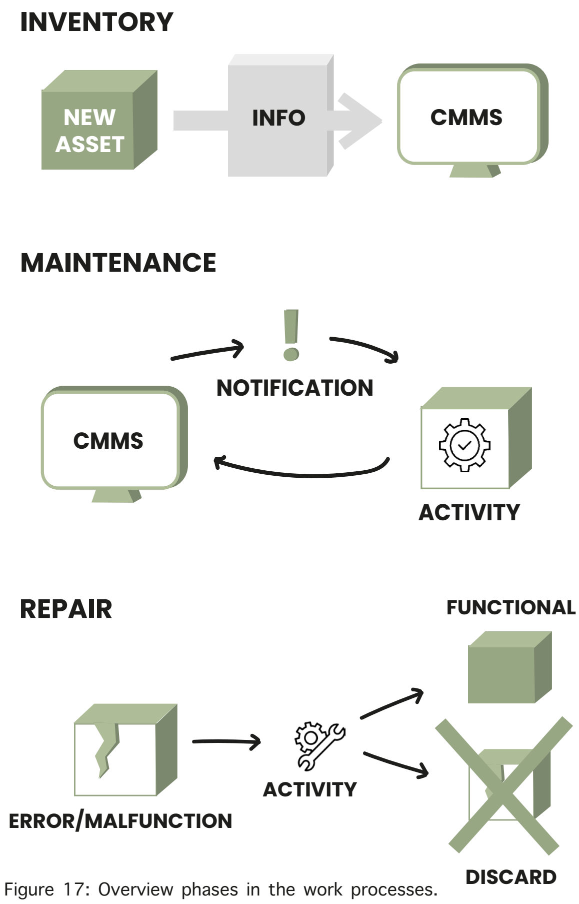
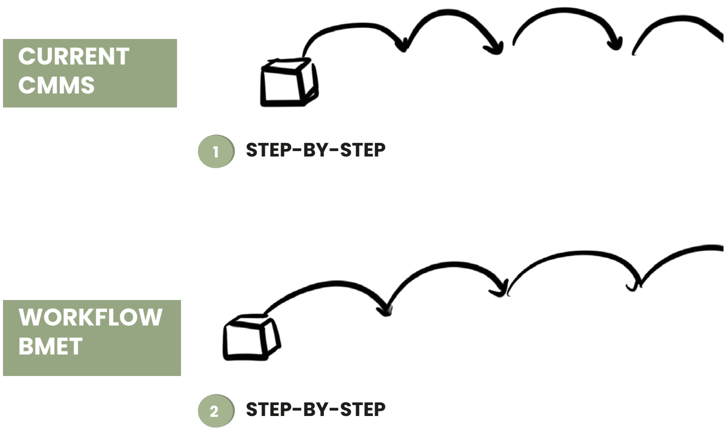


Figure 17: Overview phases in the work processes.

3.4 MAIN INSIGHTS



INVENTORY

At inventory the goal is to get all the necessary information of the new/donated medical device into the CMMS. In the CMMS, this is already a step-by-step process in line with the work process of the BMETs. Therefore the process of Inventory is placed outside the scope of this project but should be added in a complete software.

Figure 18: Inventory comparison between current system and workflow.

MAINTENANCE

Maintenance is now often undervalued by BMETs because repairs are preferred over maintenance. The system gives little guidance that these tasks need to be done and are important in order to optimize the performance of equipment (page 11).

The number of open tasks and a bar with extensive task information [3][4] are both displayed to BMETs in the current system.
However, because repairs are frequently more noticeable, the BMETs prefer doing repairs than performing maintenance [7].
A defined period is frequently set aside for performing maintenance [6], during which a paper checklist is used [5], obtained from the system, and then re-entered. Therefore, the new design should provide more guidance in the form of announcing the priority of maintenance [8], a clear overview of the tasks that need to be done [9] and an integrated checklist so that the BMET spends less time in the system [10].

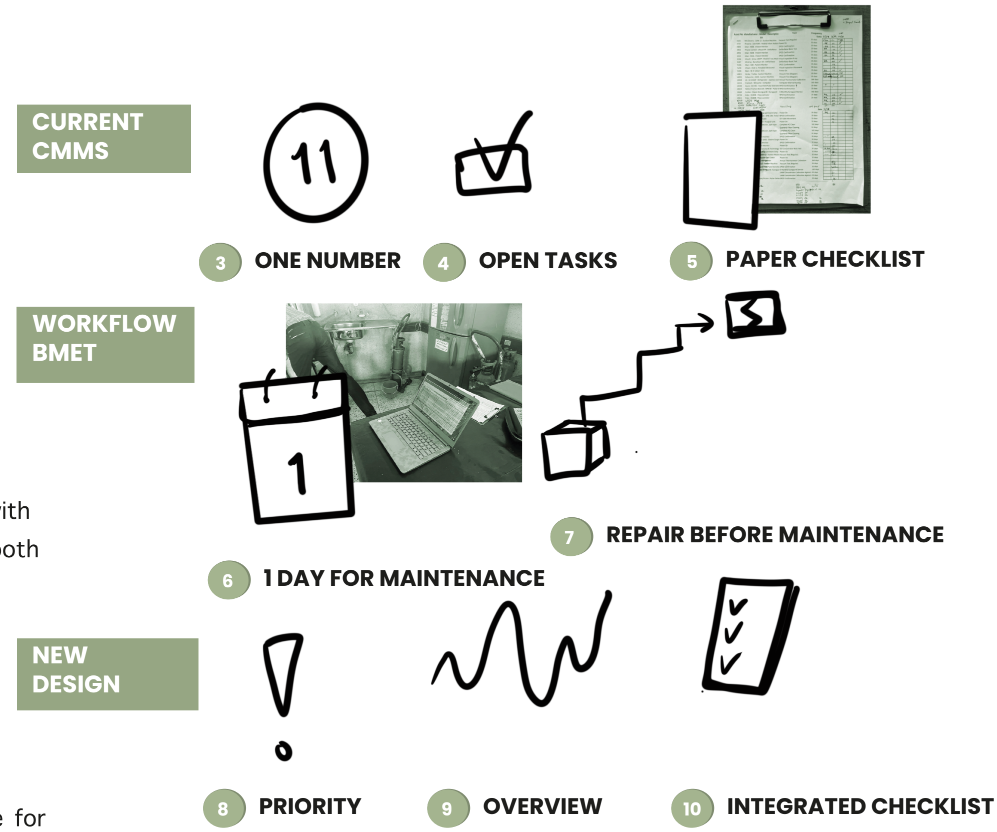


Figure 19: Maintenannce comparison.

> “ Copying the maintenance number every 4 weeks to an excel sheet to see if we are falling behind more often or that we are speeding up.”
> -BMET United Mission Hospital Tansen

> “ According to risk. So in the beginning we have defined the risk. I would love that to be in the system. We do it now outside the system in an Excel. For different devices we have determined the risk with some kind of formula. Based on when it is used, what kind of device it is and what is the requirement of the device. And then the risk translates to a maintenance interval.”
> - BMET 2 INF Green Pasture Hospital

3.4 MAIN INSIGHTS

REPAIR

When a broken device is reported by phone or because it is brought to the office, it is now often not logged into the CMMS but carried out as needed. The most important thing in the repair phase is of course that a device is repaired but logging it in can have significant added value for decision making for the future (see chapter 2.1). In addition, the broken device stays marked and can't be overlooked.

It takes a lot of time to enter a new task [11], so it is frequently neglected. When a repair is reported via phone call [12] or by having the device brought to the desk [13], the BMETs frequently start working on it right away. The BMETs write the issue on a whiteboard [14] instead of indicating it in the system if it cannot be resolved immediately because this is more comprehensible. Consequently, the new system should enable fast entry [15] of a new repair activity which clearly shown as a new to-do [16].

Figure 20: Repair comparison.

CONCLUDED PROBLEM STATEMENT

Based on the insights of the emphasize phase it is clear that the CMMS system's inability to seamlessly integrate into the work processes of BMETs is due to its excessive emphasis on data and functionality within the system. This results in information overload and a lack of clarity for the BMETs.

The next chapter will elaborate on the problem statement, the design requirements that arise from this phase and which direction the design took to solve the problem statement.

DEFINE

OVERVIEW

Within this chapter, the focus shifts from empathetic insights (chapter 3) to concrete problem-solving. The establishment of a clear design goal is emphasized, aligning with the requirements identified in the empathize phase. Moreover, the chapter delves into the formation of an interaction vision, resulting in a seamless and effective interplay between the CMMS and the BMETs. This vision serves as a guiding principle for the ensuing ideate and prototype phases.

SUMMARY

The current state of interaction with the system is like searching your route on a very detailed map, the amount of information and functionalities are so overwhelming and hampering effective use by BMETs. To overcome this challenge, the imperative lies in creating a design that offers visual accessibility, akin to accessing someone's criminal records. With one look you can understand their history and asses their current situation.

4.1 THE DEFINED PROBLEM SPACE

WWWWWH CHECKLIST

To sharpen the problem statement after the insights gained in the empathize phase the WWWWWH checklist is used (Van Boeijen et al., 2014). The problem space will be defined as followed:

WHO has the problem?

The user of the system: BMETs working with a CMMS that didn't fully incorporated there way of working.

WHAT is the problem?

The problem lies in the overwhelming number of information and functions a within the CMMS, combined with the way information is displayed, resulting in a cluttered system. This cluttered interface is akin to looking at the map of Amsterdam to search for the metro (see Figure 21) BMETs get an overwhelming amount of information in one screen that doesn't give clarity.

WHERE is the problem?

The problem appears when BMETs interact with the system to determine the next tasks maintenance or repair task they wanted to perform.

WHEN is the problem?

The problem occurs when BMETs opt to use the system only for specific devices, opposed to integrating it into their regular work because it takes too much time and effort for them to acquire rapid information.

WHY is it a problem?

Without being aware of the status of other devices in the hospital, the BMETs wind up repairing the devices that were brought in. This lack of awareness could result in more failures, more maintenance costs, and lower service quality on other devices.

HOW is it a problem?

Utilizing the CMMS for maintenance and repair could significantly improve equipment lifespan and patient safety, as indicated by Khider and Hamza (2022). Neglecting its use could result in more breakdowns, higher costs, and compromised patient well-being. Moreover, the data generated by the system could prove invaluable in hospital-wide decision-making regarding the purchase of new equipment and spare parts in the future.

Figure 21 : Illustration of problem space.

4.2 DESIGN GOAL

" I WANT TO DESIGN AN **INCLUSIVE INTERFACE** FOR BMETS IN NEPAL BY **VISUALIZATION** OF MEDICAL DEVICE DATA."

4.3 INTERACTION VISION

The system should be quick and uncluttered which should give the user a sense of how the device is doing at a glance. To enhance this experience, the following interaction vision was developed with the use of an analogy.

ANALOGY

Like checking someone's criminal records as a police officer.

INTERACTION QUALITIES

- Openness
- Clarity
- Predictable
- Quickly

STORYLINE

As I secured someone's criminal records from the archives, I instantly noticed how incredibly light the file felt in my hands. In that fleeting moment, a mere glimpse of all the information provided a comprehensive overview of the individual's past. A quick look at the file enabled me to understand their history and assess their current situation, viewing them as a person with a kind and caring nature.

Figure 22: Illustration of the interaction vision.

The design statement and interaction vision are used as a start point in the ideation and prototype phase and are carefully looked back upon in every iteration step. So it could function as a guided principle throughout the project.

4.4 LIST OF REQUIREMENTS

The list of requirements (Van Boeijen et al., 2014) is drafted on the basis of the process, equipment, and value analysis. The objective is to ensure that the design of the interface meets all essential criteria. The following list of requirements show the characteristics and design objectives that will guide in creating the final design.

The list consists of five categories: Values, Reliability, Features, Context and User Interface design. Where wishes are used to select between concepts and design solutions, the demands regarding this topic should be fulfilled.

LEGEND

The icons indicate from which analysis the requirements occur:

◆ Process analysis
◇ Equipment analysis
△ Value analysis

VALUES

DEMAND

[1] The user should have the freedom to determine his/her own day planning. △
[2] The system should provide task in a suggestive way. △
[3] The system should show the person that performed the maintenance/repair. △
[4] Looking for information about a device should be quick and easy. ◆
[5] The BMET should be able to make a new tasks in under 30 seconds. ◆ △

WISHES

[6] The system should positively influence the communication in the team. △
[7] The names from every team member should be in the system. △

RELIABILITY

DEMAND

[8] The system should show the planned and executed maintenance check of medical devices. To ensure the feeling of safety and reliability. △
[9] The system should shown the history of a medical device. △
[10] Medical devices status could be working, partially working and out of order. ◆ ◇
[11] Repair task could be placed on hold when waiting on spare parts. ◆ ◇
[12] The system should have a modus that your process could be saved anytime. △
[13] Deleting data should only be possible with an extra confirmation. △

WISHES

[14] Everybody should have there own entry data. △
[15] The system should have an overruling admin account. △

FEATURES

DEMAND

[16] The system should have minimal mandatory information needed. ◆ △
[17] The system should show the status, priority, name and location of a medical device. ◆ ◇
[18] The system should have a to-do list structure for maintenance and repair tasks. ◆ △
[19] The system should display the amount of maintenance and repair work you've carried out and remaining to do. ◆
[20] The system should provide an overview of one individual medical device. ◆
[21] The system should show a overview of maintenance planning. ◆
[22] The system should have an integrated maintenance checklist. ◆
[23] BMET should be able to search for a medical device based on asset number, location and/or name. ◆
[24] The system should have an option to open the manual. ◆
[25] The system has the contact details of the manufacturer and supplier. ◆

4.4 LIST OF REQUIREMENTS

WISHES

[26] The system should show a picture of the medical device. ◆ ◇

[27] BMET should have the feeling that he/she get a clear overview of there task. △

[28] The system should provide a quick way to leave tips & tricks. ◆

[29] The system should show an overview of the status of medical devices at 1 location. ◆

CONTEXT

DEMAND

[30] The system should support the main communication tool: Calling. ◆

[31] The system should have an offline mode for limited connectively. ◆

[32] The system should be a desktop application. ◆

USER INTERFACE DESIGN

DEMAND

[33] The language in the system should be English. △

[34] The interface should be consider user-friendly by the BMETs. △

IDEATION & PROTOTYPE

OVERVIEW

The pathway to arriving at the final design is explained, encompassing the method used for evaluating the prototypes through a mixed-method approach. The progression unfolds, beginning with the creation and assessment of lo-fi prototypes, towards a hi-fi prototype. The insights gained from these evaluations are used to make iterative refinements.

SUMMARY

Utilizing Norman & Draper's interfaced design steps (1986), the chapter outlines the systematic approach employed to reach the final design. This involved testing both lo-fi and hi-fi prototypes for usability. The usability assessment yielded positive results overall, yet highlighted areas lacking clarity in terms of priority. Consequently, iterative refinements were introduced to pave a clearer path towards the final design.

5.1 PROTOTYPE APPROACH

PROTOTYPE APPROACH

For streamlining the design of an interface the design steps prepared by Norman & Draper (1986) are used. A schematic overview of this is shown in Figure 23. To test the usability and visual clarity of the design, a test was conducted after step 4 (a low fidelity (lo-fi) prototype) and step 6 (high fidelity (hi-fi) prototype), so that these insights could be included in the iteration steps.

To get inspiration before prototyping an ideation phase took place. In the ideation phase, the techniques of brainstorming, both individually and by using input from others, were used to arrive at different insights about visualizing data and how to show priority and status. Additionally, other asset management systems were studied to draw inspiration from and learn from their approaches.

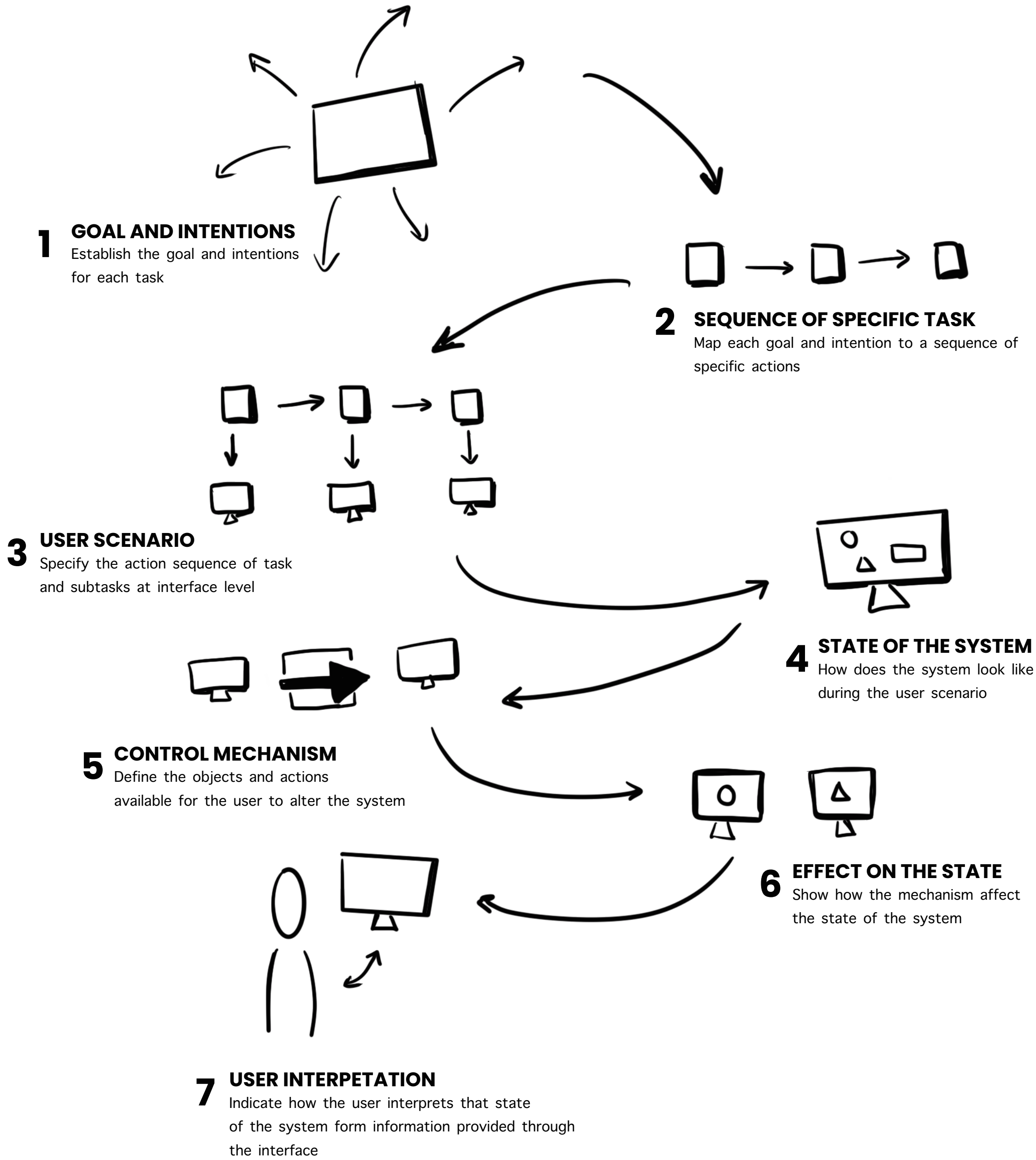


Figure 23: Design steps for the design of an interface.

5.2 EVALUATION APPROACH

PARTICIPANTS

A mixed-method approach was used to evaluate after every iterations step. Because Hudson et al. (2007) showed that there is a difference between novice user and expert user behaviour when testing user interfaces, it is necessary to map how much experience the test participants had. To get an idea of this from the test participants, the user cube (Figure 24) from Nielsen (1993) is used. The cube consists of 3 dimension (Wu, 2000):

- Experience with the system.
- Experience with computers in general.
- Experience with the task domain.

For testing the high-fi prototype, at least 5 people were participating as 85% of the usability problems are found after testing 5 participants (Nielsen & Landauer, 1993).

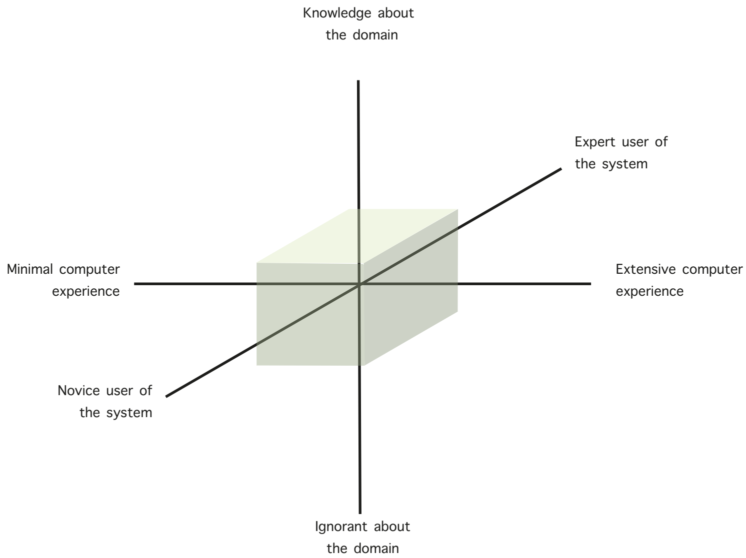


Figure 24: User cube from Nielsen (1993).

QUALITATIVE RESEARCH

The main objective of the qualitative research was to obtain the visually accessibility of the design goal was incorporated in the design. Was it for the participants or did they feel they needed more information. To get a fair picture of this, the participants were informed about the domain in which the tests took place and asked questions in a non-structured interview way afterwards.

QUANTITATIVE RESEARCH

The quantitative part was used to test whether the usability was acceptable. 3/5 aspects of usability (learnability, errors and satisfaction) could be tested in this phases. Since all participants saw the prototypes for the first time, the efficiency of its use could not be tested. This is because this requires participants with experience of one and the same system (Nielsen J., 2010).

Figure 25: Building blocks of usability.

To test memorability of the system the participants would have to use the system for a second time. In the time frame of this iterative process there wasn't a possibility to test after a week again so memorability wasn't possible to test.

Usability Satisfaction is measured by using the System Usability Scale (SUS) (Brooke, (1996) and 6 differential scales from Coleman et al. (1985). SUS was specifically designed so that designers have a quick and reliable way to measure the subjective component of usability satisfaction. (Peres et al. 2013).

Learnability is measured by letting a participant who never used the system before complete a certain task and measure how long it takes to complete this tasks.

Errors are simply measured by counting the time the errors occur and how severe the error is.

5.3 IDEATION

During the ideation phase, a culmination of brainstorming sessions and an exploration of various CMMS platforms revealed several insights. Integrating pie charts and infographics emerged as a potent strategy for enhancing the clarity of cluttered information, presenting data in a more digestible format. Incorporating images of devices emerged as a possible solution for improving device recognition. The widely recognized colour scheme of green, orange, and red was identified as an effective means of conveying both priority and status. Furthermore, it became evident that the home screen garnered the highest user attention, underscoring its significance as a focal point for critical information dissemination.

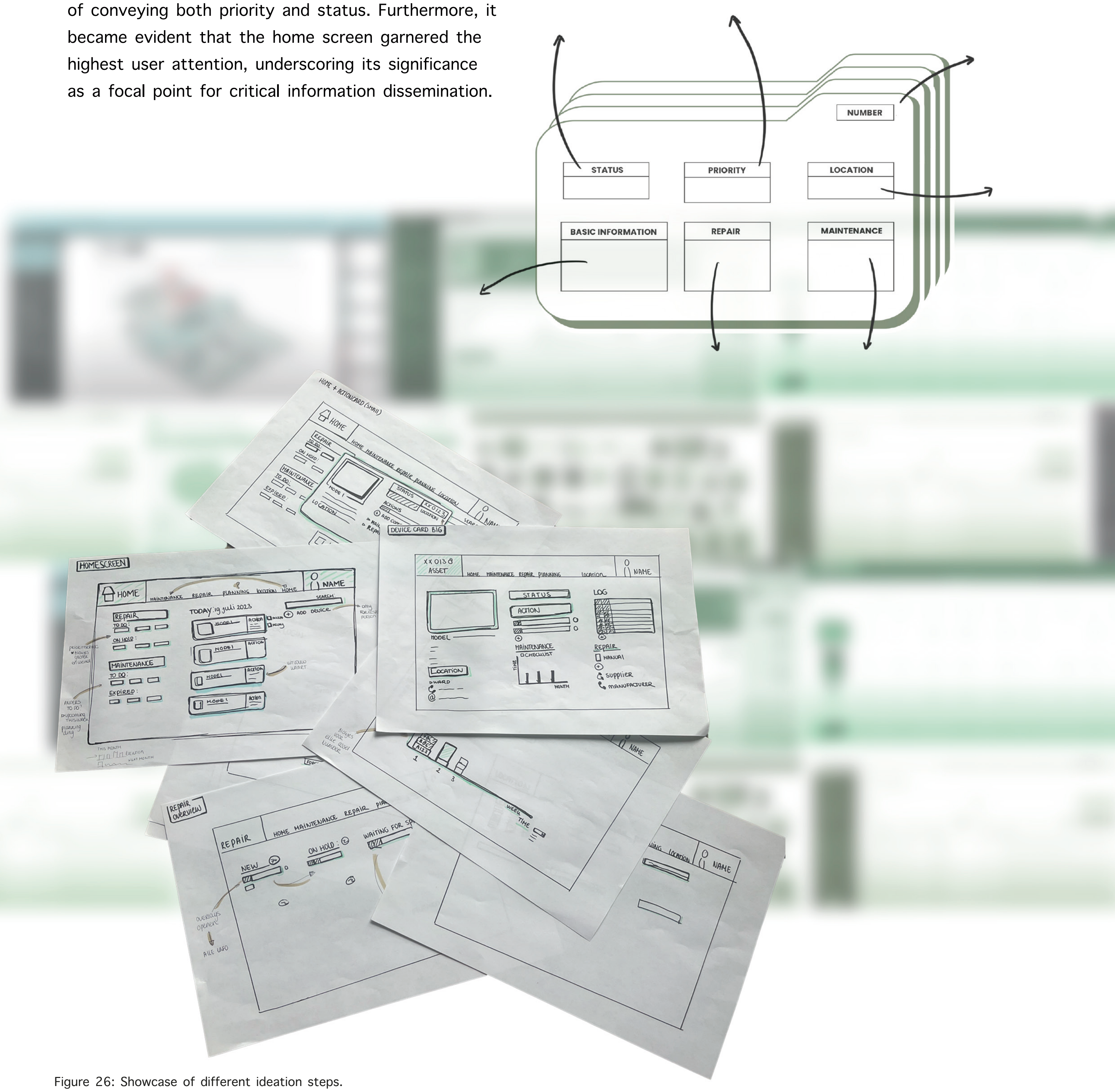


Figure 26: Showcase of different ideation steps.

