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INTEGRATING SYSTEMS AND DESIGN THINKING IN HEALTHCARE: A USER-CENTRED PERSPECTIVE

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ABSTRACT

The design of healthcare systems has unintentionally contributed to a rise in medical errors, partly due to the integration of new technologies into outdated systems. By applying user-centred design, we can gain valuable insights from diverse perspectives, helping to develop and refine products and services that improve the healthcare process and enhance safety for all stakeholders. This paper explores the application of design thinking to analyse healthcare systems, with a specific focus on the pre-surgical process. It highlights three key design tools—ecosystem mapping, participatory workshops, and data visualizations—that were instrumental in identifying issues, proposing interventions, and communicating findings. User-centred design proves to be an effective approach for creating solutions that align with the needs of all users involved in the healthcare process.

KEYWORDS

User-Centred Design, Ecosystem Mapping, Participatory Workshop, Information Visualization, Pre-Surgical

1. INTRODUCTION

Patient safety remains a major focal point in healthcare research (Acevedo & Kuo 2021; Wacker 2020; Buchert & Bulter 2020). There has been an estimated 40% increase in adverse events due to medical errors in the past 30 years (Nauman et al. 2021). Studies show that approximately 50% of adverse events are attributed to preventable medical errors, a statistic that has remained unchanged for ten years (Schwendimann et al. 2018; de Vries et al. 2008). Over the past two decades, it has been found that a major cause of medical error is attributable to poorly designed healthcare systems which contribute to an environment conducive to human error (Kohn,

Corrigan & Donaldson 2000). Consequently, there is a strong focus on research that improves healthcare systems to ensure patient safety and a need to incorporate user-centred design processes to understand the patient experience and guide effective design interventions. In this study, surgical procedures, specifically procedures associated with pre-operative care, are explored through systems design as well as user-centred design approaches.

Surgical outcomes are largely affected by the patient's physical and psychological conditions (Levett & Grimmett 2019). The pre-surgical phase, which begins when the patient agrees to surgical treatment up until surgery, presents a crucial opportunity to enhance the patient's condition, thereby minimizing surgical risks and complications. This phase entails coordination among various hospital departments and necessitates thorough communication and planning among specialized clinics, pharmacies, laboratories, healthcare providers, the patient, and their caregiver(s). This complexity is further highlighted by the administrative stress put on the healthcare system with the increased demand for surgical care.

This paper introduces different tools for engaging stakeholders in pre-surgical care using design methodologies. We combine systems analysis with user-centred design. As part of a three-year project, the aim is to enhance pre-surgical care by uniting healthcare professionals, designers, and patients, promoting a user-centred and integrated approach that creates experiences people desire. Through journey mapping techniques, engaging participants in workshops, and utilizing information visualization, we were able to explore the pre-surgical process, develop design solutions, and communicate the obtained knowledge. The findings present a view of the complexity of socio-technical systems within healthcare and inform the practicality and feasibility of user-centred design processes.

2. USER-CENTRED DESIGN

The exponential growth in technology has enabled parallel technological advances in medicine. This constant addition of new devices, software, and processes to legacy systems is a contributing factor to poor system design (Adams et al. 2017). User experience researchers and designers use various methods to help identify design opportunities and innovations of products and services. Specifically, user-centred design is a framework that attempts to focus on people at every step of the design process. It examines tools, environments and tasks from a human-centred perspective. In this case, placing patients, their families, and healthcare workers at the heart of healthcare delivery.

Regardless of context, it is evident that mapping relationships and concepts within complex systems is a valuable way to gain a comprehensive understanding and make improvements. These tools and processes, however, are not linear and do not have templates. The designer's path is dynamic and requires customization based on the situation. This investigation will explore three methods to show the effectiveness of design thinking in assessing surgical systems: ecosystem mapping, participatory design workshops, and qualitative data analysis through information visualization.

3. METHODOLOGY

The design process is typically seen as a series of diverging and converging steps-repeatedly exploring a wide range of aspects before focusing on concentrated points. In the initial phase of our study, we performed an environmental scan. Our focus was understanding the pre-surgical system and uncovering the nature of the issues at hand (Figure 1). We thoroughly reviewed the information and systems architecture to gain insight into the intricate network of interactions within the healthcare system. This involved understanding how people and technologies interact, both within and outside the hospital. These reviews provided a foundational understanding of the pre-surgical system, nested within broader surgical and national healthcare frameworks. Central to our work was the building of multiple ecosystem maps. By comprehensively examining the socio-technical context, we uncovered key touchpoints and interactions, laying the groundwork for subsequent methodologies aimed at enhancing the pre-surgical care experience.