5.4 LO -FI WIREFRAME

PROTOTYPE 1

The initial prototype constitutes a low-fidelity wireframe, primarily aimed at testing steps 1 to 4 of the design process outlined by Norman & Draper (1986). The testing involved three participants, and the test plan can be found in the Appendix C.3. The main focus of this test was to assess the accessibility of static screens and the clarity of their elements. In order to create a low threshold for feedback on this elements the prototype was paper and the interaction pattern was formed by wires. Additionally, the flow of the system was validated (Appendix C.1).

To maintain a critical approach and ensure the avoidance of excessive functionalities, the wireframes were developed following Hoekman's 3Rs (2009) principles:

- ▶ **REQUIREMENTS:** Only include things that are absolutely necessary.
- ▶ **REDUCTION**: Remove as many screen elements, interactions and words as you can be.
- ▶ **REGULARITY**: Be consistent in formatting, layout and wording.

Figure 27: Overview of the wireframe. The whole wireframe can be found in Appendix C.2.

Figure 28: participant testing the wireframe.

5.4 LO-FI WIREFRAME

THE TEST

The comprehensive test results, evaluating the accessibility and clarity of wireframe elements, are available in Appendix C.4.

Regarding usability (SUS score = 85), the system performed well in the test. However, assessing learnability aspect of usability was challenging since participants could view all screens simultaneous.

"Because of the design of this test, I could already easily see what the next screen was and had actually seen all my options and more information at a glance, nevertheless, I think you could also learn it quickly." (N=3)

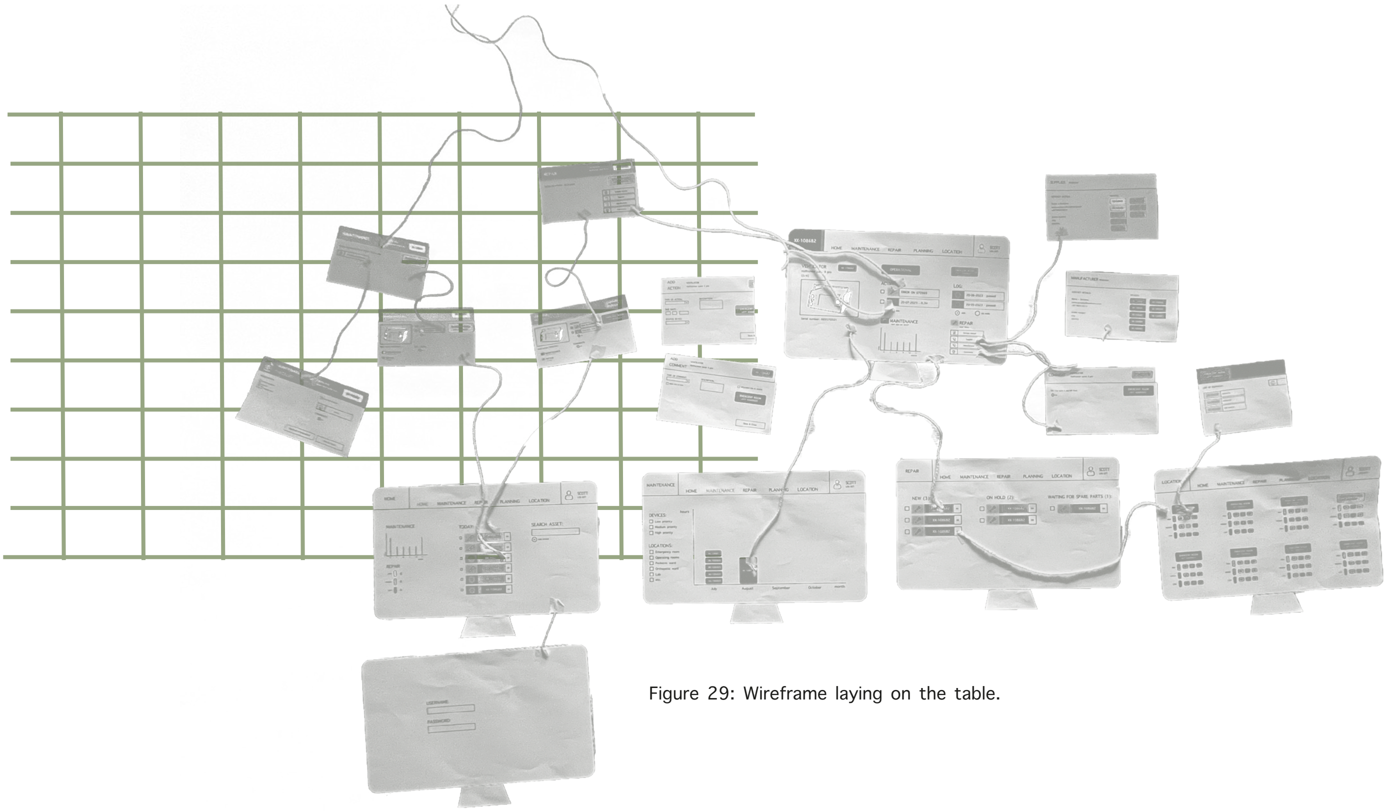


Figure 29: Wireframe laying on the table.

Figure 30: homescreen with priory colours highlighted.

MAIN INSIGHTS

- Participants found the accessibility to be clear and didn't feel the need for additional information.
- The priority of certain elements was unclear. Only one participant (N=2) identified the colour difference between the asset numbers.
- The wireframe lacked information about the total number of tasks completed by the end of the day, which affects the assessment of the achievement value.
- Participants encountered some difficulties in understanding how to close pop-up screens with actions and more information about the devices.

5.5 HI-FI PROTOTYPE

PROTOTYPE 2

During this phase of iteration, the transition is made from a physical paper format to a digital medium to test steps 5,6 and 7. In the process of developing the prototype, we incorporated the insights gained from the tests conducted with prototype 1. The primary focus while designing this prototype remained on functionality, with minimal emphasis on aesthetics but incorporating interactions into the design. This approach aimed to provide participants with ample room for sharing comments and posing questions.

During the evaluation of prototype 2, the central attention was directed towards how users perceived the interface, the different buttons, and the transitions between them. The specifics of the testing setup can be found in Appendix C.5. The testing was carried out with a group of 7 participants, each presented with 2 scenarios. Among these participants, 4 engaged in an A-B test, while 3 took part in a B-A test. This latter approach was chosen to mitigate the learnability factor within the testing.

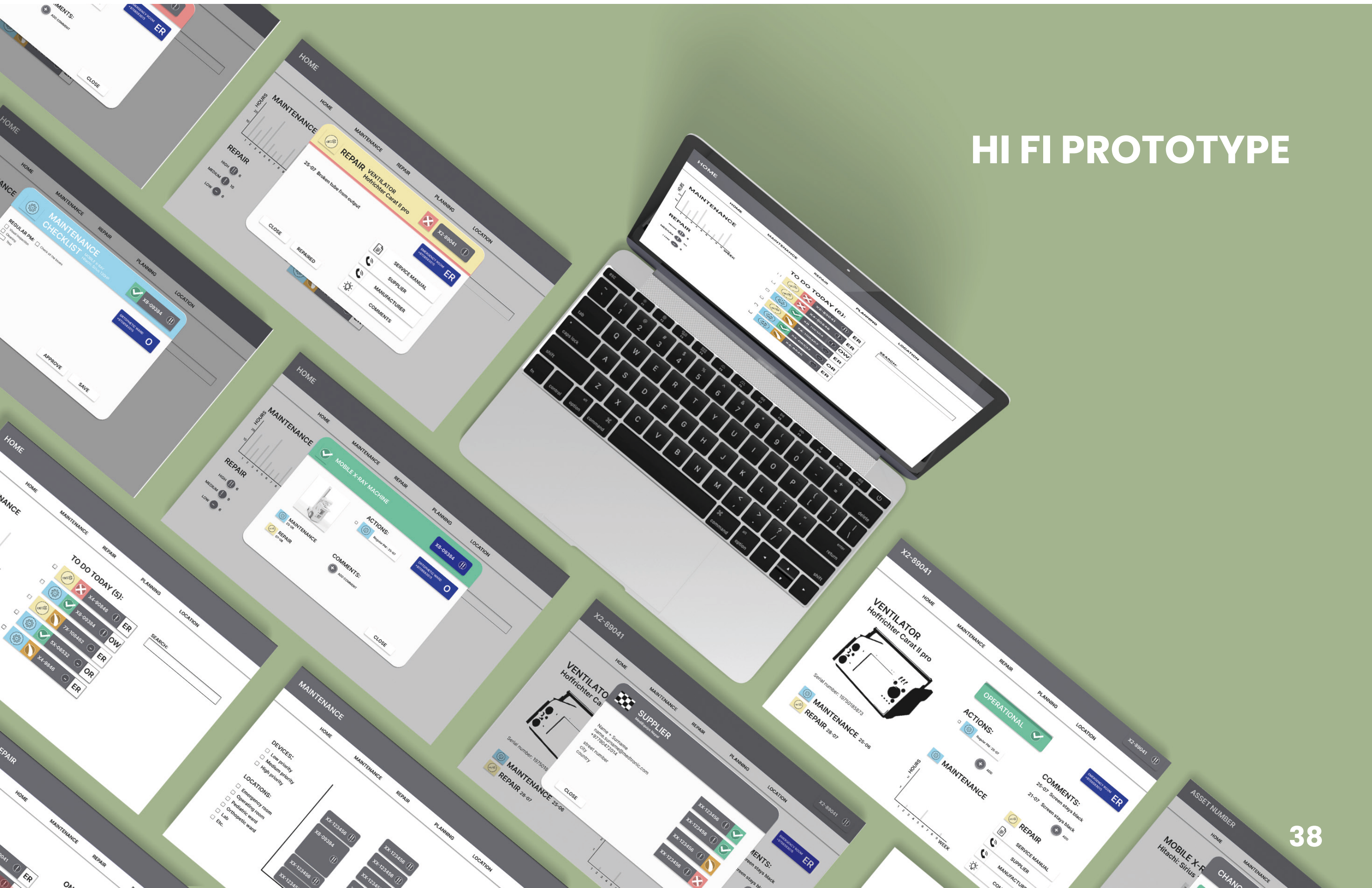
[LINK TO PROTOTYPE 2]

Figure 31: Participant interacting with prototype 2.

Notably, some participants in this phase possessed greater domain experience compared to those involved in testing with prototype 2.

THE TEST

Overall, usability was perceived positively (SUS score=83, Excellent). Each participant could quickly perform the tasks in the system, so learnability was also high. However, many participants did note that performing a maintenance or repair task in between would result in another interaction with the system since the expectation was that this interaction would then have to be performed two times. The overall test results are showed in Appendix C.6.



5.5 HI-FI PROTOTYPE

MAIN INSIGHTS

1. Presently, the status of the device garners more attention then its priority.

2. Maintenance and repair currently still provide guidance in the to-do list whereas device prioritization should do so with the aim of making maintenance as important as repair.

3. The pop-up screen displaying devices quickly has the same size as the repair or maintenance card. To improve clarity, a clearer distinction should be made between device card and task card.

"I was confused because the cards had the same shape. Again it looked like it was about a device but then it was a repair card." (N=6)

"The red boxes catch my attention the most, and I would prefer to address them first. It feels odd that they are not all positioned at the top." (N=5)

4. The function of the asset number button remains unclear, leading participants to miss the additional information about the device hidden behind it. Although, this information was found unnecessary by 5 out of 7 participants.

5. The symbols representing suppliers and manufacturers closely resemble telephone symbols, causing participants to hesitate in clicking them out of concern for initiating an immediate call.

5.6 HI-FI PROTOTYPE 2

[LINK TO PROTOTYPE 3]

HI-FI PROTOTYPE 2

HI-Fi prototype 2 represents a redesigned version of the initial HI-Fi prototype, integrating insights derived from the test described on page 38. Hi-Fi prototype 2 can be opened using the link on the right side.

THE TEST

For evaluating this prototype, The streamlined cognitive walkthrough method (Spencer, 2000) was used. This method was used because our participant had a lot of experience using a CMMS system in the Netherlands, yet had no prior exposure to the Nepalese context. The participant is working as a BMET in a hospital in the Netherlands. This approach gathers valuable feedback regarding the functionality and user interaction of the interface. In particularly identifying any illogical or unclear elements. The focuses was less on whether the participant could locate specific buttons, as this aspect had already been examined in previous iterations.

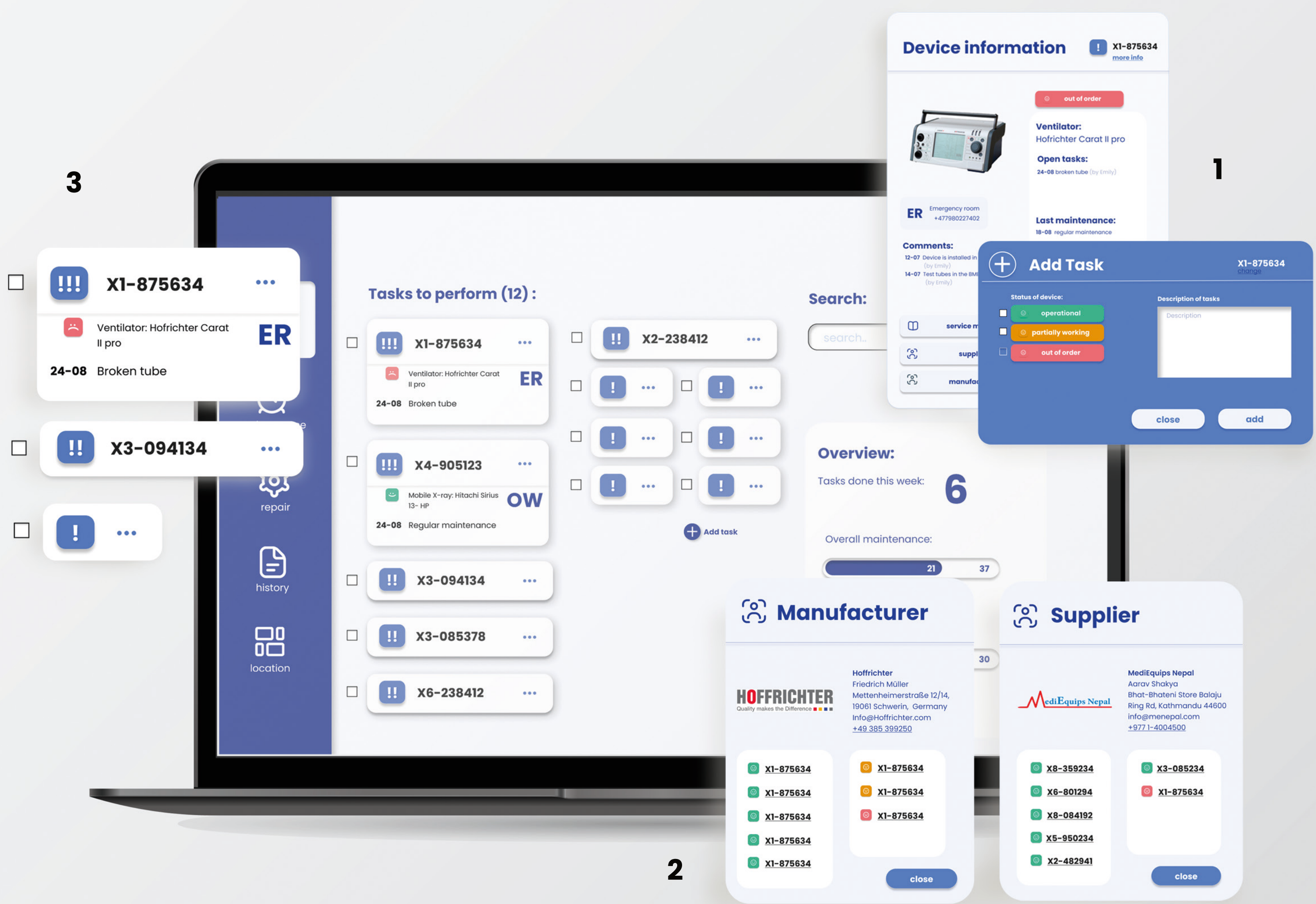
MAIN INSIGHTS

The main insight of this test are used to come up with the final design. This main insights are:

1. The current process for creating tasks within the system is not streamlined and involves too many steps. This should be readily apparent from the home screen.

2. When medical devices malfunctions occur, BMETs prioritize information on potential replacement devices over details about what kind of devices the manufacturer or supplier made.

3. When discussing medical devices with colleagues, it is more common to use names rather than asset numbers. While the CMMS operates based on asset numbers, this approach does not mirror real-life work practices.



FINAL DESIGN

OVERVIEW

This chapter presents the end-result of the previous chapter's efforts: the final design. It highlights the functionalities and presents the building blocks, emphasizing their key features, user experience, and incorporated medical device information. Furthermore, the chapter includes an evaluation of this final design conducted with BMETs in Nepal.

SUMMARY

The final design serves as a visual representation of the transition from a data-based to a task-based interface. Following the assessment by the BMETs, it was clear that the interface was oriented towards task-based functionality. The design received a high usability score, but there are remaining opportunities for further refinement.

6.1 FINAL DESIGN

The final design of this project emerges from the iterative stages undertaken during the ideation and prototype phases. This design aims to demonstrate how the design goal “I want to design an inclusive interface for BMETs in Nepal by visualization of medical device data” in order to make a system that is more aligned with the workflow of the BMETs without overloading them with information.

Within this section, we show the key functionalities of the design, denoted by (A). These indicators correspond to specific elements in the accompanying image below.

Furthermore, throughout the text, you will encounter [1] markers. These icons are cross-references to the design requirements outlined in Chapter 4.4 on page 30.

[LINK TO FINAL PROTOTYPE]

[LINK TO FINAL DESIGN VIDEO]

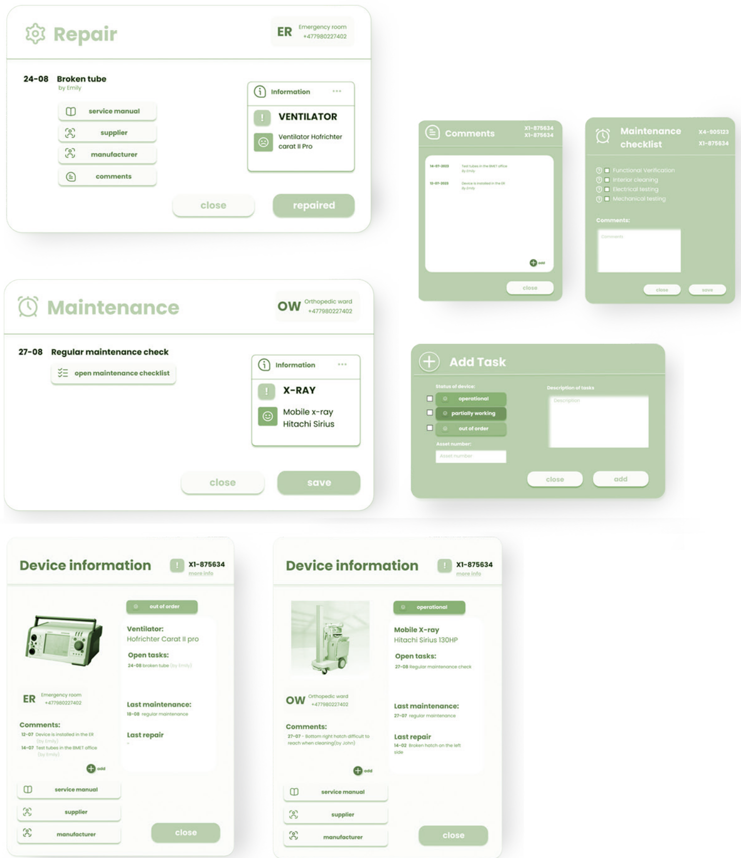


Figure 32: overview of the final design.

6.1 FINAL DESIGN

HOMESCREEN

The main screen in the final design is the homescreen, serving as the central screen for all essential information. Located on the left side of this screen is a navigation menu (A) to help you move around. The homescreen is designed to encompass everything you need for your daily tasks, while the other screens serve as supplementary displays for more detailed information.

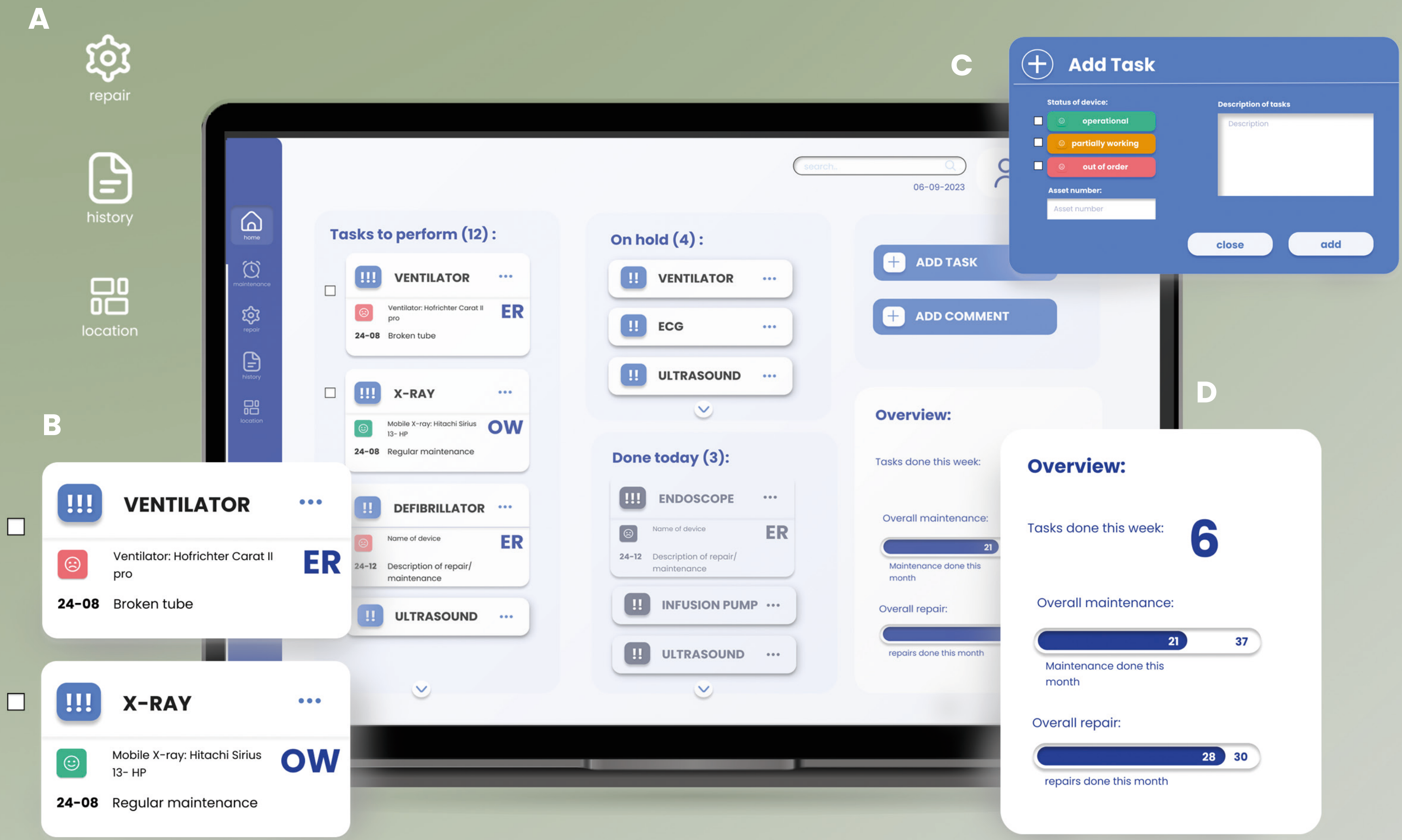
To improve visual clarity regarding device prioritization, the homescreen places a strong emphasis on active tasks and highlights their significance in the form of a to-do list [1, 2, 18].

Consequently, tasks with the highest priority (determined by device priority and waiting time) are represented with larger icons, containing more details, and positioned in the upper left corner.

Priority is indicated by exclamation marks, while medical device status is conveyed through colours and symbolized by smiley icons (B). Tasks that require spare parts or specialized expertise are neatly organized in the "on hold" box [11], and completed tasks can be found at the bottom of the screen.

From the homescreen, adding a new task (C) is a quick process [10, 23]. You only need to provide the status of the device, the asset number, and a brief job description.

Furthermore, the homescreen includes a summary of completed tasks and offers insights into the number of open tasks related to maintenance and repair (D) [19].

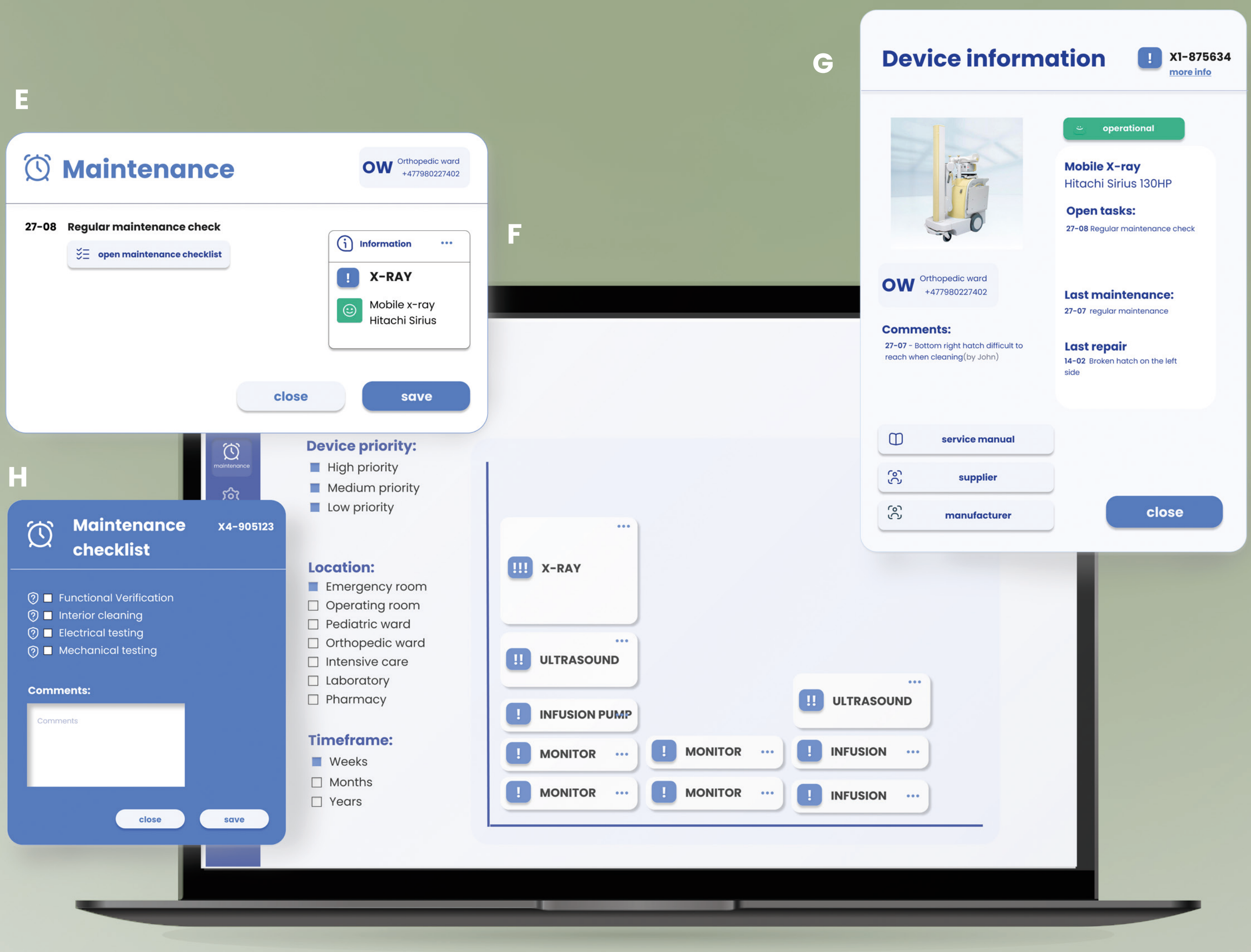


6.1 FINAL DESIGN

MAINTENANCE

The maintenance tasks are presented through "task cards"(E) [30] providing a snapshot of medical device status and priority. Should more information be required users can access this information via an associated information button (F). This opens up a "device card" (G) [3, 4, 8, 9, 17, 19, 20, 26]. These device cards offer users a historical view of the device's usage, maintenance and repair.

Embedded within the "maintenance task card" is a link to the maintenance checklist (H). This checklist [22] circumscribes various tasks along with an explanation about the task and offers the ability to mark check boxes and provide comments. To facilitate user navigation an overarching maintenance overview page [21] is available presenting a view on the workload distribution across different time periods.



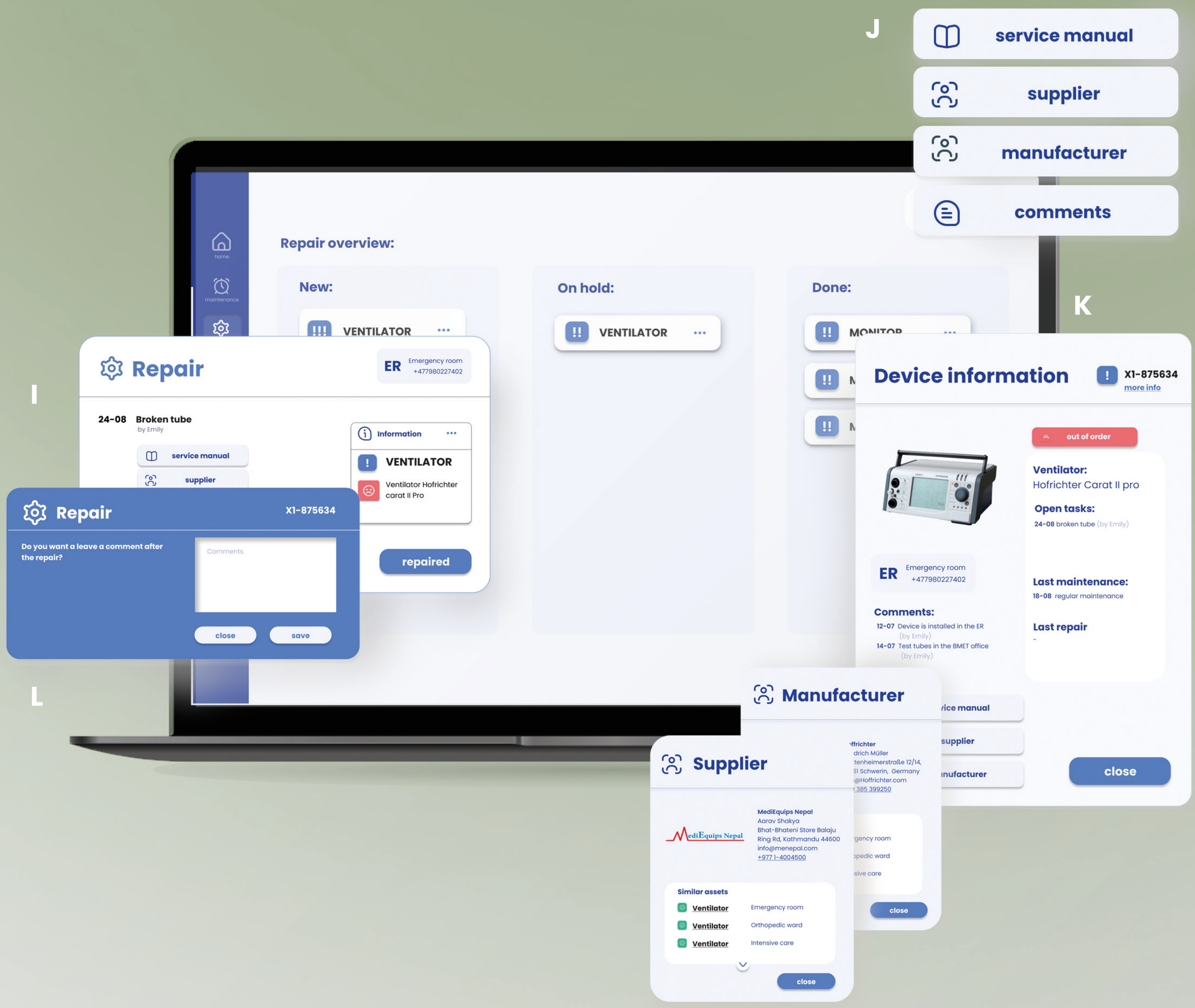
6.1 FINAL DESIGN

REPAIR

The repair tasks follows a process similar to that of maintenance tasks. Each task initiates a "task card" (I) revealing the error or malfunction and ensuring access to information such as manuals, supplier/manufacturer contacts and comments (J) [24, 25, 30]. Moreover, the repair card facilitates access to the device card (K), allowing for a comprehensive overview of the medical device's status.

In case of a malfunctioning medical device, a red "out of order" tag appears on both the task card and device card, providing a visual indicator of the device's status. This label changes automatically when the device is repaired.

Upon completion of a device repair, a pop-up (L) prompts users to leave a comment, reminding the user to offer insights and suggestions for device repair, further reinforcing the values of trust and collaborative improvement [6, 8].



6.2 BUILDING BLOCKS

According to Kang (1998), features serve as building blocks for designing domain-specific software solutions. This emphasis how important it is to identify the key components that make up the final design. Features are the core of the structure of a software system, as shown by their functional relevance across a variety of configurations.

The key features of the final design are outlined below:

- A task-oriented homescreen containing a priority-based to-do list.
- A comprehensive portrayal of maintenance workload, presented on the maintenance screen.
- A systematic categorization of repair tasks into "New," "On Hold," and "Done" statuses, offering an at-a-glance overview.
- An instructive chart of location-based medical device statuses.
- Search functionality enabling swift access to medical devices
- Incorporation of new medical devices seamlessly.
- Pop-up cards with information about medical devices of tasks.

These features work together to create a human-centric experience, which is important to the software's use. They show their influence in the ways listed below:

1. Facilitating a overview of medical device statuses.
2. Guiding users in identifying tasks with priority, irrespective of task nature.
3. Empowering users to locate devices based on their unique asset numbers.
4. Enabling users to effortlessly append new devices and tasks into the system.

The medical device information that is used to facilitate this features and experiences are:

- Name of medical devices
- Name of medical devices given by the manufacturer
- Level of priority
- Maintenance interval
- Supplier contact details
- Manufacturer contact details
- Asset number

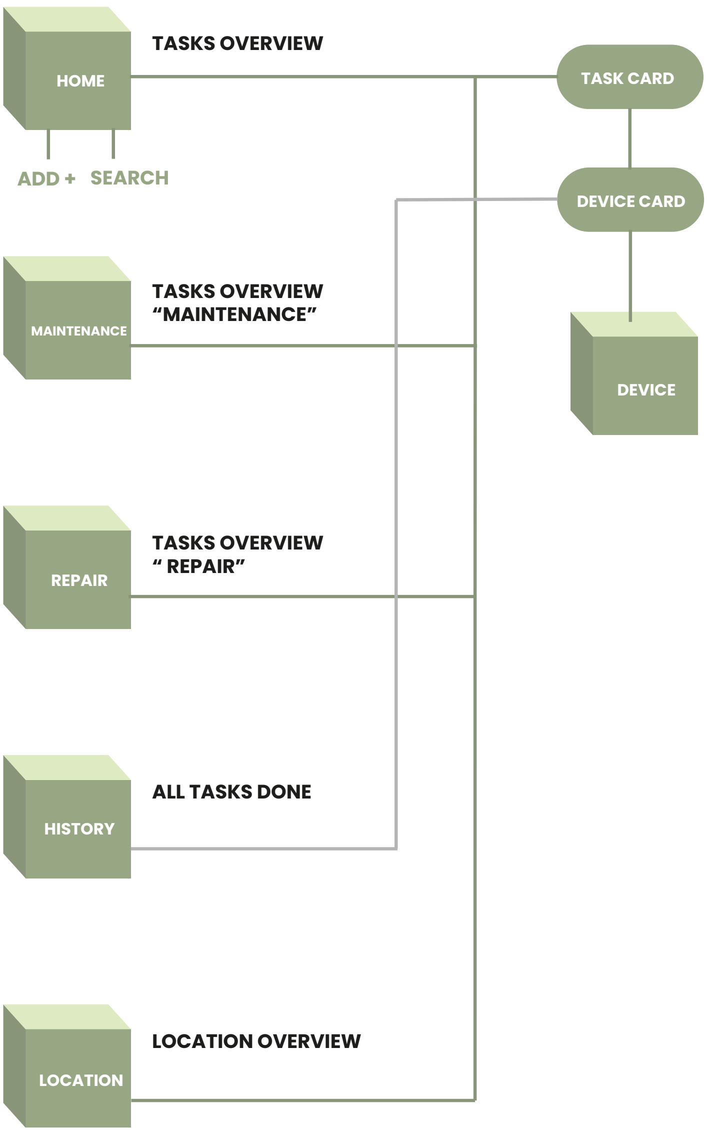


Figure 33: Overview of the main building blocks used in the final design.

6.3 EVALUATION

THE EVALUATION TEST

Because the aim of the project is to use a human-centered approach to design for the context of Nepalese hospitals, the final evaluation was carried out with -BMETs from hospitals in Nepal. This evaluation aimed to determine if the prototype had aligned more with the BMETs' existing workflow. The evaluation was conducted using the Lookback software, allowing for both video chat interaction with participants and real-time observation of their screens featuring the interactive prototype created in Figma. Two separate sessions were organized, each involving two BMETs sharing a single laptop. In both instances, one BMET was of European origin, while the other was of Nepalese origin.

The evaluation employed a mixed-methods approach, combining quantitative and qualitative data collection. Quantitative data were gathered through an online questionnaire, utilizing the same set of questions that were used in previous assessments of the low-fidelity and high-fidelity prototypes. The SUS methodology was used to get insights on the usability level. This questionnaire was completed together which forced a conversation about the questions asked and gave qualitative insights.

For qualitative data collection, participants were guided through the prototype using scenarios developed during the ideation and prototype phase (as detailed in Chapter 5). Participants interacted with the prototype themselves and engaged in unstructured interviews. The questions aimed to delved into their experience while using the prototype.

A description of the entire evaluation setup can be found in the Appendix D.1.

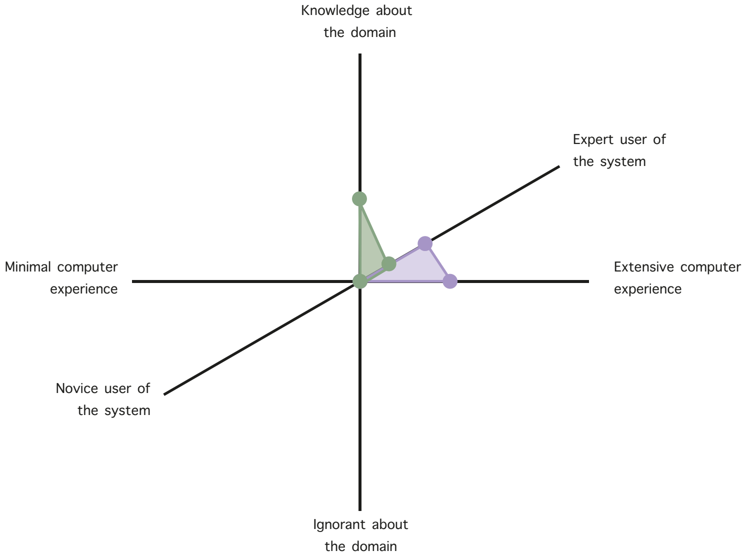


Figure 34: User cube of the evaluation test.

Figure 35: Session 1 using a showcase of the final design

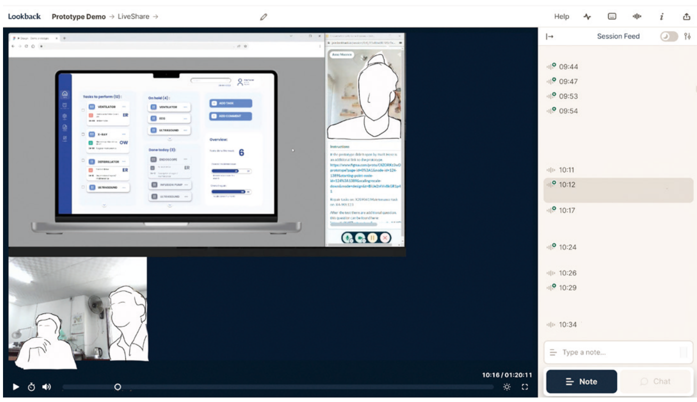


Figure 36: Session 2 using Lookback for testing the final design.

6.3 EVALUATION

RESULTS

TASK FOCUS

The prototype maintained a strong focus on tasks. Participants reported that the software was effective when it came to task-oriented activities.

> "For the daily workflow and the daily tasks, yours is nicer than ours." (N=1)

STREAMLING USER BEHAVIOUR

Two participants found that the system guided them efficiently through tasks, reducing unnecessary steps and complexity.

> "You keep us doing it in in one way. Too many systems have multiple ways. In the current system you can do things in in so many different ways and that is an disadvantage because users work differently. Quite often you do don't do it the easiest way, but you you find a a longer way and make it your own. To really streamline the tasks, that's good idea." (N=1)

INFORMATION ON HOME SCREEN

Participants were pleased to find that the home screen served as a comprehensive dashboard, offering quick access to essential data and functions.

> "I have Information enough just from looking at the homescreen." (N=1)

> "I think it's a clear homescreen In my experience there is generally a chunk of overdue things because we generally have more things to do than we can actually manage." (N=2)

CLARITY

The system received praise for its clarity. Participants found the interface and navigation to be straightforward and easy to understand.

WORK-CENTRIC APPROACH

Two participants appreciated that the software prioritized task completion over data entry, allowing them to focus on their primary responsibilities rather than spending excessive time on administrative tasks.

> "So, I think I like how you organize this more focused on doing work instead of filling a database." (N=2)

ENHANCED FUNCTIONALITY

Participants noted that the software prototype offered more comprehensive functionality compared to their current system. Several features and tools were identified as valuable additions that were missing in the existing system.

> "I think it's, it's more complete than our current system just because it's so there's some functions we are missing that are actually in this." (N=2)

SUS

In the quantitative data analysis, the System Usability Scale score was 97.5 out of 100, indicating an excellent user experience Figure 37 displays the results of each question's scoring.

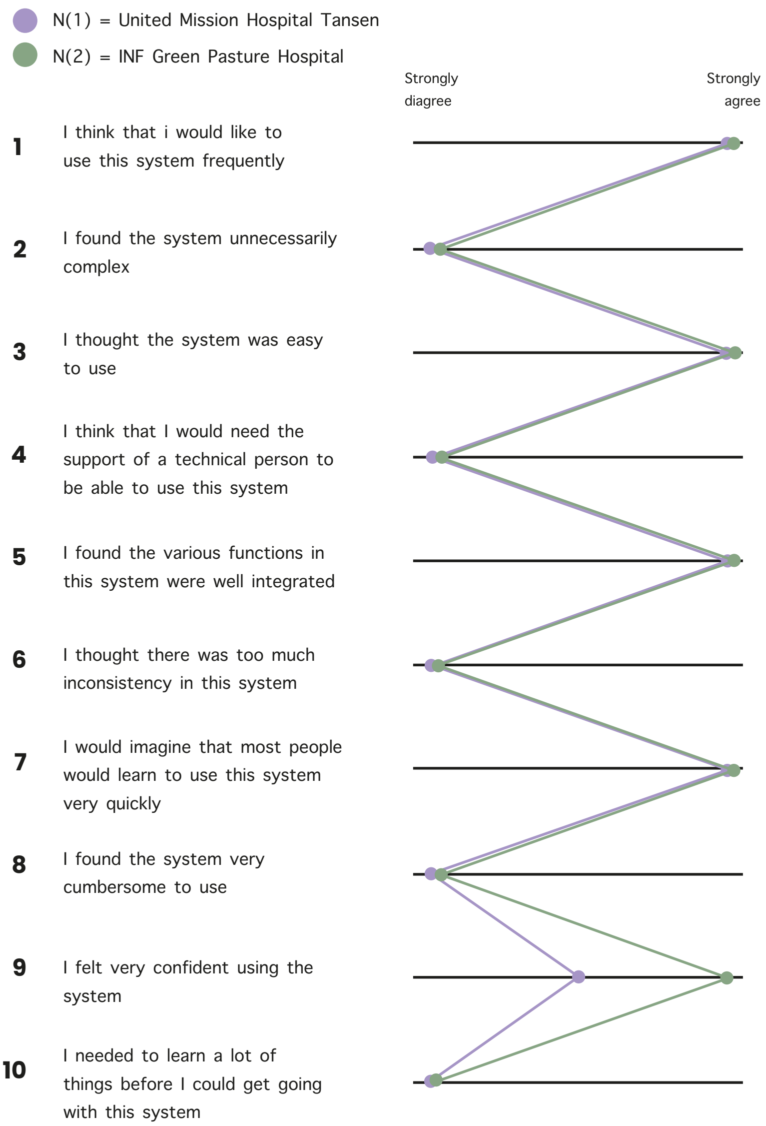


Figure 37: Results of the System Usability Scale.

6.3 EVALUATION

IMPRESSIONS

For the overall impression, the prototype received positive feedback, with users describing it as aesthetically pleasing, comprehensive, cooperative, straightforward, and secure. However, it received a lower rating for speed during use.

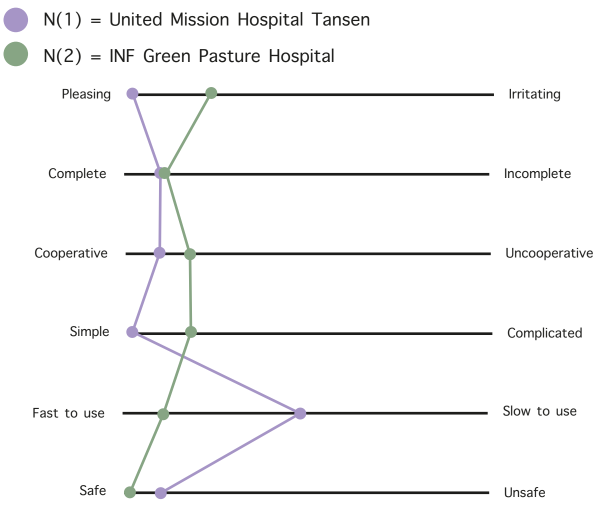


Figure 38: Overview of the impressions on the final design.

CONCLUSION

Based on feedback from the participants, the system establishing a clear focus on tasks. They noted that the prototype excelled task-oriented activities, prioritizing task completion over data entry. During the final design evaluation, various features and tools were identified as missing in the existing system but present in the prototype. However, participants also offered minor suggestions for adjusting or adding small functionalities to the prototype, which can be found in the Appendix D.2.

Participants found the home screen, in particular, to be user-friendly and easy to navigate. While some suggestions were made to incorporate more colour for task prioritization, it was emphasized that this should not compromise clarity.

Overall the prototype had a high score on usability and made a step alligment with the workflow of BMET's.

DISCUSSION

LIMITED NUMBER OF PARTICIPANTS

The test had four participants (2x2), which, while possibly due to resource and time constraints, limited the amount of feedback received. A larger sample group would have provided a better usability understanding of the prototype.

SCENARIO-BASED

The test used scenario-based testing instead of observing real workflows over an extended period. While scenarios are useful for testing, they may not capture the complexities of actual usage. Future evaluations should consider incorporating more real world testing.

TECHNICAL CONTEXT DIFFICULTIES

Technical failures disrupted the test when the prototype stopped working due to computer issues and bad connection. Therefore, we had to switch to a showcase instead of a interactive test environment.

PROTOTYPE

The prototype's development stage meant that some functionalities were not fully usable. This limitation could have affected participants' experiences.

CONCLUSION & RECOMMENDATIONS

OVERVIEW

The project's overarching conclusions are presented in this chapter. Examining how the final design reflects feasibility, desirability, and viability. Additionally, recommendations are offered to help future designers with comparable projects, improve the final design, and identify areas that require additional research.