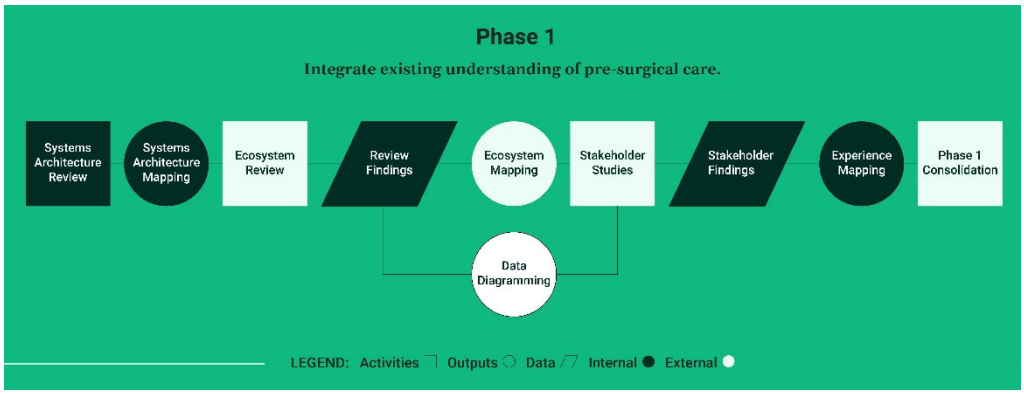

Figure 1. Research framework illustrating the multifaceted approach for the pre-surgical system's initial scope. It involved activities, outputs and data for internal team use or external sharing with stakeholders

3.1 Ecosystem Mapping

Ecosystem maps simplify the display of information, concepts, and their interrelationships, enhancing the ability to grasp and manage super-complexity. The design team developed various diagrams to examine existing digital system structures and their user flows—the paths specific users take to complete tasks. These diagrams, combined with insights gathered from interviews and literature analysis, culminated in the creation of ecosystem maps for each user (Figure 2).

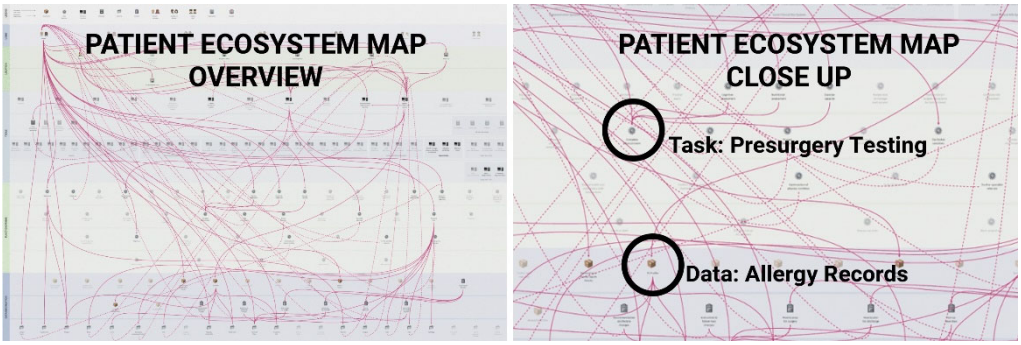

Figure 2. Individual ecosystem map of patients. Each icon is a component like task or data. The lines connecting components illustrate the exchange of information between them, both inputs and outputs

The individual maps were combined to create one large overlaid ecosystem map (Figure 3). This map displays users, locations, tasks, tools, and information, along with their connections, allowing us to highlight the busiest intersection points. These points occur where user paths, interfaces, inputs, system outputs, and data flows overlap. Additionally, since the maps were developed from a user-centered perspective, the overlaid map could isolate specific stakeholders, offering an alternative method for comparing and analysing the experiences of each role. Ecosystem maps offer a visual method for extracting insights that guide brainstorming, foster creative thinking, and ultimately shape design solutions.