7.1 CONCLUSION

GENERAL CONCLUSION

The aim of this project was to contribute to the development of a more inclusive CMMS by using a human-centered approach in the design of an interface tailored for use in Nepal. Through the application of the context mapping method, we identified a disparity between the system and the workflow. Mainly caused by an overload of information and functionalities. Consequently, our design had to make a transition from a data-centric system to a task-oriented one, achieved by visualizing useful medical device data. Following a series of iterative steps, an evaluation conducted BMETs in Nepal confirmed that this prototype represents a significant step towards a task-based interface and that this task-based integrates better with their daily workflow.

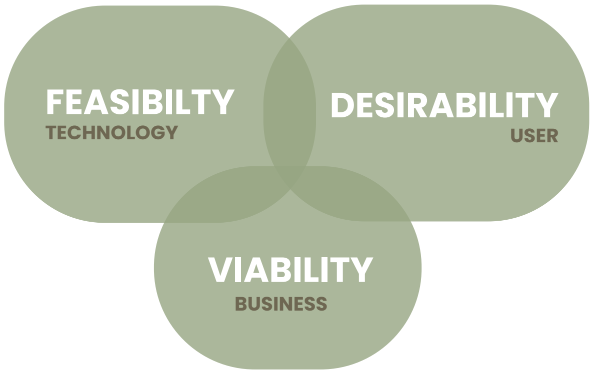


Figure 39: Illustration on Feasibility, Desirability and Viability

The users were at the centre of the entire project, in order to reach a more thorough conclusion, the project was viewed from 3 angeles: Technology angel in Feasibility, User angle by Desirability and Business angle in Viability.

FEASIBILITY

From a technical perspective, the design could be made with existing technology. Utilizing a Figma prototype provides software developers with a straightforward pathway to translate the prototype into a functional application. Moreover, in the local context, integration into the existing hospital IT infrastructure, now reliant on desktop systems without a connection between other hospital internal software, is feasible.

DESIRABILITY

The focal point of this project was using a human-centric approach to enhance the usability of a CMMS in a low-middle income setting. Desirability was an important factor throughout the project's duration. The design was made to seamlessly align with the workflows of BMETs, with minimal disruption to their work routines. While the evaluation highlighted potential improvements, it is evident that a big improvement has already been achieved compared to existing systems. This improvement lies in the system's user-centric approach, displaying only essential information relevant to daily tasks which improves the usability of the system.

VIABILITY

This project aims to serve as an inspirational source for companies and NGOs seeking to develop CMMS solutions from a human-centered perspective. In the context of Nepal, this project can serve as a foundational framework, illustrating how CMMS can be designed to better suit the work environment, especially in a low-to-middle incomes setting. This approach can significantly increase CMMS use and the benefits that came alongside for hospitals. For existing CMMS developers, the insights in this project can provide valuable inspiration to enrich their systems and increase the usability.

7.2 RECOMMENDATIONS

FOR FUTURE DESIGNERS

When embarking on the design of a CMMS system, consider the diverse approaches available. This project shows a human-centered approach to enhance usability, particularly when crafting a CMMS for a different context. Nowadays, it is common to prioritize functionality in design, but it's essential as a designer to recognize that seamlessly moving a well-functioning software from one context to another is never desirable. Therefore, invest time in understanding the unique workflows and users values while working in these distinct contexts.

Furthermore, the analyses conducted in this project provide valuable insights into CMMS usage, and the building blocks outlined in Chapter 6 can serve as a starting point for your own interface design.

FOR THE FUTURE DESIGN

FROM PROTOTYPE TO APPLICATION

While the current prototype is made in Figma, it is important to transition it into a functional application with a back-end for data storage, requiring collaboration with a software developer. In this appliciation the possibility of adding new assets should be incorporated. In the project we mainly focussed on the repair and maintenance tasks because the adding of new assets was already a streamlined process with the real world context. Although adding assets is still a crucial component of the system, it must be determined which data is actually necessary before implementation.

SMARTPHONE USE

Presently, CMMS is mostly utilized on laptops and desktop computers in Nepal. However, as smartphone ownership is widespread, the future is likely to witness a shift towards mobile usage or a combination of both devices. Adapting the desktop application into a mobile version is a next step for making it easier for the BMETs to create a quick task with device images.

NEXT ITERATION

The recommendations that could be used in a next iteration on this prototype and comes from the evaluation could be found in Appendix D.2.

FOR FUTURE RESEARCH

ON THE TOPIC

The overarching goal of this project was to make a more inclusive CMMS. This was achieved through a comprehensive study involving two hospitals in Nepal. Based on the evaluation, it is evident that the CMMS system for these Nepalese hospitals aligns more closely with their specific needs and opportunities. While the core principles of a CMMS system remain consistent, the context varies, and thus, the CMMS may not always be a good fit. Which factors are most important to check while redesigning a CMMS for a new context is something that had to be studied so that the unique requirements of users in a context could be met.

ON THE DESIGN

To know of the new designed CMMS's real-world usability is improved, it is important to conduct research that involves its use in a typical workday and over an extended period with observations as main research method. The current evaluation was based on a fictitious scenario and has not undergone testing during a full workweek. Such testing would provide deeper insights into how well the new design aligns with the BMETs' workflow and how they interact with the system. Aswell that their is a lot of uncertainty about how the prototype will performe in other Nepalese Hospitals. Additionally, the project's time constraints permitted the testing of only 3 out of 5 usability aspects. Future research should be conducted on how well the prototype score on memorability and efficiency testing to ensure the overall usability of the system.

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Attributes for the mockup designers used in this rapport:
Frontpage Photo by Samrat Khadka on Unsplash
by rezaazmy on Freepik
by designwarrior on Freepik
by rawpixel.com on Freepik

APPENDIX

1. DESIGN BRIEF
2. HREC APPROVAL

A

DESIGN FOR our future

TU Delft

IDE Master Graduation

Project team, Procedural checks and personal Project brief

This document contains the agreements made between student and supervisory team about the student's IDE Master Graduation Project. This document can also include the involvement of an external organisation, however, it does not cover any legal employment relationship that the student and the client (might) agree upon. Next to that, this document facilitates the required procedural checks. In this document:

- The student defines the team, what he/she is going to do/deliver and how that will come about.
- SSC E&SA (Shared Service Center, Education & Student Affairs) reports on the student's registration and study progress.
- IDE's Board of Examiners confirms if the student is allowed to start the Graduation Project.

USE ADOBE ACROBAT READER TO OPEN, EDIT AND SAVE THIS DOCUMENT

Download again and reopen in case you tried other software, such as Preview (Mac) or a webbrowser.

STUDENT DATA & MASTER PROGRAMME

Save this form according the format "IDE Master Graduation Project Brief_familyname_firstname_studentnumber_dd-mm-yyyy".
Complete all blue parts of the form and include the approved Project Brief in your Graduation Report as Appendix 1 !

family name: Moonen 6413
initials: A.E. given name: Anne
student number: 4548442
street & no.:
zipcode & city:
country:
phone:
email:

Your master programme (only select the options that apply to you):
IDE master(s): IPD / DfI / SPD
2nd non-IDE master:
individual programme: - - (give date of approval)
honours programme: Honours Programme Master
specialisation / annotation: Medisign / Tech. in Sustainable Design / Entrepeneurship

SUPERVISORY TEAM **

Fill in the required data for the supervisory team members. Please check the instructions on the right !

** chair: J.C. Diehl dept. / section: DfS
** mentor: G.J. Pasman dept. / section: DCC
2nd mentor:
organisation:
city: country:

comments (optional): Dr. Ir. R.M Oosting (Assistant Professor BioMechanical Engineering) will join the team in the roll of a client

Chair should request the IDE Board of Examiners for approval of a non-IDE mentor, including a motivation letter and c.v..

Second mentor only applies in case the assignment is hosted by an external organisation.

Ensure a heterogeneous team. In case you wish to include two team members from the same section, please explain why.

TU Delft

Procedural Checks - IDE Master Graduation

APPROVAL PROJECT BRIEF
To be filled in by the chair of the supervisory team.

chair J.C. Diehl date 03 - 04 - 2022 signature Jan-Carel Diehl Digitally signed by Jan-Carel Diehl Date: 2023.04.03 14:53:05 +02'00'

CHECK STUDY PROGRESS
To be filled in by the SSC E&SA (Shared Service Center, Education & Student Affairs), after approval of the project brief by the Chair.
The study progress will be checked for a 2nd time just before the green light meeting.

Master electives no. of EC accumulated in total: 27 EC

Of which, taking the conditional requirements into account, can be part of the exam programme 27 EC

List of electives obtained before the third semester without approval of the BoE

YES all 1st year master courses passed

NO missing 1st year master courses are:

ID4070 IDE Academy

name Robin den Braber date 12 - 04 - 2023 signature Robin den Braber Digitaal ondertekend door Robin den Braber Datum: 2023.04.12 13:21:30 +02'00'

FORMAL APPROVAL GRADUATION PROJECT
To be filled in by the Board of Examiners of IDE TU Delft. Please check the supervisory team and study the parts of the brief marked **.
Next, please assess, (dis)approve and sign this Project Brief, by using the criteria below.

- Does the project fit within the (MSc)-programme of the student (taking into account, if described, the activities done next to the obligatory MSc specific courses)?
- Is the level of the project challenging enough for a MSc IDE graduating student?
- Is the project expected to be doable within 100 working days/20 weeks ?
- Does the composition of the supervisory team comply with the regulations and fit the assignment ?

Content: APPROVED NOT APPROVED

Procedure: APPROVED NOT APPROVED

- the missing course ID4070 should be finished before the green light meeting

comments

name Monique von Morgen date 17 - 04 - 2023 signature

Initials & Name A.E. Moonen 6413 Student number 4548442

Title of Project A step towards inclusive maintenance management systems in hospitals

Personal Project Brief - IDE Master Graduation

TU Delft

A step towards inclusive maintenance management systems in hospitals — project title

Please state the title of your graduation project (above) and the start date and end date (below). Keep the title compact and simple. Do not use abbreviations. The remainder of this document allows you to define and clarify your graduation project.

start date 13 - 03 - 2023 — 13 - 09 - 2023 end date

INTRODUCTION **

Please describe, the context of your project, and address the main stakeholders (interests) within this context in a concise yet complete manner. Who are involved, what do they value and how do they currently operate within the given context? What are the main opportunities and limitations you are currently aware of (cultural- and social norms, resources (time, money,...), technology, ...).

The project focuses on the interactions with computerized maintenance management system (CMMS) in hospitals in three different contexts. The involved hospitals are INF Green Pastures Hospital (Pokhara, Nepal), MOI Teaching and Referral Hospital (Eldoret, Kenya), and Academisch Ziekenhuis Paramaribo (Paramaribo, Suriname). In these hospitals, various students and professors have been engaged in implementing and improving the CMMS before. As opposed to this work, which was more concentrated on designing and executing a system, my work is going to be more focused on the usability of the system.

The main aim of this project is to contribute to a more inclusive global healthcare system by including local opportunities and limitations in the design of a CMMS. On the other hand, you don't want a CMMS that is excessively tailored to a single context because this limits a supplier's ability to scale up and raises the cost of the final product for the end user. Therefore, the CMMS must be adaptable to address local challenges.

The CMMS is an important factor of a hospital. In the overall healthcare sector, a lot of problems in healthcare service delivery arise because of poor management and upkeep of medical device conditions (Zamzam et al., 2021). The system's complexity is determined by the size of the hospital, type of hospital, location, and resource management. However, the concept of a strong CMMS will be the same for a high-income setting or a rural location in a low-to-middle-income nation. (World Health Organization, 2012) Based on internship reports, during the lifecycle of a device, three main elements occur that must be integrated into the system. Those three elements are inventory, maintenance, and decommissioning. In figure 1, an overview of this stage with its stakeholders and actions is shown.

Especially in the maintenance stage, a lot of interaction happens between the engineers (or technical staff) and the medical staff. Since the fundamental aim of this system is still to improve patient care, it is crucial that the system facilitate effective interaction between the technical staff and the medical personnel. (World Health Organization, 2012) Understanding each stakeholder's needs is crucial to establishing a strong working relationship.

The main stakeholders of this project are:
- TU Delft (Inclusive Global Health lab, R.M. Oosting)
- INF Green Pastures Hospitals (Medical staff & technical staff)
- MOI teaching and referral Hospital (Medical staff & technical staff)
- Academisch Ziekenhuis Paramaribo (Medical staff & technical staff)

Every context has its own organizational culture that will influence the needs, and therefore shape the form of the interaction, of the employees of the hospital.

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Personal Project Brief - IDE Master Graduation

TU Delft

introduction (continued): space for images

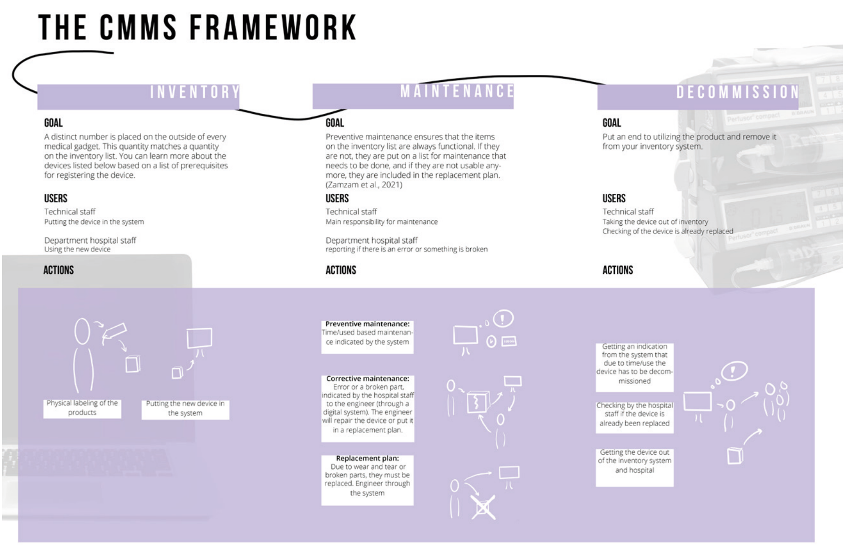


image / figure 1: The CMMS framework

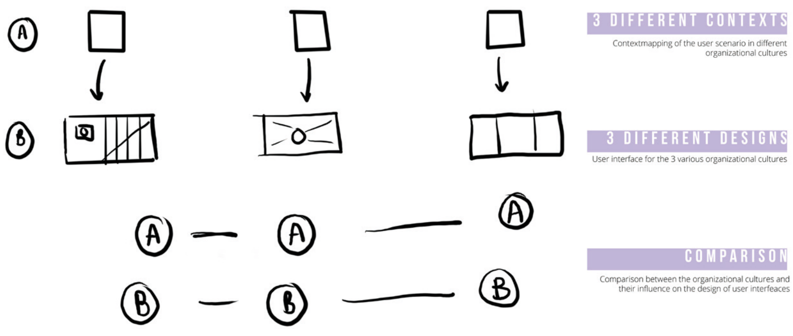


image / figure 2: Approach to the project

Initials & Name A.E. Moonen 6413 Student number 4548442

Title of Project A step towards inclusive maintenance management systems in hospitals

TU Delft

Personal Project Brief - IDE Master Graduation

PROBLEM DEFINITION **

Limit and define the scope and solution space of your project to one that is manageable within one Master Graduation Project of 30 EC (= 20 full time weeks or 100 working days) and clearly indicate what issue(s) should be addressed in this project.

The three hospitals included in this research each have a distinctive organizational culture that affects staff customs and behaviors (Plog, 1976). Organizational culture is "the collective programming of the mind that distinguishes the members of one company from others," according to Hofstede (2010).

We enter an organizational culture when our own values have already taken shape, therefore it is more practice-based than national cultures. (Hofstede 2010). To get insights into this organizational culture the current practices must be mapped out for the framework of the CMMS, which are mentioned in the introduction.

A translation based on these organizational cultures needs to be created to provide a more inclusive CMMS for various contexts. To do this, the distinctions between the three contexts must be established.

The interaction with the system must then be adjusted to reflect these variations to create a more user-friendly system that will aid in the management and maintenance of the current medical devices. It is possible to utilize the mapping of present practices as a starting point for imagining the desired interactions.

Our goal in using this more human-centered design approach for the CMMS is to get knowledge on how to create a user interface that is intuitive for various organizational cultures. A visualization of this approach is shown in figure 2

ASSIGNMENT **

State in 2 or 3 sentences what you are going to research, design, create and / or generate, that will solve (part of) the issue(s) pointed out in "problem definition". Then illustrate this assignment by indicating what kind of solution you expect and / or aim to deliver, for instance: a product, a product-service combination, a strategy illustrated through product or product-service combination ideas, ... In case of a Specialisation and/or Annotation, make sure the assignment reflects this/these.

In order to have a beneficial impact on the administration and maintenance of medical equipment, the project's goal is to adapt a CMMS based on preferable user interactions between medical and technical staff with the system adaptable to an organizational culture

What I am expected to deliver…

A concept interface design. The concept will illustrate how user experience changes the look and feel of the product and empowers users in their day-to-day use in their organizational culture. The interface should be intuitive and not require elaborate training to use the system.

The technical and medical staff will employ the design, which will be concentrated on the procedures taking place within the CMMS framework figure 1

The differences in organizational cultures and how those differences are translated into the user interface are clearly correlated in the design.

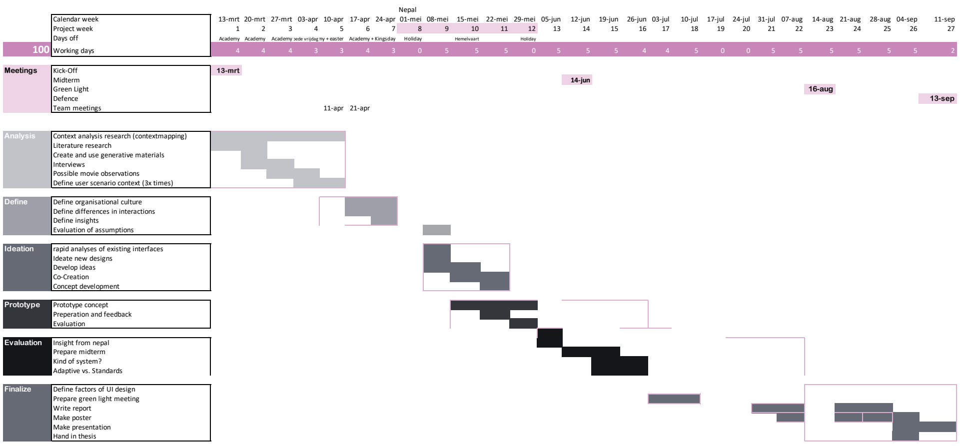
TU Delft

Personal Project Brief - IDE Master Graduation

PLANNING AND APPROACH **

Include a Gantt Chart (replace the example below - more examples can be found in Manual 2) that shows the different phases of your project, deliverables you have in mind, meetings, and how you plan to spend your time. Please note that all activities should fit within the given net time of 30 EC = 20 full time weeks or 100 working days, and your planning should include a kick-off meeting, mid-term meeting, green light meeting and graduation ceremony. Illustrate your Gantt Chart by, for instance, explaining your approach, and please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any, for instance because of holidays or parallel activities.

start date 13 - 3 - 2023 | 13 - 9 - 2023 end date



The approach of this project will begin with an analyzing phase. This will be focused on human-centered research using context mapping. The most important things to get clear are the user scenario and the different stakeholders involved for these 3 contexts and the organizational culture that surround this.

For this purpose, I will do a literature study that combines different forms of literature such as student reports that have worked before in this setting. To provide a comprehensive overview and insightful information, the study will also be expanded with interviews with personnel who operate in these contexts.
This analyzing phase will form the base for the ideation and prototyping phase. In the define phase, I will create this base by highlighting the key insight of the analyzing phase.

I want to present a plausible mock-up of the concept to maximize the concept's validity. In one of the scenarios, presumably Nepal, I want to use the prototype to test the insight and assumptions I made.. The mock-up needs to be as accurate as it can be without jeopardizing hospital patients. I scheduled a few free days in Nepal around the week of evaluation so that I could explore the region and have some extra time for unforeseen circumstances.

On a practical note, I must complete my last course: IDE Academy while working on this project. Five of my Wednesdays will be consumed by this. You never know if you're going to receive the workshop you're applying for, so I took 8 Wednesdays out of the schedule just to be safe.
In this time span, a lot of public holidays will be taken place which lowers the number of workdays that you will see in the schedule.

Initials & Name A.E. Moonen 6413 Student number 4548442

Title of Project A step towards inclusive maintenance management systems in hospitals

Personal Project Brief - IDE Master Graduation

TU Delft

MOTIVATION AND PERSONAL AMBITIONS

Explain why you set up this project, what competences you want to prove and learn. For example: acquired competences from your MSc programme, the elective semester, extra-curricular activities (etc.) and point out the competences you have yet developed. Optionally, describe which personal learning ambitions you explicitly want to address in this project, on top of the learning objectives of the Graduation Project, such as: in depth knowledge a on specific subject, broadening your competences or experimenting with a specific tool and/or methodology, ... Stick to no more than five ambitions.

In shaping my graduation project, I wanted to challenge myself to design human-centered where the target audience is further away from me. Projects during my masters frequently centered on users who I could readily relate to and design for. It appeals to me in this project that I can't do exactly that and must instead learn about the context through user testing and interviews, and then critically evaluate the insights you obtain in the process.

Together with challenging myself, the Inclusive Global Health Lab's mission appeals to me. ensuring greater access to healthcare for people in the Global South. Instead of transferring everything that has been designed up in the West to these regions, delve into their challenges to find a more inclusive solution. A technique that, in my opinion, is significantly more sustainable than simply allocating resources.

During my master's program, I discovered that I enjoy creating and testing interfaces the most. I consequently also want to focus on developing mock-ups and user testing them in the project.
The task is challenging because I have to be mindful to scope early in the CMMS at the interaction level and provide a detailed illustration of the translation between these various contexts.

The biggest pitfalls for me personally include explaining my decisions and weaving a logical narrative out of them in a report. Writing is more frequently a pitfall since I find it difficult to be clear in what I want to express on paper.

While examining a concept, I also perceive real challenges. When can you genuinely state that something is supported by science, and when do you start drawing conclusions too quickly?

I want to proactively focus on the 2 attention points above throughout the project

FINAL COMMENTS

In case your project brief needs final comments, please add any information you think is relevant.

HREC APPROVAL

Date 26-May-2023
Contact person Grace van Arkel, Policy Advisor Academic Integrity
E-mail

Human Research Ethics Committee TU Delft
(http://hrec.tudelft.nl)

Visiting address
Jaffalaan 5 (building 31)
2628 BX Delft

Postal address
P.O. Box 5015 2600 GA Delft
The Netherlands

Ethics Approval Application: A step towards inclusive maintenance management systems in hospital
Applicant: Moonen, Anne

Dear Anne Moonen,

It is a pleasure to inform you that your application mentioned above has been approved.

Thanks very much for your submission to the HREC which has been conditionally approved. Please note that this approval is subject to your ensuring that the following condition/s is/are fulfilled:
(i) risks regarding non-EU countries are sufficiently reflected on, like the risk of experiencing consequences of your opinions

"In addition to any specific conditions or notes, the HREC provides the following standard advice to all applicants:
• In light of recent tax changes, we advise that you confirm any proposed remuneration of research subjects with your faculty contract manager before going ahead.
• Please make sure when you carry out your research that you confirm contemporary covid protocols with your faculty HSE advisor, and that ongoing covid risks and precautions are flagged in the informed consent - with particular attention to this where there are physically vulnerable (eg: elderly or with underlying conditions) participants involved.
• Our default advice is not to publish transcripts or transcript summaries, but to retain these privately for specific purposes/checking; and if they are to be made public then only if fully anonymised and the transcript/summary itself approved by participants for specific purpose.
• Where there are collaborating (including funding) partners, appropriate formal agreements including clarity on responsibilities, including data ownership, responsibilities and access, should be in place and that relevant aspects of such agreements (such as access to raw or other data) are clear in the Informed Consent."

Good luck with your research!

Sincerely,

Dr. Ir. U. Pesch
Chair HREC
Faculty of Technology, Policy and Management

APPENDIX

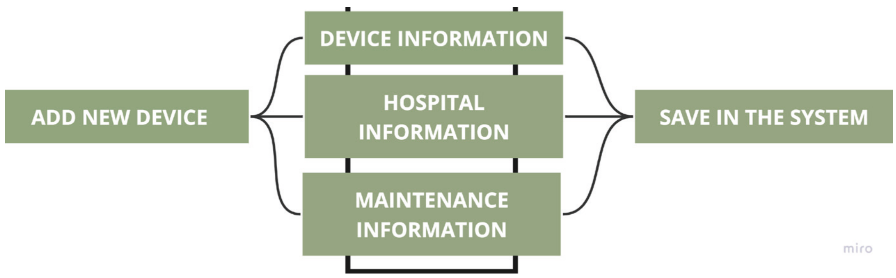
1. PROCESS OVERVIEW
2. GENERATIVE SESSION MATERIAL
3. PROCESS ANALYSIS
4. EQUIPMENT JOURNEY
5. OVERVIEW VALUES

B

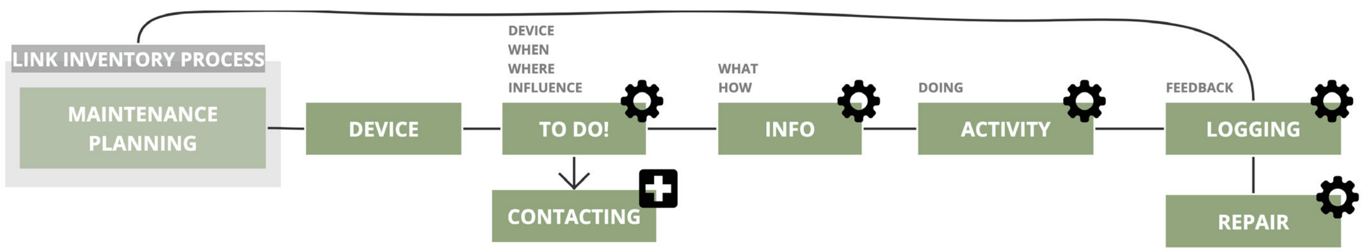
PROCESSES

B.1

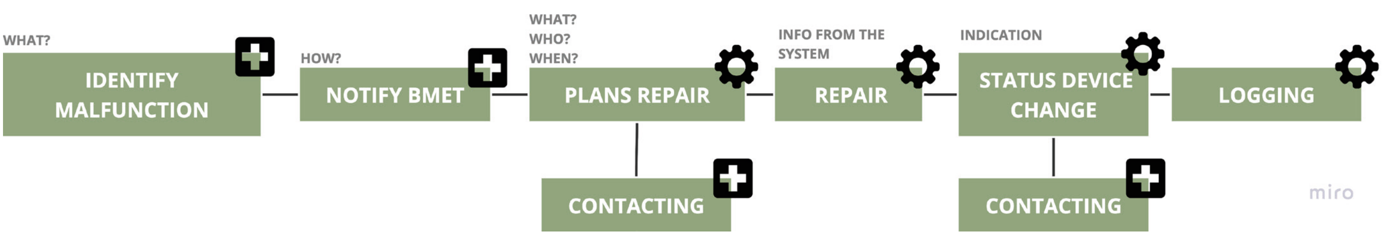
INVENTORY



MAINTENANCE



REPAIR



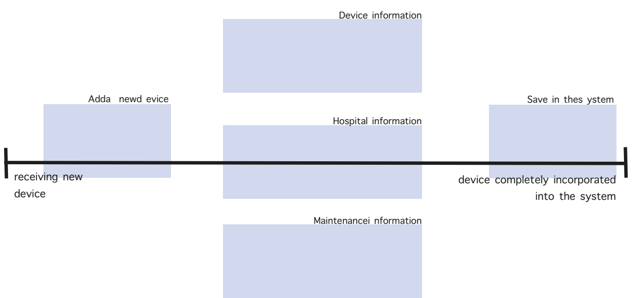
GENERATIVE SESSION MATERIAL

B.2

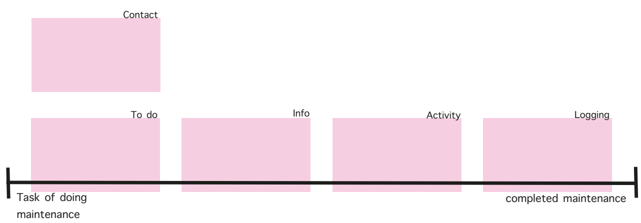
inventory

maintenance

inventory



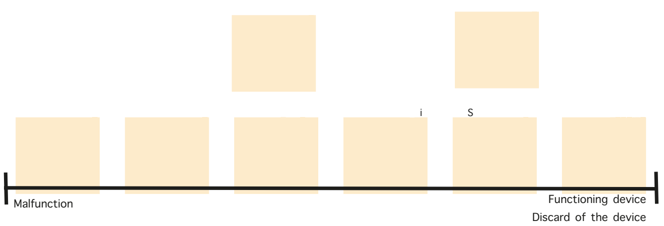
maintenance



repair

Construction year	Manufacturer	Costs
Equipment type	Description of device	Value
Status	Model	Function
Asset type	Location	Serial number
Ownership	Responsible engineer	Warranty period
Department	Maintenance type	Maintenance schedules
Section	Maintenance interval	Priority
Deadline date	Description of error	Control value
Asset number	Supplier contacts	Error code
Manual	Availability	Picture of the device
Availability spare parts	Name medical staff	Hospital planning
		Frequency of use

repair



inventory

maintenance

repair

inventory

maintenance

repair

inventory

maintenance

repair

inventory

1.
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maintenance

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repair

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PROCESS ANALYSES

B.3

DUTCH HOSPITAL

The Dutch hospital is a hospital located in Amsterdam the Netherlands. The hospital has no specialist role and focuses mostly on providing basic healthcare. The hospital has 330 beds in total.

The hospital independently bought all of the supplies utilized in the facility. The Ultimo software is a CMMS used by the BMETs at this hospital.

Based on an interview and tour of the this hospital with a BMET, the following findings were obtained:

INVENTORY

Figure B.3.1: process of inventory this hospital

1. ADD A NEW DEVICE One individual alone is responsible for adding a new medical device. A device can never enter the hospital without passing the responsible party because his office is positioned where all items enter. This procedure is also known as the new medical device entrance inspection.

2. INFORMATION The device is entered by the responsible person. In doing so, the following information is entered:

- Location
- Registration number
- Supplier
- Responsible engineer
- Serial number
- Model
- Type
- Purchase value
- Service provider
- Department
- Contract with supplier
- Replacement date
- Order price
- Order number
- Risk score
- Picture

3. LABELLING The device will be labelled with a sticker containing inventory number and barcode.

Barcode we don't actually use" - Dutch BMET

4. TRAINING: Following the information from the manufacturer, training is planned for the medical staff working with the device.

5. DEVICE AT LOCATION: BMET is responsible for installing the device on site.

6. DEVICE IN USE

MAINTENANCE

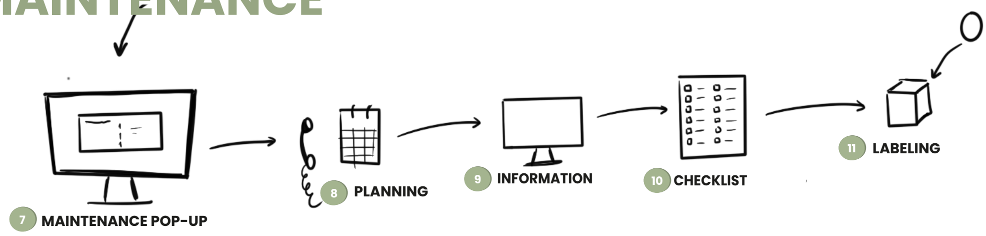


Figure B.3.2: process of maintenance in this hospital

7. MAINTENANCE POP-UP The system displays the tasks that need to be performed in a certain month. Everything in the hospital kicks off on the first of the month, and then the BMETs are free to arrange their own maintenance schedule for the remainder of that month

> "You create a work order for one month per device. When you've completed that, Ultimo sets this up again for the next one and it pops up again automatically." - Dutch BMET

> "Everything is on the first of the month and then you have the entire month to sort that out, you can't specify a month in the system but a day which is a bit dull." - Dutch BMET

8. PLANNING The BMETs create a work order and make calls to the departments for scheduling maintenance.

> "If you need to do maintenance in January you call the department to schedule it. In some departments this is more difficult than others." - Dutch BMET

> ""In the OR, they start operating at 7 and often go on until 6 so that is often a bit of a fit. But actually it's often down to the individual staff who make it harder or easier." - Dutch BMET

9. INFORMATION Quick look at the device to know the location and download the checklist for maintenance.

10. CHECKLIST The checklist is taken from another system. This outlines the steps required for medical equipment maintenance. These steps are run through by the BMET. Should there be anything anomalous here, it is specified as a repair job in the system.

> "These protocols are often created using a manual and shared with 24 other hospitals." - Dutch BMET

11. LABELLING After successful completion of the checklist, the device is given a service sticker with the month and year of the last maintenance check. After this, it should be indicated in the system that maintenance was carried out according to the protocol

Figure 12: Maintenance sticker

REPAIR

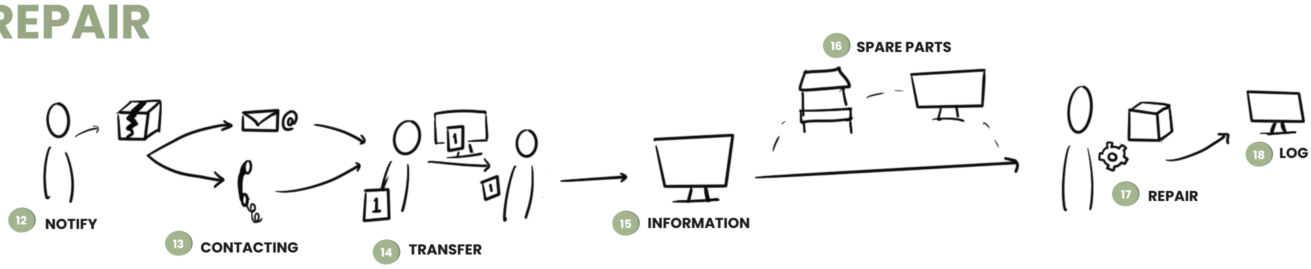


Figure B.3.3: process of repair in this hospital

12. NOTIFY By medical staff or in the maintenance process (skip step 13 and 14).

13. CONTACTING When a malfunction occurs, a call is immediately made, an e-mail is sent or a job is immediately created in ultimo. The service desk creates a job immediately. In case of a phone call, this is done by the BMET itself.

> "Calling or malfunction reporting via mail/Ultimo happens 50/50. Often when reporting it says it's broken or doesn't work." - Dutch BMET

.

14. TRANSFER The malfunction report must be created by the BMET in Ultimo if it has not already been done by another department.

> "By creating the Job, there is immediately a hook for making a log." -Dutch BMET

15. INFORMATION The BMET researches the device's specifications, including how it appears and any problems that have occurred.

> "When you get a call, it's nice to have a quick look in the system to see exactly which device it's about." -Dutch BMET

> "When malfunctions occur, there is always stress, which is why it is very useful to be able to quickly find device information." -Dutch BMET

16. SPARE PARTS The BMET can check the system to see whether the device has any available spare parts. A modest warehouse within the hospital is primarily filled with spare parts for high-risk equipment. The department can at times be able to borrow full devices from this warehouse.

> "We don't have a very large warehouse but some parts you don't want to wait for delivery time so we stock those. Mainly for high-risk devices."
> -Dutch BMET

17. REPAIR Activity of repairing or waiting. If there are not the right materials, they are ordered and the job remains open in the system. In some cases, there are also devices that may only be repaired by the manufacturer.

18. LOG To close the job, it is necessary to indicate exactly what has been repaired and close the job card. This automatically names who solved the malfunction.

INF GREEN PASTURES HOSPITAL AND REHABILITATION CENTRE

Nepal's Pokhara is home to the INF green pastures hospital and rehabilitation centre Hospital. Pokhara, with a population of about 265000, is the second-largest city in Nepal. Leprosy patients were the focus of the hospital's creation 60 years ago. The hospital has recently grown and, in addition to providing basic treatment, now focuses substantially on spinal cord injury rehabilitation, reconstructive procedures, palliative care, and has an entirely dedicated ear centre. The hospital has 40 beds and sees roughly 11,000 patients a year.

The hospital can either buy its own medical supplies from a Nepalese provider, but it also receives a lot of donated supplies.

CMMS system is now being used by the hospital. There are currently 2 BMETs on the team.
The following results are based on an interview and tour with a BMET from INF Green Pasture Hospital:

INVENTORY

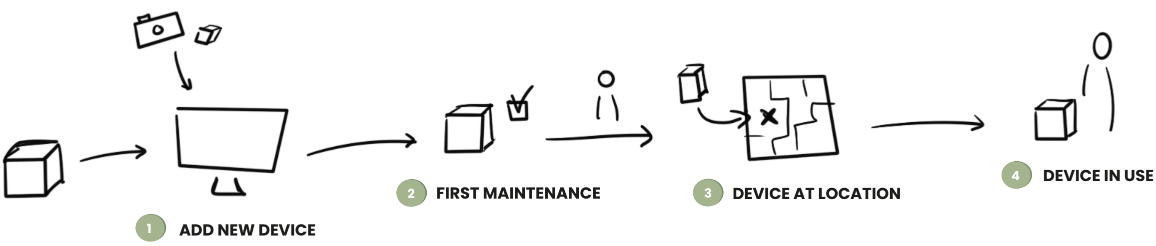


Figure B.3.4: process of inventory INF Green Pasture Hospital

1. ADD A NEW DEVICE The various information entered at this stage:

- Serial number
- Picture
- Title
- Device model
- Location (Department)
- Device type
- Manufacturer
- Application risk
- Maintenance type
- Maintenance interval (based on risk factors)
- Inventory number
- Year of construction
- Purchase price (only with warranty)
- Supplier contacts
- Status (operational, partly working or out-order)

> ". So in the beginning we have defined the risk. I would love that to be in the system. We do it now outside The system in an Excel. For different devices we have determined the risk with some kind of formula. Based on when it is used, what kind of device it is and what is the requirement of the device. And then the risk translates to a maintenance interva.l"
> - BMET 2 INF Green Pasture Hospital

2. FIRST MAINTENANCE An excel file that will serve as a checklist is created based on the manual. The BMET will verify the device once by going through the maintenance checklist prior to installing it at the ward.

> "After new device comes, we normally do the PPM and on the same day we add it as a due date." -BMET 1 INF Green Pasture Hospital

3.DEVICE AT LOCATION The device is brought to the ward. The explanation of how to use the device is now often given by the BMET should it be necessary.

3.DEVICE AT LOCATION The device is brought to the ward. The explanation of how to use the device is now often given by the BMET should it be necessary.

> "Because some things are straightforward, they don't need training, they are self explanatory. Some instructions can be done by users. For others it should be the actual, there representative of the manufacturer. But that's very tricky in Nepal. So that might be up to us in the end as well, yeah. But it indicates the risk of the complexity of the device."
> - BMET 2 INF Green Pasture Hospital

4. DEVICE IN USE

Figure B.3.7: Showing researcher how to upload picture in the system

MAINTENANCE

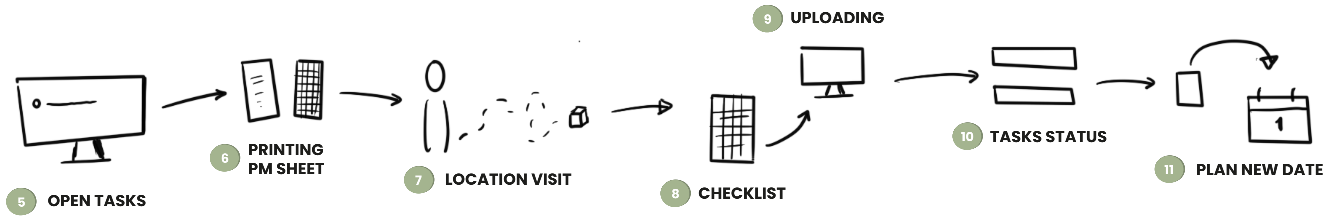


Figure B.3.5: process of maintenance INF Green Pasture Hospital

5. OPEN TASK The maintenance event (task) that needs to be completed is displayed on the overview screen. Based on the interval that is set for each device. There is a list of maintenance and repair duties under "device-tasks." The BMET selected a single assignment.

6. PRINTING PM SHEET Every device has a excel sheet with a maintenance checklist. This checklist is printed.

7. LOCATION VISIT To check if the equipment is available, the BMET visits the ward. If this is not the case, another device is frequently sought out and considered for maintenance.

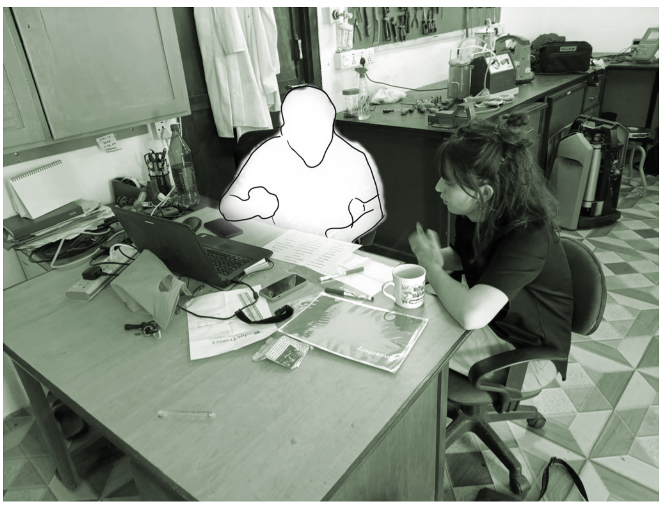


Figure B.3.6: Discussing the most important information used in the processes

8. CHECKLIST The BMET is completing the device-specific checklist, and writing down any disruptions.

9. UPLOADING A second scan and upload of the checklist adds it to the job.

> "And every time we have to do maintenance and we have to download that file again and again add it and upload it again - BMET Green pasture"

10.TASK STATUS The task's state changes to done from new/to-do.

11. PLAN NEW DATE Before completing the task, a new due date is scheduled for the next maintenance moment. This depends on the maintenance interval determined in the inventory.

REPAIR

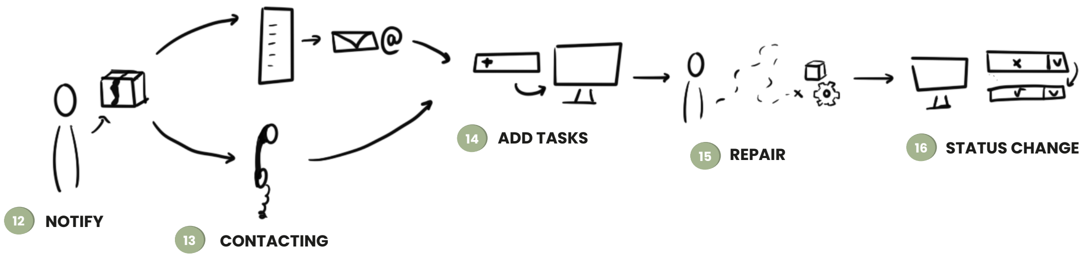


Figure B.3.8: process of repair INF Green Pasture Hospital

12. NOTIFY By medical staff or in the maintenance process (skip step 13).

13. CONTACTING The medical staff usually calls the BMETs. Another possibility is to fill in a form prepared by the BMETs to get a better idea of the severity of the malfunction.

"At the moment it is a little bit difficult (for other staff members) to get to the page and then record the problem. Then you have to do it in this app and it's more complicated. So I think I will wait until we have the QR-stickers on every device. " -BMET 2 INF Green Pasture Hospital

"Repair form or something. That they have to fill in along with the information. What is the problem and is it an emergency or not? We have that details in that form. But they are not filling that form."
- BMET 1 INF Green Pasture Hospital

"Sometimes I do not prefer them because they are not problem specific. This is that just this is not working and we have to do it again. E-mail them or phone them that what was the problem. So we have that one form where they have complete information, is it an emergency or not? What is the problem? When was the issue that happens? We have that form. So the forms give clear information for us as well." -BMET 1 INF Green Pasture Hospital

14. ADD TASKS Searching the device and generating the task in the system. The BMET must first inspect the location to determine exactly what needs to be repaired because descriptions are sometimes unclear. If this is unclear, the task's name frequently changes to "something is broken." The device's state in this instance is non-operational. Here, it frequently also considers the history of repairs made to the medical device.

15. REPAIR Repair the device. If parts are needed, find out where they can be obtained from. This is also where we often consider whether the cost of repairing.

16. STATUS CHANGE The task must be closed after repair. The two options in this are completed and pending. After that, manually set the device's state to operational or partially functional.

"But I think after repair, by default they should say now it's fully operational. And only if you know it's not fully operational then they should choose to do limited instead of now it is, they don't change it "
-BMET 2 Green pasture

Figure 19: Place to repair medical devices in INF Green Pasture Hospital

UNITED MISSION HOSPITAL TANSEN

The United Mission Hospital Tansen is situated in Tansen. There are roughly 32,000 people living in Tansen. The hospital serves a population of almost one million people because many patients travel from adjacent places. 11000 inpatient admissions and 89000 outpatient visits are handled annually by the facility. The medical centre has 169 beds. The hospital provides a range of surgical procedures, maternity care, dental care, counselling, and patient testing and treatment for TB, HIV, and leprosy.

Although the hospital is increasingly considering purchasing its own, a lot of medical equipment is donated. As a result, the hospital's inventory is a mix of donated and privately acquired items.

Four individuals make up the biomedical team, each of whom has a specific area of specialty. The hospital use a custom-built system they refer to as "the dashboard"

The following results are based on an interview, 4-day observation and a tour with a BMET from United Mission Hospital Tansen.

Figure B.3.9: Spare parts corner at United Mission Hospital Tansen

INVENTORY

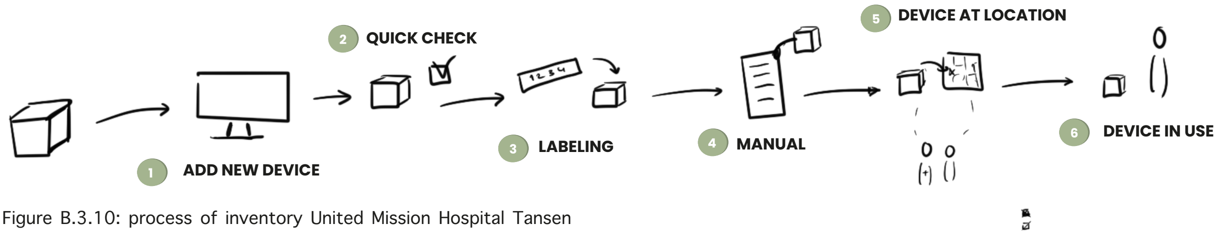


Figure B.3.10: process of inventory United Mission Hospital Tansen

1. ADD NEW DEVICE The information added in this stage:

- The supplier
- Manufacturer
- Owning department
- Location
- Serial number
- Working status (working, partially working and not working)
- Active status (active, inactive)
- Manual

> "Minimally we put the user manual in the system, but the service manual is way more valuable for our part." - BMET United Mission Hospital Tansen"

2. QUICK CHECK The device is turned on, and its functionality is examined.

3. LABELLING The system generates a unique asset number. The BMET prints a number sticker on a Dymo label printer and places it on each asset.

> "To tag it we use a dymo label printer, old fashioned but really handy to put on the number of the device." - BMET United Mission Hospital Tansen

4. MANUAL Where possible, a printed manual will be included with the devices in addition to them. On the basis of the manual, a maintenance checklist is also created. The basis for choosing equipment maintenance tests is also provided by this checklist. Standard tests are pre-programmed in the system to connect to the devices.

5. DEVICE AT LOCATION The device is brought to the site. Here, a brief explanation of the device is often done by the BMET to the head of the department. The head of the department takes responsibility for explaining this in some situations

6. DEVICE IN USE

Figure B.3.11: Inventory numb□r on lamp

MAINTENANCE

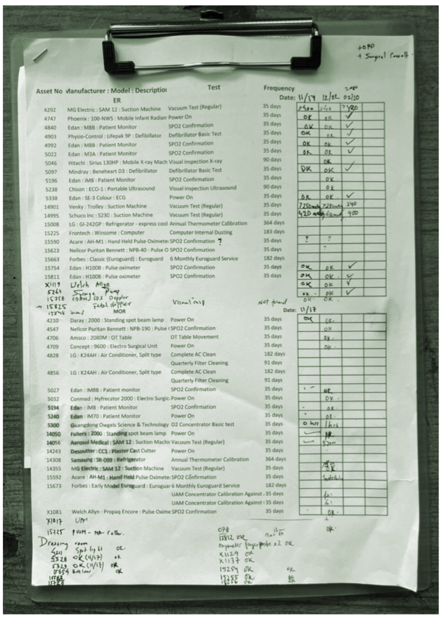
Figure B.3.12: process of maintenance United Mission Hospital Tansen

7. ONE DAY Every Wednesday, the hospital is open for emergencies only. This is where the BMETs hold their technical rounds. These technical rounds are meant to do maintenance and repairs where possible.

8. ONE DEPARTMENT The hospital has divided the wards into five categories. Every week, a different category is up for review.

9. CHECKLIST For each category, there is a paper checklist to be taken to the ward.

> "Test sets documents are mostly formed by the user manual of the devices." -BMET United Mission Hospital Tansen



25: Maintenance checklist at United Mission Hospital Tansen

Figure B.3.13: Technical rounds at United Mission Hospital Tansen Emergency room

10.LOCATION VISIT The team goes to the site taking 1 laptop with them to enter test results right away and make adjustments to the system where necessary.