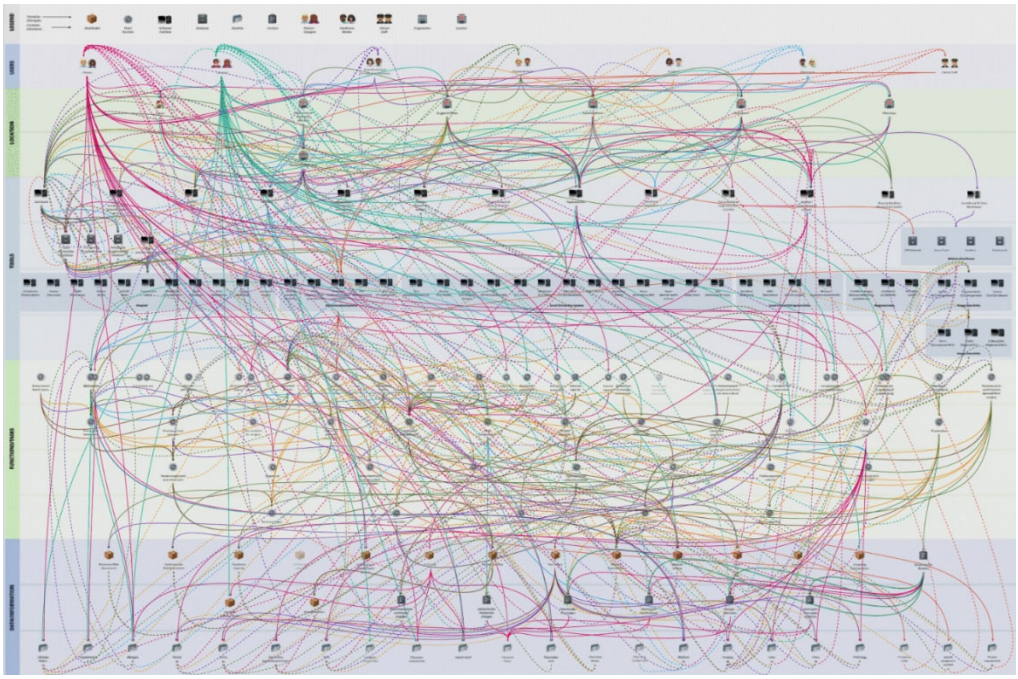

Figure 3. Final ecosystem map showing the entire data flow between all users. The different colors of lines represent different users like patients, nurses, and anesthesiologist

3.2 Participatory Design Workshops

Participatory design workshops are collaborative sessions where individuals gather at key moments during the design process, using specific tools to ensure quality results that are feasible and meet their needs. They serve as a platform for education, research, or problem-solving across various disciplines. Participants are encouraged to tackle problems using design thinking methodologies and collaborative design practices, gaining new perspectives that can generate innovative outputs.

Due to COVID-19 restrictions and the inability to hold in-person workshops, the design team developed a workshop that allowed participants to engage independently from the comfort of their homes. Each participant received a kit containing detailed instructions and resources. Their task was to record their own journey map, with the kit providing guidance on how to do so (Figure 4). Journey mapping provides a detailed visualization of a specific user's tasks, tools, thoughts, and emotions all set on a timeline.

Figure 4. Contents of each kit provided to participants, including the materials, instructions, and templates needed for them to complete and record their own journey maps

The first workshop involved 17 participants from across five roles including patients, familial support, nurses, anesthesiologists, and administration. Participants were asked to engage with the provided materials by jotting down tasks and notes on pre-filled and empty task cards. These task cards were then placed on the map in chronological order with additional details such as start, break, and end times. Stickers were used to represent the level of difficulty for each task, while arrows were created to indicate subtasks and alternative tasks that could be done simultaneously (Figure 5). Once completed, participants were instructed to take a photo of their map and send it to our team.