11. ROUNDS During the rounds, all devices in the room are finished evenly by means of the paper checklist. In addition, missing devices are searched for and additional devices are returned to their proper locations.

12. PASS/FAIL The devices can only get pass or fail for the maintenance tests. These are translated from the paper to the computer. In case of a pass, a new test is automatically created for 35 days from now.

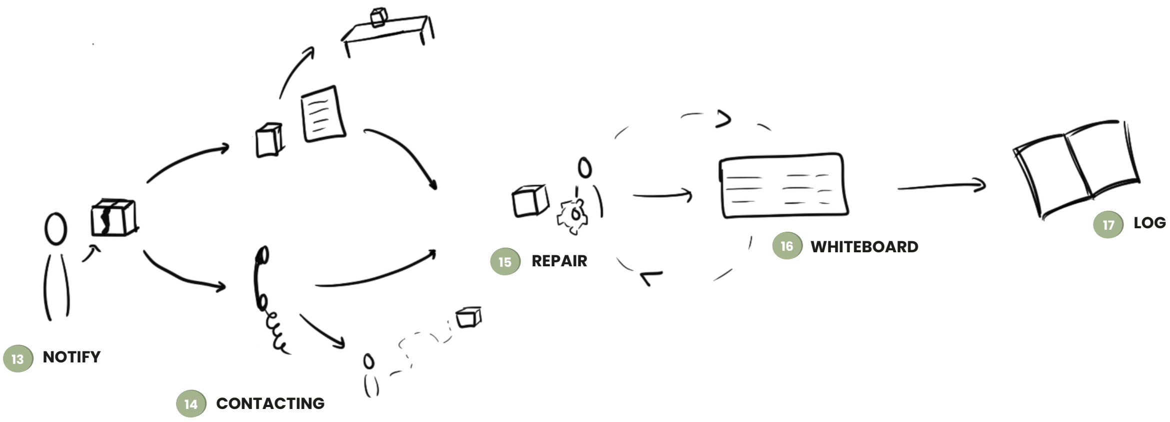


Figure B.3.14: process of repair United Mission Hospital Tansen

13. NOTIFY By medical staff or in the maintenance process (skip step 13).

14. CONTACTING The majority of communication is over the phone, and medical staff frequently brings small devices with them along with a job note.

> "Take the broken devices with us and put it on a desk, otherwise it would take long to repair it." - BMET United Mission Hospital Tansen"

> "Almost every broken device has a note (job request) with it , system is also used for other departments." - BMET United Mission Hospital Tansen"

15. REPAIR Except for large appliances, which are produced on site, everything is repaired at the office. There are frequently few spare components available for repairs, hence they are frequently removed from older appliances.

> "For expensive and high risk equipment we try to get spare parts as soon we put it in the inventory system, often with donated equipment it is hard."- BMET United Mission Hospital Tansen

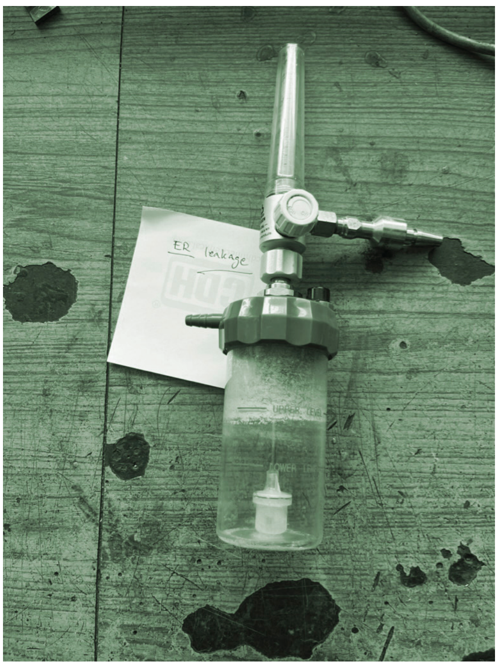


Figure B.3.15: Product that needed repairing after technical rounds United Mission Hospital Tansen

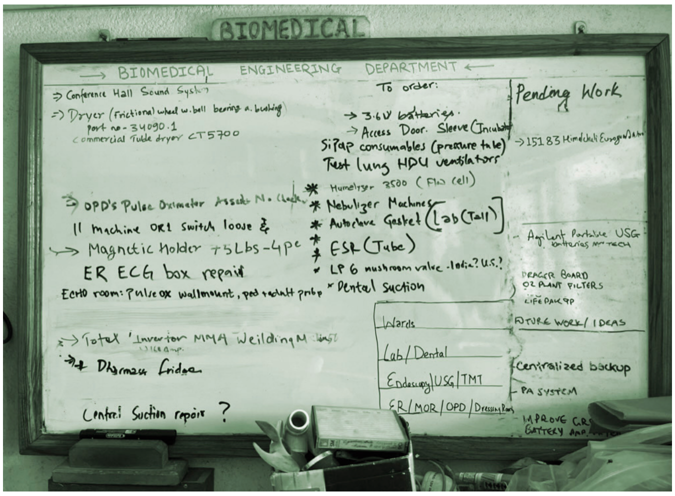


Figure B.3.16: Whiteboard used for logging repairs

16. WHITEBOARD It is noted on the whiteboard when a device is too large to bring into the office or cannot be repaired all at once. Appliances that require repair but are awaiting parts are located next to it. On the whiteboard to the right are the parts that still need to be ordered.

> "For repairs the whiteboard is the most useful tool, otherwise I have to be really strict on that everything has to be recorded inside the system but I don't see the real plus value of that". -BMET United Mission Hospital Tansen

17. LOG The BMETs log how many hours they spent repairing each device in a paper book. This is mainly used for hospital management..

INVENTORY

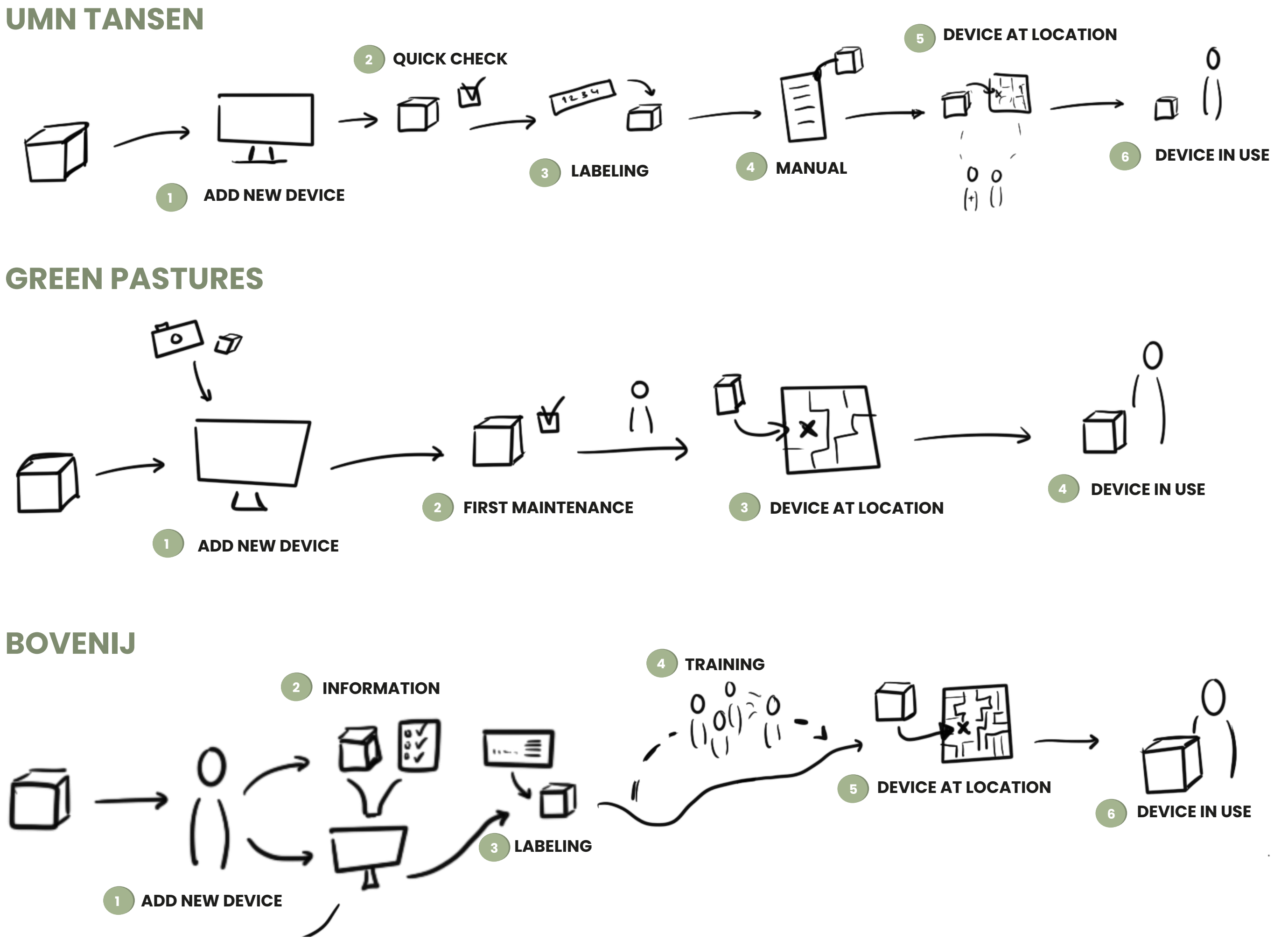


Figure B.3.17: overview process of inventory

DIFFERENCES

AMOUNT OF INFORMATION

The amount of information and kind of information when adding a device varies from hospital to hospital:

- Dutch Hospital: 16
- INF Green Pasture Hospital: 15
- United Mission Hospital Tansen: 7

RISK ASSESSMENT

- Dutch Hospital: Using a sheet to calculate the risk. Assessing the score based on experience and putting it into the CMMS.

> "With higher risk, you handle the device differently. You do maintenance more often and run faster when there is a defect." -Dutch BMET Hospital

- Green pasture: A excel sheet based risk analysis
- United Mission Hospital Tansen: no risk assessment

> "We are not really looking into which is a critical device for us and what is not." -BMET United Mission Hospital Tansen

SIMILARITIES

DOCUMENTS

Inventories frequently demand that a device have at least a digital manual. This manual is frequently used as a reference guide for maintenance and repairs.

LABELLING

Only at Green pasture Hospital is this not currently done; however, there are plans to do so in the future, therefore labelling the devices might be considered as similar.

MAINTENANCE

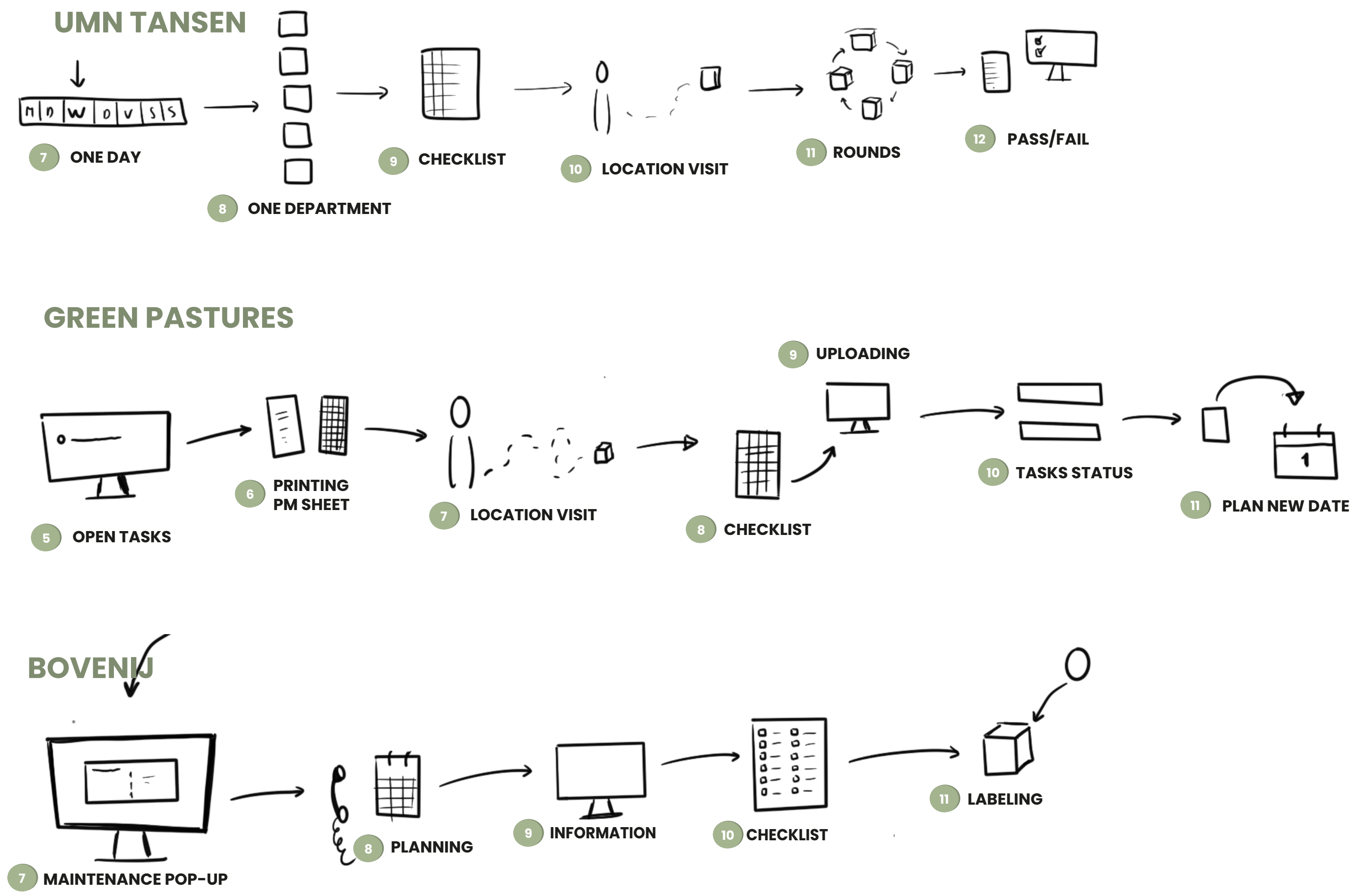


Figure B.3.18: overview process of maintenance

DIFFERENCES

WORKLOAD OVERVIEW

The workload can only be seen clearly in a visual summary at the hospital in the Netherlands.

MAINTENANCE INTERVAL

Interval for maintenance varies greatly per location

- Dutch Hospital: 1-3 year
- Green Pasture: 3-12 months
- United Mission Hospital Tansen: 35 days

LABELLING

Physical labelling of the maintenance is only done in the hospital in the Netherlands.

CONTACT DEPARTMENTS

Actually, only the hospital in the Netherlands performs scheduling, verifying to see if the device is now available, and informing the departments in advance.

SIMILARITIES

APPROACH BY DEPARTMENT

Although in all systems maintenance is indicated by device, the performance of maintenance is classified by the department so as not to interfere with care.

MAINTENANCE CHECKLIST

All hospitals work with a non-integrated maintenance checklist

Figure B.3.19: Maintenance to a suction machine in the ER United Mission Hospital Tansen

REPAIR

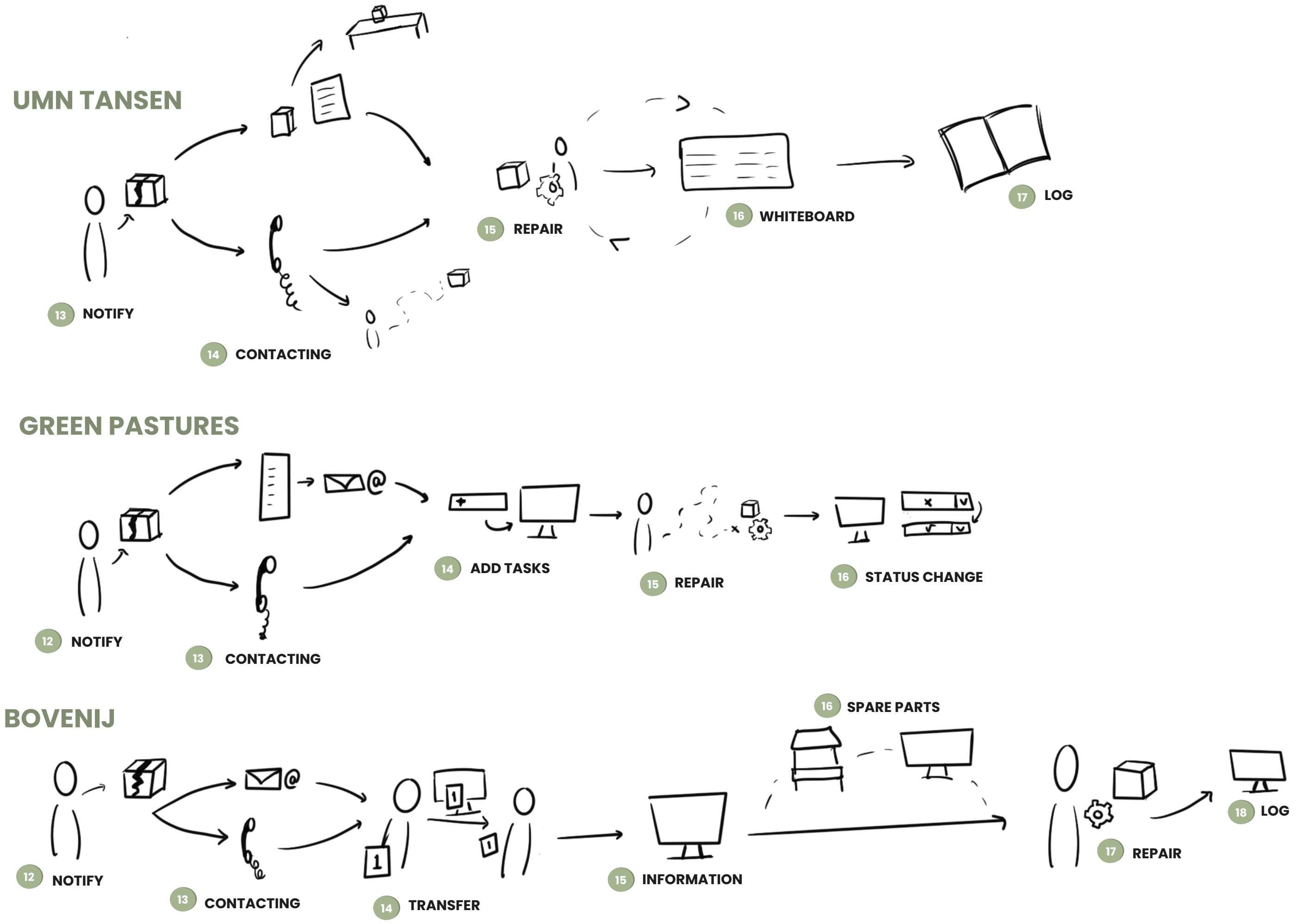


Figure B.3.20: overview process of repair

DIFFERENCES

TASK CREATION

A task is first created in the system at in the Dutch Hospital & Green Pastures. In United Mission Hospital Tansen, the whiteboard serves as the primary information source during the repair phase instead of the system.

RESPONSIBLE BMET

At the hospital in the Netherlands repair is specifically assigned to a BMET, often based on experience.

PARTIALLY FUNCTIONING

Devices may resume partial functioning in United Mission Hospital Tansen and INF Green Pasture Hospital. This is noted in the system to prevent future occurrences of these being overlooked for repairs.

> "Manage to repair a little bit but not fully. So instead of not working, it might be working again, but not, yeah, you want to repair it. So in that case here we still can use it in the West, something that is not fully comfortable, you can never put into the hospital."
> - BMET2 Green pasture

DEVICE HISTORY

Only at the hospital in the Netherlands is it explicitly attempted to look back on a device's past.

> We are not really looking into which is critical device for us and what is not." -BMET United Mission Hospital Tansen

SIMILARITIES

COMMUNICATION

Most interactions take place over the phone in all hospitals. The preferred approach for all BMETs is similar.

REPAIR REQUEST

When relaying repair requests, doctors and nurses at all 3 organizations were not sufficiently detailed. They frequently struggle to pinpoint precisely what is wrong with the device. Most of the time, "it doesn't work" serves as the summary.

EQUIPMENT JOURNEY

B.4

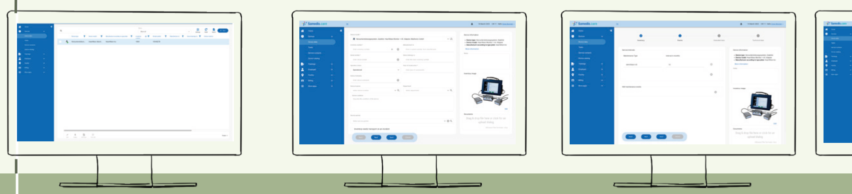
B.4

INVE

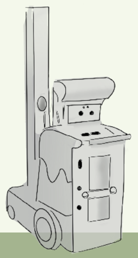
DONATION FROM A DOCTOR
Receiving the device and collecting information from the doctor

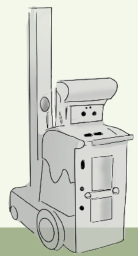
FIRST USE - TESTING
Testing the basic funcitionalities of the device

ADD NEW DEVICE IN THE SYSTEM
Adding the necessary information into the CMMS



ADD NEW DEVICE IN THE SYSTEM
Following a linear process with mandatory information fields





PURCHASED DEVICE
Receiving the device from a supplier

FIRST USE - TESTING
Testing the basic funcitionalities of the device

ADD NEW DEVICE IN THE SYSTEM
Adding the necessary information into the CMMS

DONATION

With donation, a lot of information about the device's history is often lost. In addition, many devices that are donated are often already out of production. Which makes receiving spare parts very difficult.

BASIC INFORMATION

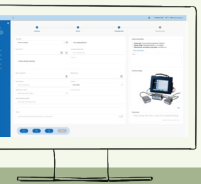
Upon completion, there is an overload of information that is mandatory to fill in. In doing so, some of it is never used again and other headings are not clear what they are used for.

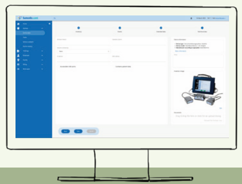
KNOWLEDGE GAPS AND CONCERS

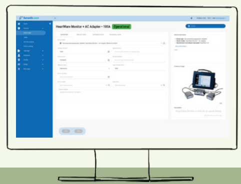
NTORY

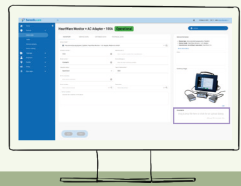
PUTTING A LABEL ON THE DEVICE
Every device has his own unique asset number

FINDING MANUALS
Looking online for manuals

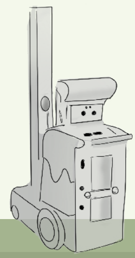








COLLECTING MANUALS
Downloading manuals from the internet and uploading them in the system

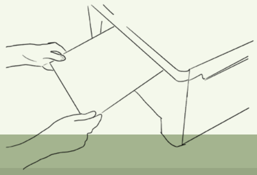


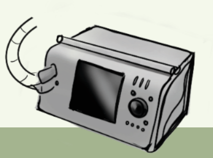
PUTTING A LABEL ON THE DEVICE
Every device has his own unique asset number

FINDING MANUALS
Looking online for manuals

COLLECTING MANUALS

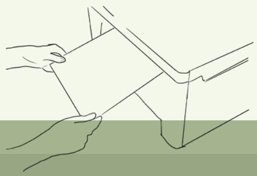
The BMETs collect appliance manuals and turn them into a maintenance checklist. These are looked up on the internet and loaded into the system. These end up in 1 big pile of documents where you cannot change the name.

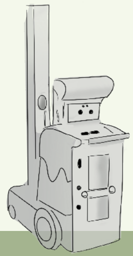




PRINTING A PHYSICAL MANUAL
To put beside the device

DEVICE IN USE
The device is installed in the department





PRINTING A PHYSICAL MANUAL
To put beside the device

INFORMATION MEETING
Explaination on how to use the device

DEVICE IN USE
The device is installed in the department

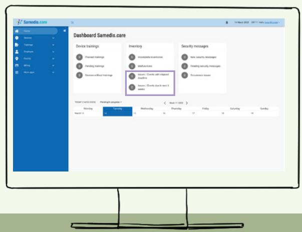
INFORMATION MEETING

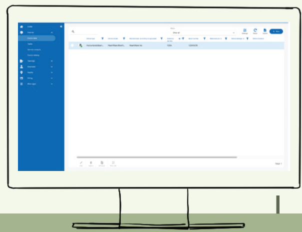
For devices, there is no set protocol on whether medical staff should receive training before they start working with a device. This is now sensitively assessed and explanations are then given by a doctor or hospital BMET.

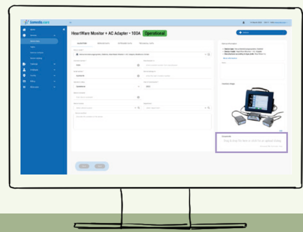
MAINTENANCE

CHECKING MAINTENANCE JOBS

Looking at the overview dashboard







MAINTENANCE OVERVIEW

Clicking on the number and searching for the device that has to have maintenance

CHECKING MAINTENANCE JOBS

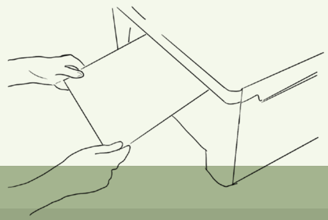
Looking at the overview dashboard

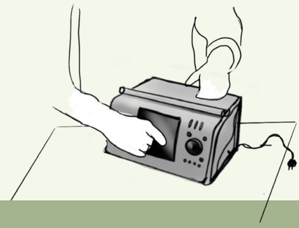
MAINTENANCE NUMBER

The dashboard often only shows a number and does not indicate which device it is and how long it needs to be serviced.

Missing information

KNOWLEDGE GAPS AND CONCERS



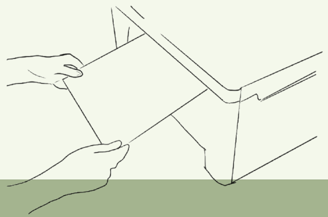
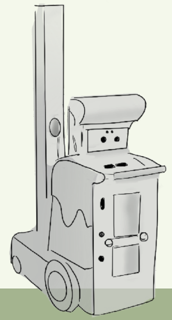
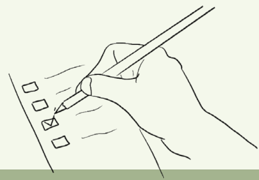



PRINTING MAINTENANCE LIST
Printing a manual checklist for the maintenance tasks.

SEARCHING THE DEVICE
Checking the device on location if it is available for maintenance

DOING MAINTENANCE
Perform the tasks as described in the checklist

CHECKING THE BOXES
Noting the actions taken

SETTING A DATE FOR MAINTENANCE
Having contact with the department to set up a maintenance appointment

PRINTING MAINTENANCE CHECKLIST
Printing a manual checklist for the maintenance tasks

DOING MAINTENANCE
Perform the tasks as described in the checklist

CHECKING THE BOXES
Noting the actions taken

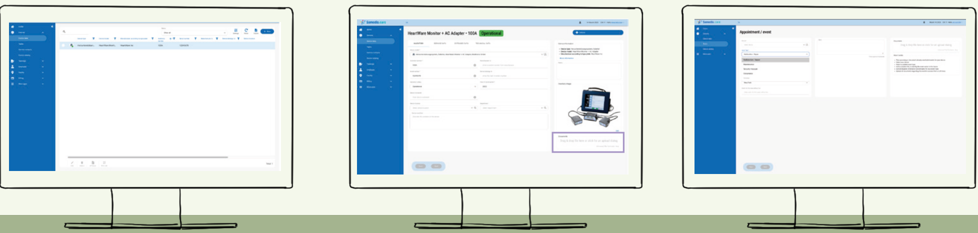
MAINTENANCE APPOINTMENT
Devices that hold up the entire diagnostics and are heavily used cannot be maintained without scheduling an appointment with the department.

MISSING TEST EQUIPMENT
Test equipment for appliances is often not present. For this, the maintenance checklist needs to be adapted to what is possible in local context.

REPAIR?
If something is found during maintenance that needs repair, it is initiated immediately and included in the process of repair.

UTTING THE RESULTS IN THE SYSTEM

he open task should be indicated as completed in the systemr



ROCESS MAINTENANCE ON DEVICE LEVEL

ploading the checklist underneath documents

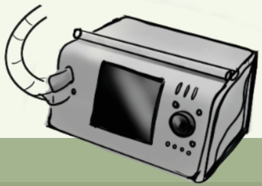
UTTING THE RESULTS IN THE SYSTEM

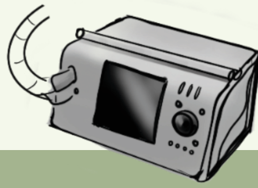
he open task should be indicated as completed in the system

COMPLETING MAINTENANCE

At the end, the completed checklist is uploaded again and the maintenance task has to be ticked off as done via the dashboard separately. This also sets a new date for the next maintenance. 2 different places in the system to log.

B.4



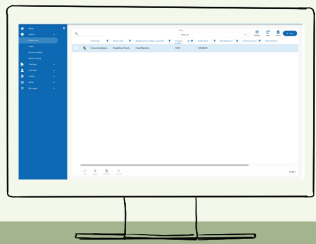


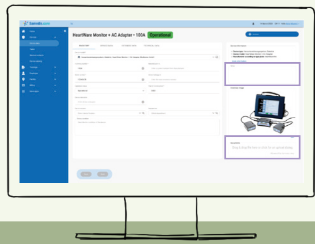
DEVICES IS DROPPED AT THE OFFICE
Finding the malfunction

REPAIRING
Repairing the device on intuition

SEARCHING FOR SPARE PARTS
If necessary, call for possible spare parts

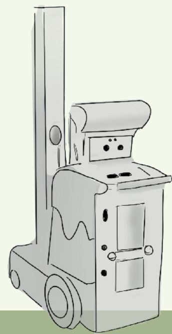
RETURNING THE DEVICE TO
Ensuring that the device gets back to





R

FINDING INFORMATION
Adding the necessary information into the CMMS



GETTING A CALL (MALFUNCTION)
Receiving the device and collecting information from the doctor

CHECKING THE MANUAL
Adding the necessary information into the CMMS

REPAIRING
Testing the basic funcitionalities of the device

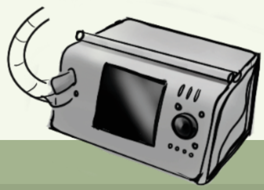
SIZE OF THE DEVICE

Devices that can be worn are always brought to the BMET office. For large appliances, phone calls are made.

LEVEL OF EXPERTISE

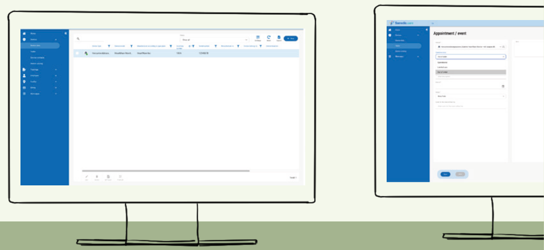
For complexes devices, the manual is consulted. For easier devices, repair is actually done on intuition and the system is not used

KNOWLEDGE GAPS AND CONCERS



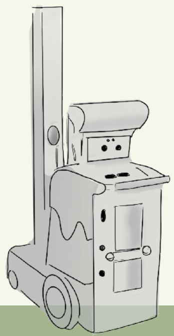
THE DEPARTMENT
o its proper location.

DECLARING THE DEVICE OUT OF ORDER
Indicating in the system that the device can no longer be used at this time



REPAIR

OUT OF ORDER LABEL
Adding the necessary information into the CMMS

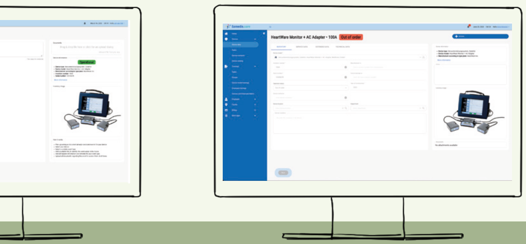


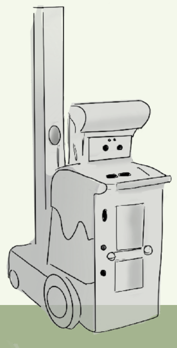
DECLARING THE DEVICE OUT OF ORDER
Indicating in the system that the device can no longer be used at this time

Missing information

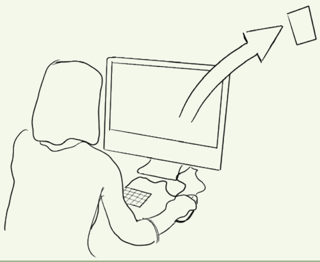
OUT OF ORDER
If a device is too complex to be repaired in 1 go or there is a need to wait for parts, the device is indicated in the system as out of order.

OUT OF ORDER
The device cannot be used until it is repaired



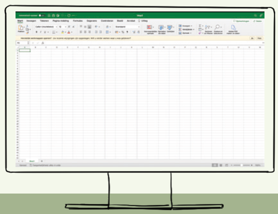


OUT OF ORDER
The device cannot be used until it is repaired

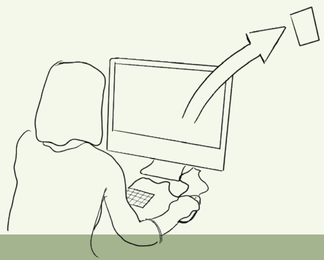


OTHER

EXTRACTING DATA
Data is extracted from the system



TRANSFER TO EXCEL
The data is converted into graphs using Excel to make the data insightful



EXTRACTING DATA
Data is extracted from the system

VISUAL INFORMATION

Data used for choices and planning is displayed in an external programme.

Missing information

KNOWLEDGE GAPS AND CONCERS

OVERVIEW VALUES

ACHIEVEMENT

SUCCESS ACCORDING TO SOCIAL STANDARDS

GETTING THE NUMBER DOWN

- The system should show how much task you completed and still have to do for maintenance and repair.

SELF-DIRECTION -ACTION

FREEDOM TO DETERMINE ONE'S OWN ACTION

PLAN YOUR OWN DAY

- The system should give a to-do list.
- The system should not control the day of a BMET.
- The system should provide task in a suggestive way.

UNIVERSALISM CONCERN

COMMITMENT TO EQUALITY, JUSTICE AND PROTECTION FOR ALL PEOPLE

TRUST IN THE MEDICAL DEVICES

- The system should show the planned and executed maintenance check. To ensure the feeling of safety and reliability.
- The system should show the status of the medical equipment.

BENEVOLENCE CARING

WELL-BEING OF THE GROUP BMETs

STRONG TEAM BOND

- The system should positively influence the communication in the team.
- The names from every team member should be in the system.
- The system should show the person that performed the maintenance/repair.
- Everybody should have there own entry data.

CONFORMITY - INTERPERSONAL

AVOIDANCE OF UPSETTING OR HARMING OTHER PEOPLE

MAKE TIME FOR INCOMING PEOPLE

- Looking for information about a device should be quick and easy.
- The system should have a modus that your process could be saved anytime.

DON'T ASK TO MANY QUESTION (DONATED)

- The system should have minimal mandatory information needed.

PERSONAL CONTACT

- The system should support the main communication tool: Calling.

POWER RESOURCES

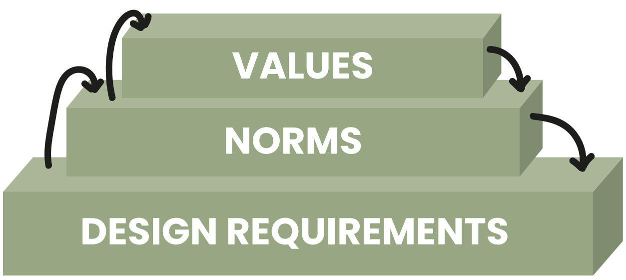
POWER THROUGH CONTROL OF MATERIAL AND SOCIAL RESOURCES

OWN OFFICE/WORKSHOP

- The system should be available without internet.
- The system should be a desktop app.

RESPONSIBLE FOR ALL MEDICAL DEVICES

- The medical devices should be labelled corresponded with the system.
- The system should show the location.
- The system should show the status of devices.



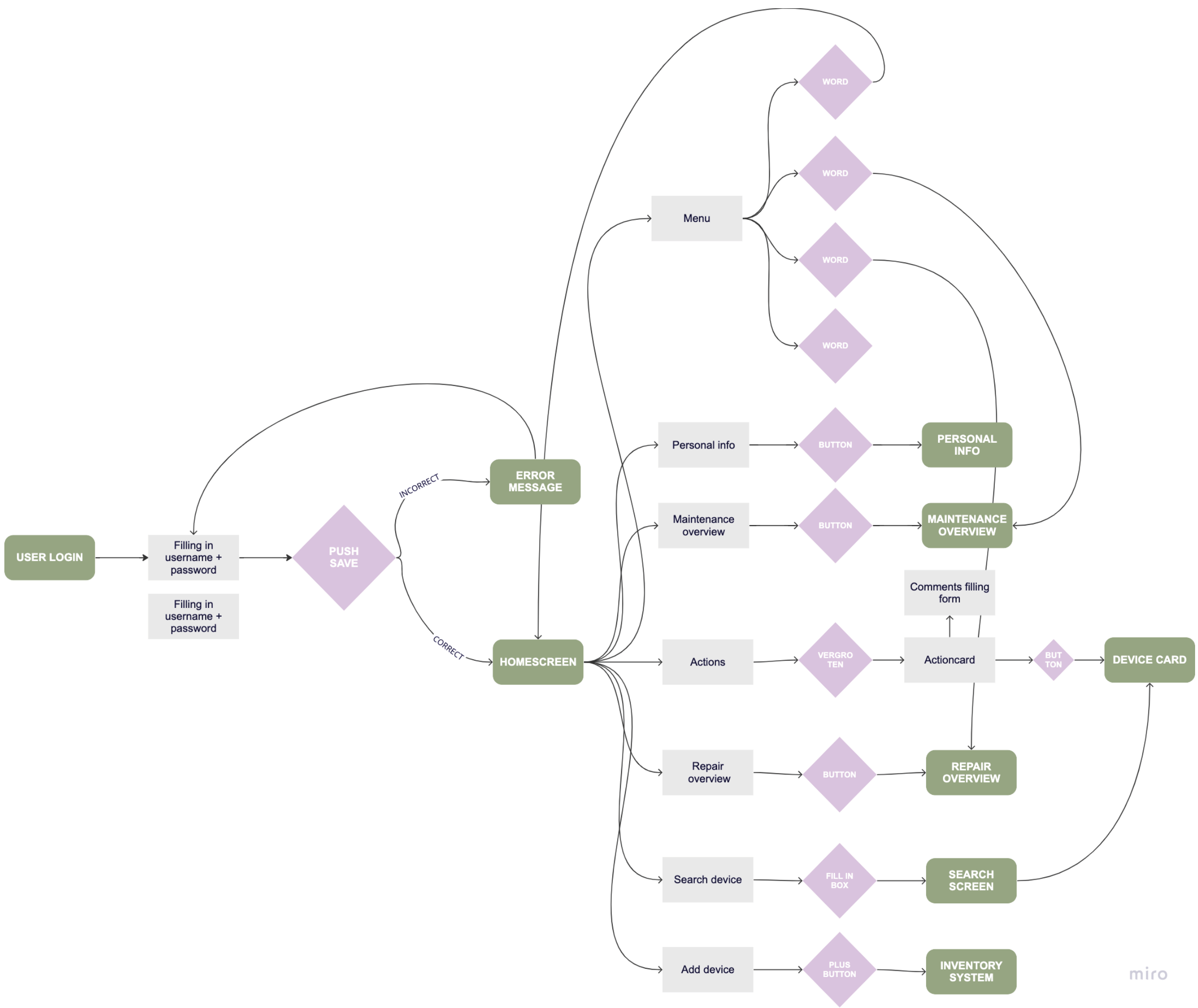
APPENDIX

1. FLOW
2. WIREFRAME
3. LO-FI TEST PLAN
4. LO-FI TEST OUTCOMES
5. HI-FI TEST PLAN
6. HI-FI TEST OUTCOMES

C

FLOW

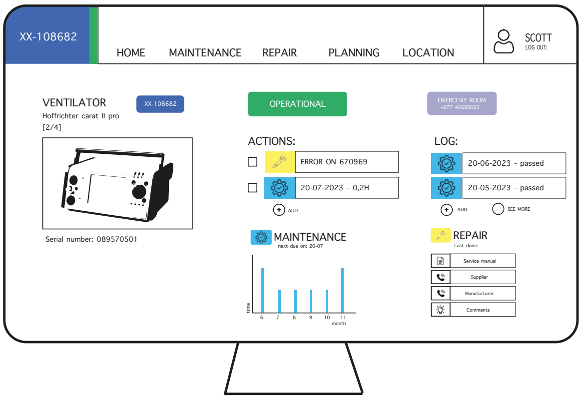
C.1



USER LOGIN
Filling in username + password
Filling in username + password
PUSH SAVE
INCORRECT
ERROR MESSAGE
CORRECT
HOMESCREEN
Menu
WORD
WORD
WORD
WORD
Personal info
BUTTON
PERSONAL INFO
Maintenance overview
BUTTON
MAINTENANCE OVERVIEW
Comments filling form
Actions
VERGRO TEN
Actioncard
BUT TON
DEVICE CARD
Repair overview
BUTTON
REPAIR OVERVIEW
Search device
FILL IN BOX
SEARCH SCREEN
Add device
PLUS BUTTON
INVENTORY SYSTEM
miro

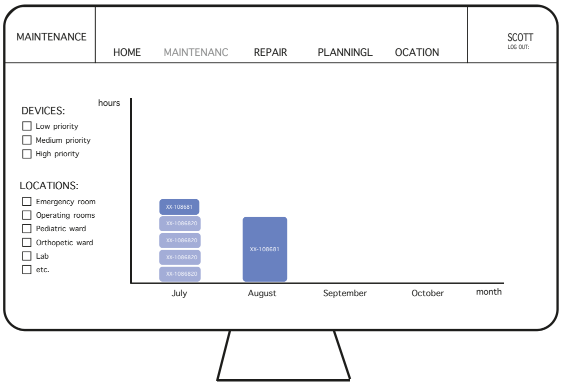
WIREFRAME

C.2

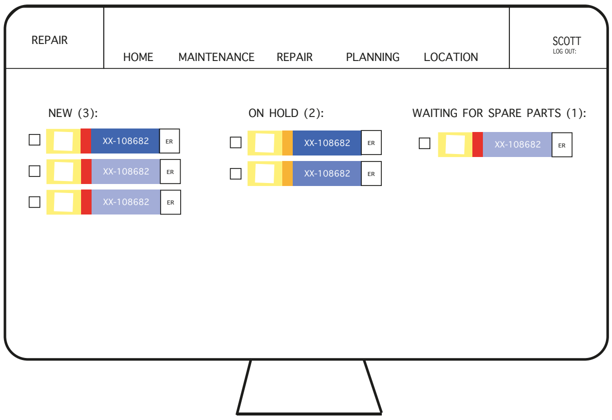


ASSET SCREEN

LOCATION SCREEN



MAINTENANCE SCREEN



REPAIR SCREEN

HOMESCREEN

MAINTENANCE
VENTILATOR
Hoffrichter carat II pro
XX-108682
Regular maintenance check -20-07
EMERCENY ROOM
+977 45689023
Maintenance checklist
VENTILATOR
Hoffrichter carat II pro
XX-108682
ACTIONS:
20-07-2023 - 0,2H
ADD
EMERCENY ROOM
+977 45689023
Serial number: 089570501
COMMENTS:
ADD
MAINTENANCE
next due on: 20-07
REPAIR
Last done:
REPAIR
VENTILATOR
Hoffrichter carat II pro
XX-108682
:ERROR ON 670969 - 20-07-2023
EMERCENY ROOM
+977 45689023
Service manual
Supplier
Manufacturer
Comments
VENTILATOR
Hoffrichter carat II pro
XX-108682
ACTIONS:
ERROR ON 670969
20-07-2023 - 0,2H
ADD
EMERCENY ROOM
+977 45689023
Serial number: 089570501
COMMENTS:
ADD
MAINTENANCE
next due on: 20-07
REPAIR
Last done:
MAINTENANCE
CHECKLIST
VENTILATOR
Hoffrichter carat II pro
XX-108682
REGULAR PM:
Visual inspection
Cleaning
Vacuum test
Check all the boxes
Print
COMMENTS:
ADD
Approve maintenance
Save & Close
ADD
ACTION
VENTILATOR
Hoffrichter carat II pro
TYPE OF ACTION:
DESCRIPTION:
DUE DATE:
EMERCENY ROOM
+977 45689023
STATUS DEVICE:
Save & Close
SUPPLIER
Medtronic
CONTACT DETAILS:
Name + Surname
name.surname@medtronic.com
+97780472014
street number
city
country
DEVICES:
XX-108681
XX-108681
XX-108681
XX-108681
XX-108681
XX-108681
XX-108681
XX-108681
MANUFACTURER
Medtronic
CONTACT DETAILS:
Name + Surname
name.surname@medtronic.com
+97780472014
street number
city
country
DEVICES:
XX-108681
XX-108681
XX-108681
XX-108681
XX-108681
EMERCENY ROOM
+977 45689023
LIST OF EQUIPMENT:
Print
XX-108682
VENTILATOR
XX-108682
VENTILATOR
XX-108682
HART MONITOR
COMMENT
VENTILATOR
Hoffrichter carat II pro
XX-108682
TYPE OF COMMENT:
DESCRIPTION:
APPLICABLE FOR AL ASSETS
NEED FOR ACTION
EMERCENY ROOM
+977 45689023
Save & Close

LO-FI TEST PLAN

THE AIM

This test aims to evaluate the . The test will involve participants completing scenario accessibility of static screens and the clarity of the elements.

OBJECTIVES

▶ Assess the ease of use and intuitiveness of the prototype.
▶ Identify navigation difficulties and unclear information.
▶ Understand user decision-making processes and inter actions with different elements.
▶ Gather user feedback to make design improvements.

PARTICIPANTS

▶ 3 Participants
▶ 1 test participant before the actual test to validate the materials and scenarios.

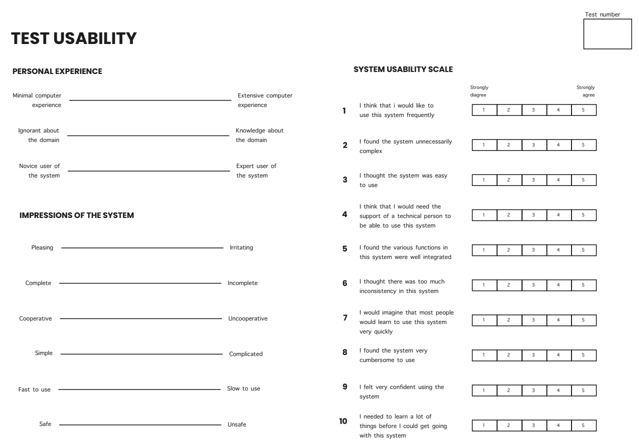
TEST MATERIAL

▶ Paper prototype with strings for the interaction.
▶ Box with post -it (broken, X8-09384).
▶ Scenario's and tasks for participants to complete.
▶ Consent forms for participants.
▶ Post-test questionnaire for usability feedback + user cube (see Figure C.3.1).

SCENARIO'S

Scenario A:
You find a device who was placed on your desk yesterday that needs to be repaired.(Place box with post-it(The device has already been entered into the system. How would you handle this repair?

Scenario B:
You have reserved one hour left (approximately 1 device) to do maintenance. How would you approach this?



Test number

TEST USABILITY

PERSONAL EXPERIENCE

Minimal computer experience	______	Extensive computer experience
Ignorant about the domain	______	Knowledge about the domain
Novice user of the system	______	Expert user of the system

IMPRESSIONS OF THE SYSTEM

Pleasing	______	Irritating
Complete	______	Incomplete
Cooperative	______	Uncooperative
Simple	______	Complicated
Fast to use	______	Slow to use
Safe	______	Unsafe

SYSTEM USABILITY SCALE

		Strongly diagree				Strongly agree
1	I think that i would like to use this system frequently	1	2	3	4	5
2	I found the system unnecessarily complex	1	2	3	4	5
3	I thought the system was easy to use	1	2	3	4	5
4	I think that I would need the support of a technical person to be able to use this system	1	2	3	4	5
5	I found the various functions in this system were well integrated	1	2	3	4	5
6	I thought there was too much inconsistency in this system	1	2	3	4	5
7	I would imagine that most people would learn to use this system very quickly	1	2	3	4	5
8	I found the system very cumbersome to use	1	2	3	4	5
9	I felt very confident using the system	1	2	3	4	5
10	I needed to learn a lot of things before I could get going with this system	1	2	3	4	5

Figure C.3.1: Physical sheet used for post-test questionnaire

PRE-TEST PHASE

▶Obtain informed consent from participants.
▶Tell participant about the Nepalese context they are working in.
▶ Tell participant about there roll as a BMET and there capabilities.

TEST-PHASE

▶ Introduce participants to the prototype and explain the scenarios.
▶ Ask participants to perform tasks.
▶ Encourage participants to think aloud during the tasks to capture their decision-making processes.

POST-TEST PHASE

▶ Administer the online questionnaire to collect partici-pants' feedback on usability and the user cube.
▶ Conduct semi-structured interviews to delve deeper into participants' thoughts and impressions.

DATA COLLECTION

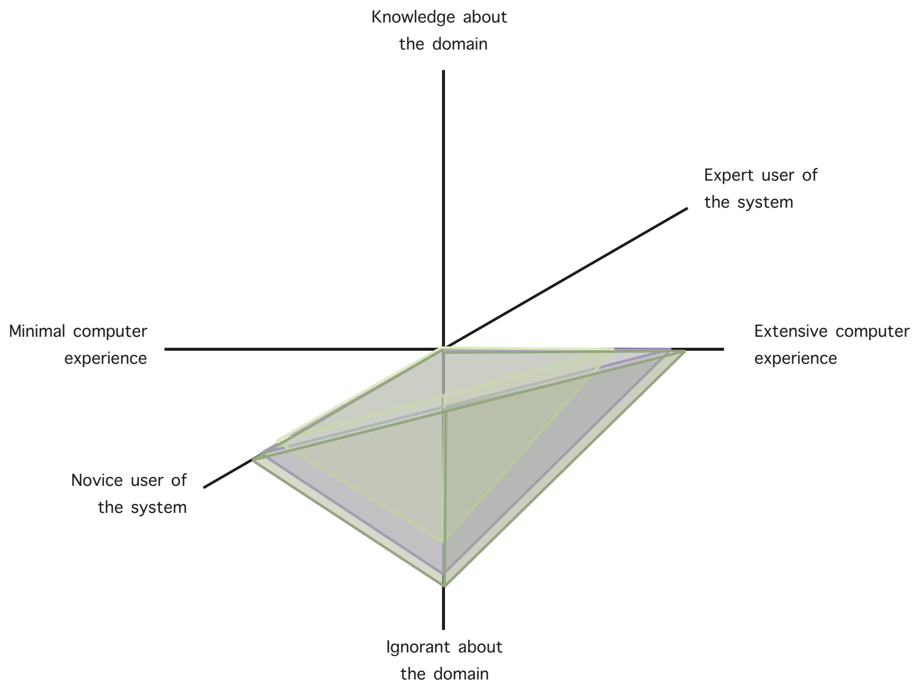
▶ Audio-recordings
▶ Time to perform the task
▶ Error rate
▶ Outcome of online questionnaire

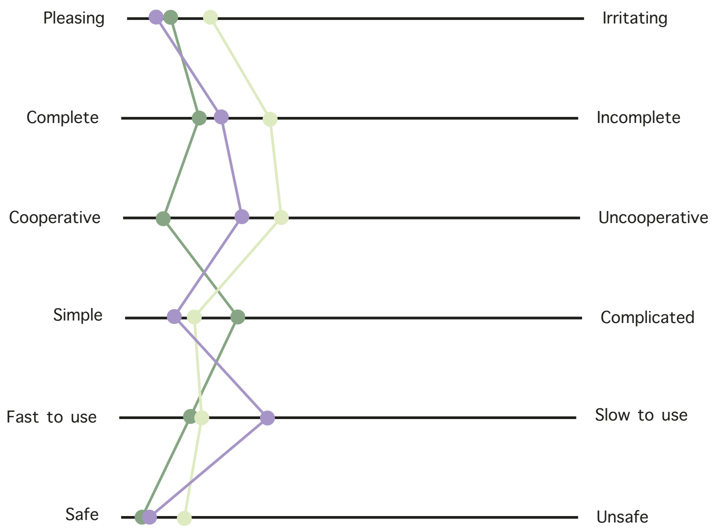
Figure C.3.2: Participant using the prototype

LO-FI TEST OUTCOMES

TEST 1 (N=3)

N(1)
N(2)
N(3)





C.4

SYSTEM USABILITY SCALE

1 I think that i would like to use this system frequently

2 I found the system unnecessarily complex

3 I thought the system was easy to use

4 I think that I would need the support of a technical person to be able to use this system

5 I found the various functions in this system were well integrated

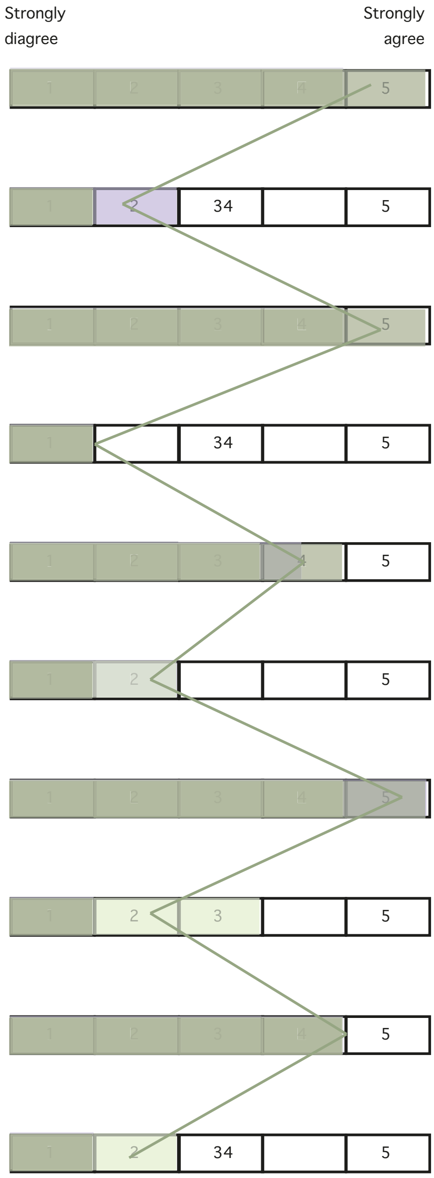
6 I thought there was too much inconsistency in this system

7 I would imagine that most people would learn to use this system very quickly

8 I found the system very cumbersome to use

9 I felt very confident using the system

10 I needed to learn a lot of things before I could get going with this system



HI-FI TEST PLAN

C.5

THE AIM
This test aims to evaluate usability of the prototype's functionalities and interactions. The test will involve participants completing scenarios that simulate real-world tasks. The results will provide insights into usability issue and areas for improvement.

OBJECTIVES
- ▶ Assess the ease of use and intuitiveness of the prototype.
- ▶ Identify navigation difficulties and unclear information.
- ▶ Understand user decision-making processes and inter actions with different elements.
- ▶ Gather user feedback to make design improvements.

PARTICIPANTS
- ▶ Minimum of 5 participants.
- ▶ 1 test participant before the actual test to validate the materials and scenarios.

TEST MATERIAL
- ▶ Prototype of the system.
- ▶ Box with post -it (broken, X8-09384)
- ▶ Scenario's and tasks for participants to complete.
- ▶ Consent forms for participants.
- ▶ Post-test online questionnaire for usability feedback + user cube (Figure C.5.1)

SCENARIO'S
Scenario A:

You find a device who was placed on your desk yesterday that needs to be repaired.(Place box with post-it) The device has already been entered into the system. How would you handle this repair?

Scenario B:

You have reserved one hour left (approximately 1 device) to do maintenance. How would you approach this?

PRE-TEST PHASE
- ▶ Obtain informed consent from participants.
- ▶ Tell participant about the Nepalese context they are working in.
- ▶ Tell participant about there roll as a BMET and there capabilities.

TEST-PHASE
- ▶ Introduce participants to the prototype and explain the scenarios.
- ▶ Ask participants to perform tasks.
- ▶ Encourage participants to think aloud during the tasks to capture their decision-making processes.

POST-TEST PHASE
- ▶ Administer the online questionnaire to collect participants' feedback on usability and the user cube.
- ▶ Conduct semi-structured interviews to delve deeper into participants' thoughts and impressions.

DATA COLLECTION
- ▶ Audio-recordings
- ▶ Time to perform the task
- ▶ Error rate
- ▶ Outcome of online questionnaire

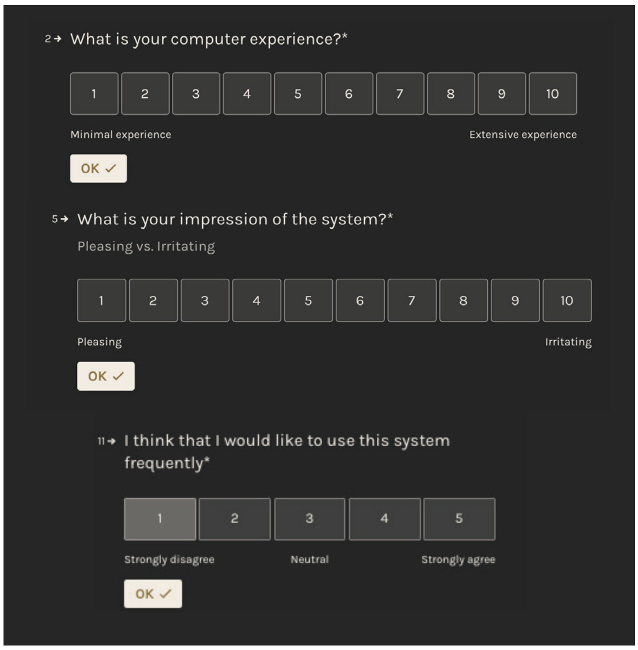
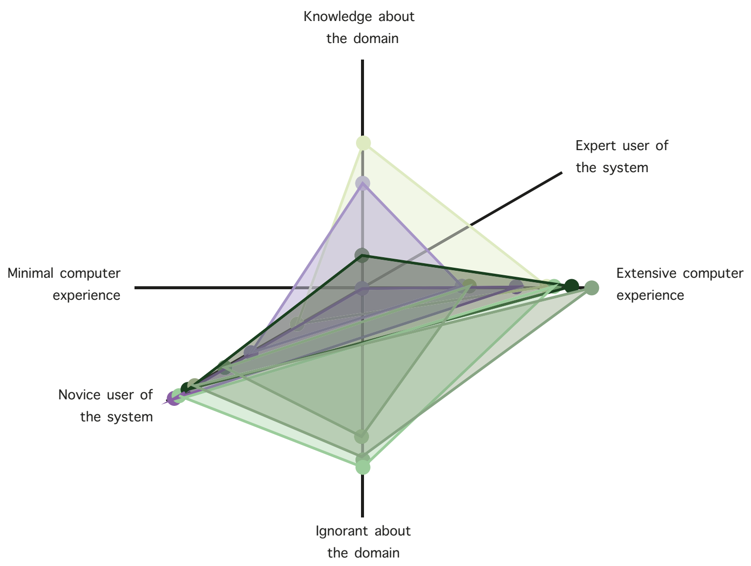
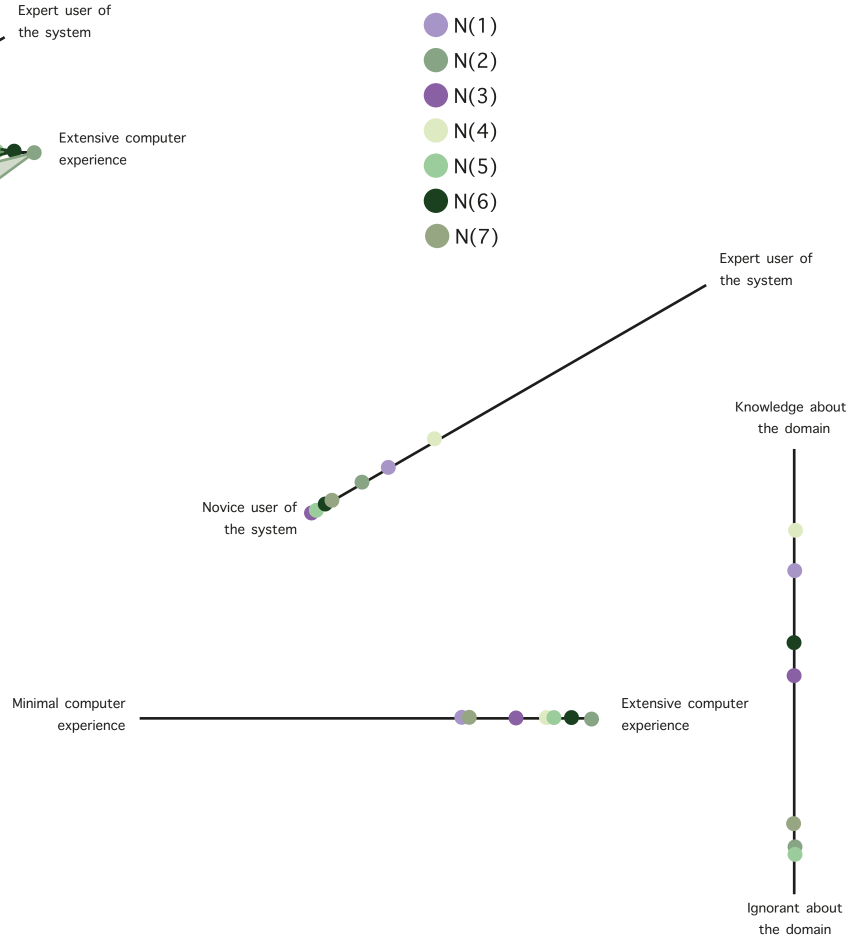


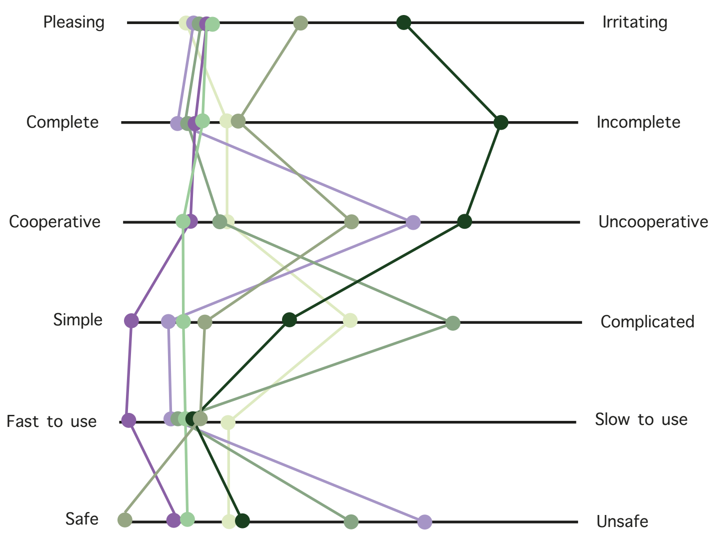
Figure C.5.1: 3 examples of questions from the online post-test questionnaire

HI-FI TEST OUTCOMES

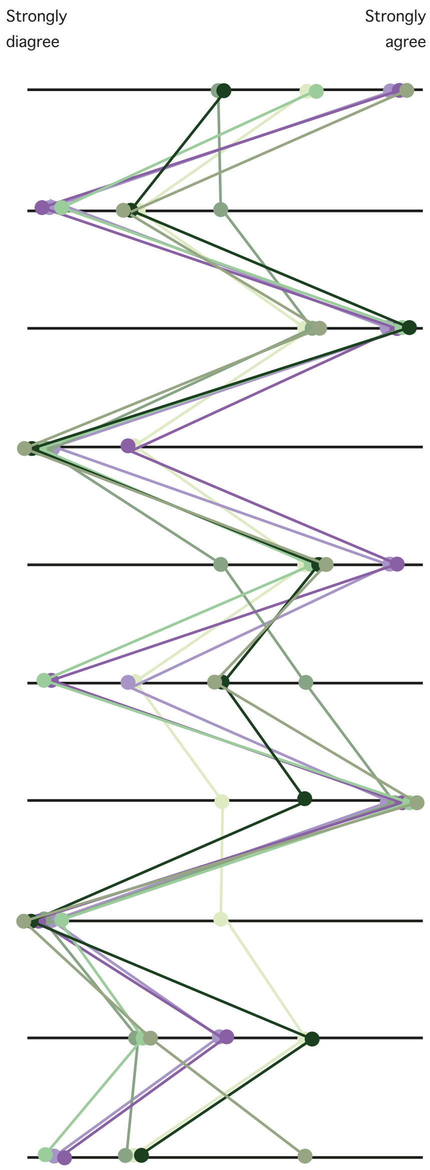
TEST 2 (N=7)







SYSTEM USABILITY SCALE



1. I think that i would like to use this system frequently
2. I found the system unnecessarily complex
3. I thought the system was easy to use
4. I think that I would need the support of a technical person to be able to use this system
5. I found the various functions in this system were well integrated
6. I thought there was too much inconsistency in this system
7. I would imagine that most people would learn to use this system very quickly
8. I found the system very cumbersome to use
9. I felt very confident using the system
10. I needed to learn a lot of things before I could get going with this system

APPENDIX

1. EVALUATION SET UP
2. SUGGESTIONS FOR REDESIGN

D

EVALUATION TEST PLAN

THE AIM

This test aims to evaluate usability of the prototype's functionalities and interactions with an experience user of a CMMS system and reflect with the participants on the feasibilty, desirability and usability.

OBJECTIVES

▶ Assess the ease of use and intuitiveness of the prototype.
▶ Identify navigation difficulties and unclear information.
▶ Understand user decision-making processes and inter actions with different elements.
▶ Gather user feedback to make design improvements.

PARTICIPANTS

▶ 2 participant, BMETs from United Mission Hospital Tansen
▶ 2 participant, BMETs from INF Green Pasture Hospital
▶ 1 participant to test the set up

TEST MATERIAL

▶ Final design prototype of the system.
▶ Scenario's and tasks for participants to complete.
▶ Online consent forms for participants.
▶ Post-test online questionnaire for usability feedback + user cube.
▶ Lookback software for test-setup.

SCENARIO'S

Scenario A:
You find a device who was placed on your desk yesterday that needs to be repaired.(Place box with post-it(The device has already been entered into the system. How would you handle this repair?

Scenario B:
You have reserved one hour left (approximately 1 device) to do maintenance. How would you approach this?

PRE-TEST PHASE

▶Obtain informed consent from participants.

TEST-PHASE

▶ Introduce participants to the prototype and explain the scenarios.
▶ Ask participants to perform tasks.
▶ Encourage participants to think aloud during the tasks to capture their decision-making processes.

POST-TEST PHASE

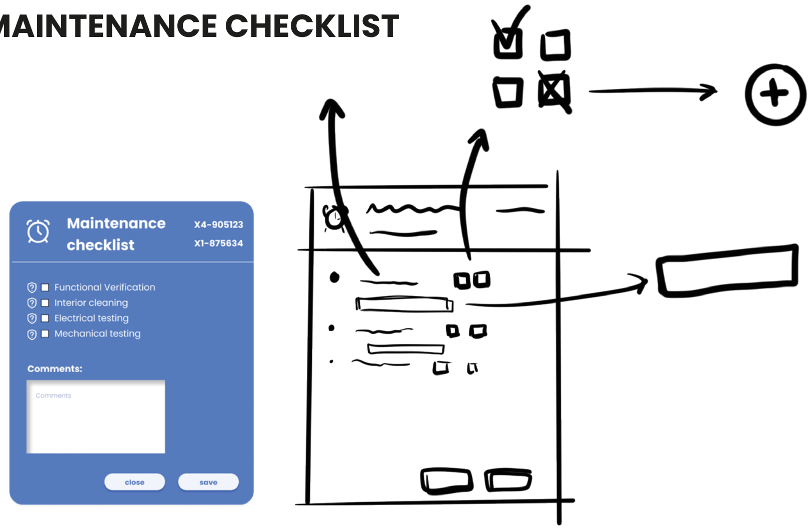
▶ Administer the online questionnaire to collect participants' feedback on usability and the user cube.
▶ Conduct semi-structured interviews to delve deeper into participants' thoughts and impressions.

DATA COLLECTION

▶ Audio-recordings
▶ Time to perform the task
▶ Error rate
▶ Outcome of online questionnaire

SUGGESTIONS FOR REDESIGN

MAINTENANCE CHECKLIST

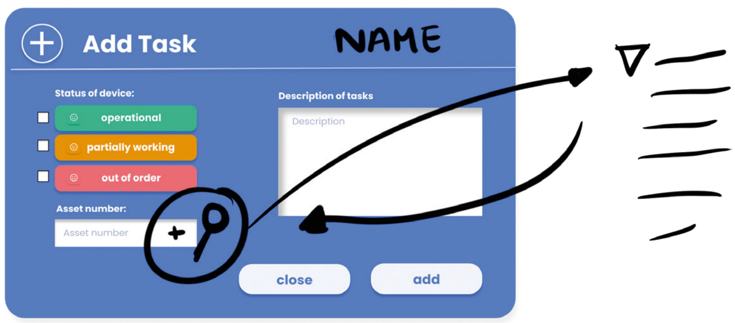


- Tasks should be given a pass of a fail instead of 1 tick box.
- Each task should have its own comment box.
- If a test fails it should make an automatic repair task for the failed test.

DEVICE INFORMATION

- The system should by last maintenance and repair give the problem + solution so that the same problems can be solved quickly.

SEARCH IN TASK

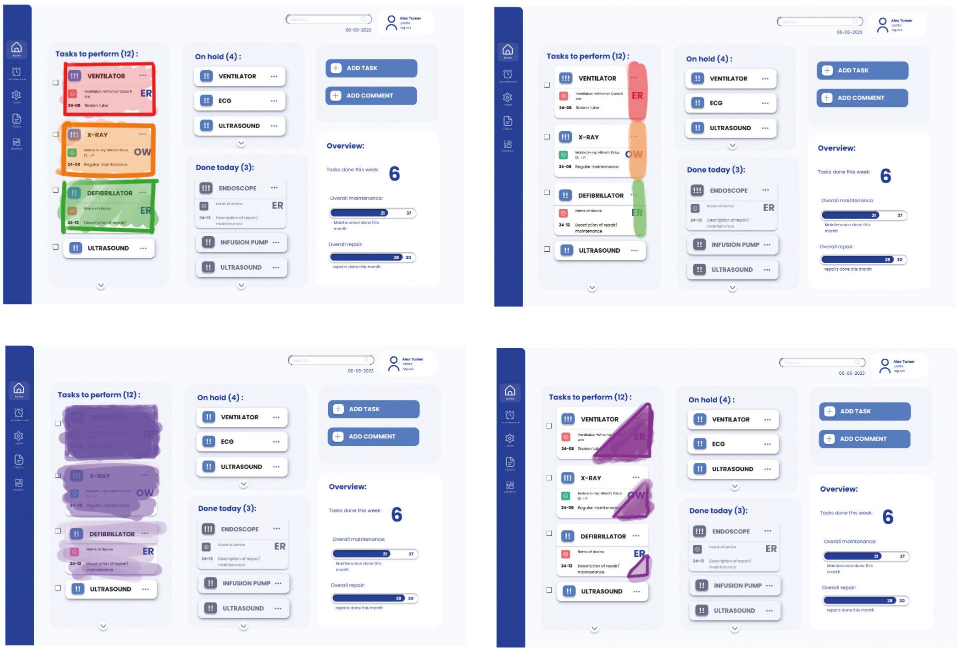


- When creating a new task, it should be possible to find the medical equipment in multiple ways. By name or location.
- After searching, the card should show which device it is to confirm that it is the same device and not accidentally swapped asset numbers.

SUGGESTIONS FOR REDESIGN

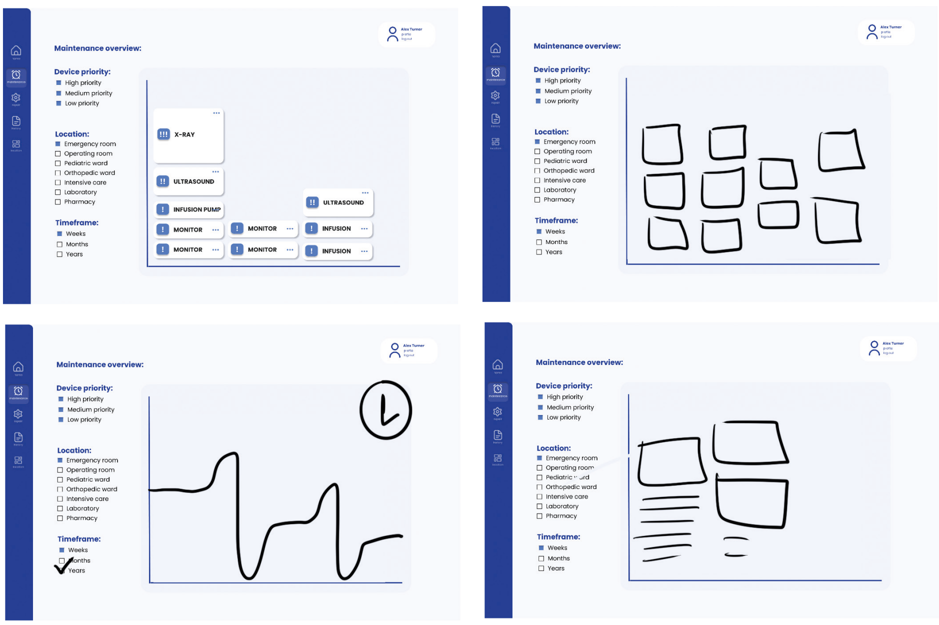
D.2

MORE COLOURS



- Priority can be even better indicated by colours. However, care should be taken to ensure that it does not come at the expense of the clarity of the device.

MAINTENANCE PLANNING



- Entering a time indication (inventory stage) for maintenance can give a better picture in maintenance planning where the big peaks are. On a monthly planning basis, you could look at the device name but on an annual basis, it would only show when the druskte peaks are.