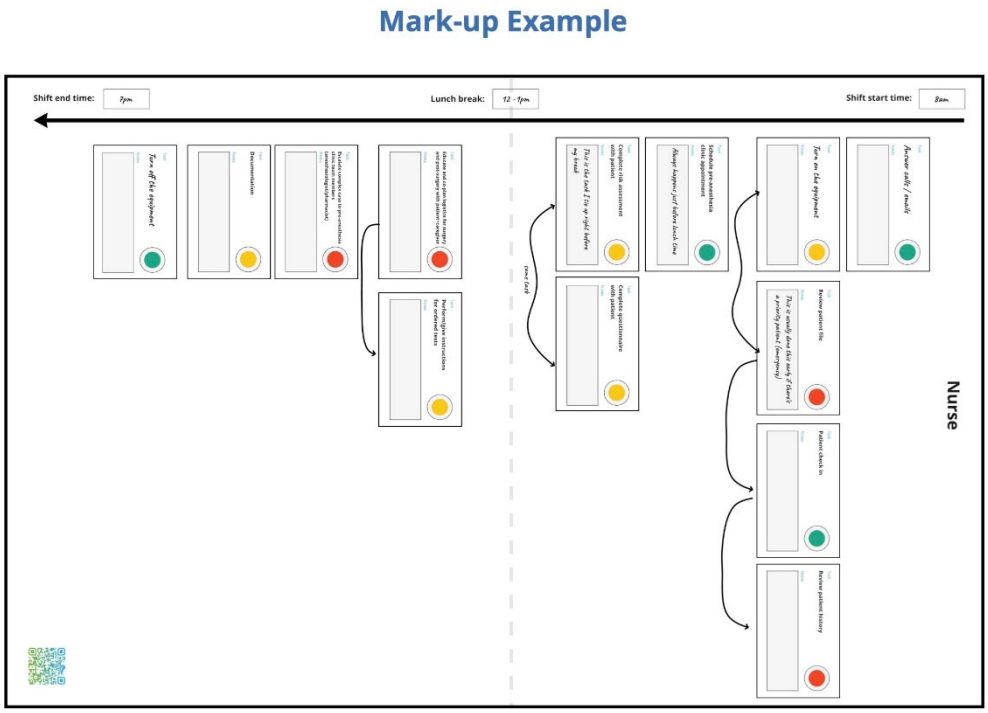

Figure 5. Journey map template filled with task cards. The stickers denote task difficulty, while the arrows indicate parallel or alternative tasks

For the second workshop, 12 participants—11 of whom had been involved in the first session—collaborated with the design team to brainstorm potential solutions. Utilising the data from the first workshop, the team created five journey maps based on each role. Each map was simplified by reducing the overall amount of information and using a cohesive style to ensure clarity and ease of understanding (Figure 6).

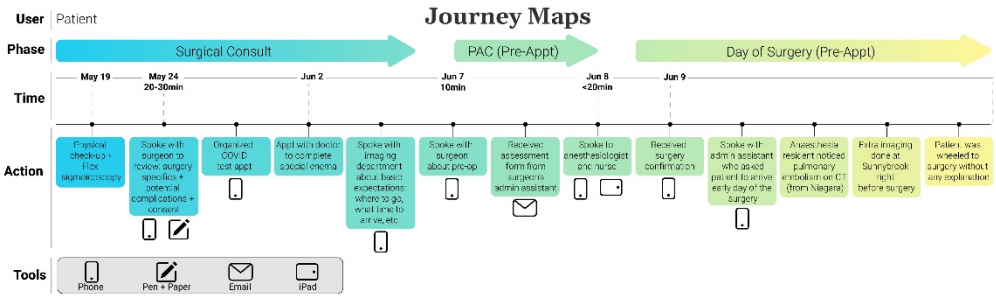

Figure 6. Simplified patient journey map used for workshop two. This map chronologically guides participants through the activities of a specific role, employing time, phases, and tools as key identifiers

The team met with participants through a remote video call and used the digital whiteboard tool Miro to facilitate collaboration. As one member of the design team facilitated the discussion, another team member transcribed their thoughts, comments, and ideas. Each participant reviewed the five simplified maps, gaining insights into the perspectives of other stakeholders. They were encouraged to examine the maps through the lenses of time, tools, and empathy. Together with the design team, they brainstormed potential interventions. These collaborative workshops harnessed the power of individuals to generate ideas, collect rich qualitative data, and provide a deeper understanding of the pre-surgical process.

3.3 Qualitative Data Analysis and Information Visualization

Qualitative data analysis is a method used to examine and interpret non-numerical data. It involves systematically organizing, and interpreting textual, visual, or auditory data collected through methods such as interviews, observations, or surveys.

Our initial analysis of participant experience data aimed to understand touchpoints and interactions, culminating in the development of detailed interactive journey maps. Where traditional journey maps are static visualizations, interactive journey maps are dynamic tools that offer an in-depth exploration of the user's journey through clickable elements. We developed interactive journey maps by combining all of the individual maps, generated by participants, into one big database that uses nodes on a timeline to represent specific tasks or events. By clicking on these nodes, internal team members could access detailed information about each moment, including tasks completed, tools used, frustrations encountered, barriers faced, and satisfactions achieved (Figure 7). For example, during the pre-appointment phase of a patient's journey, we could click on specific points, like the check-in process, to view details such as the absence of tools used, the patient's satisfaction with their interaction with nurses, and their frustration with the news playing on the waiting room television, which caused stress. We included other functions, like clicking an icon in the legend along the bottom, for instance tools, would display all entries for that specific category. Additionally, we included a feature that allows multiple maps to be viewed simultaneously. As a log of all the real-world experiences of participants, this tool provided an easy way to examine and compare the base of rich qualitative data.

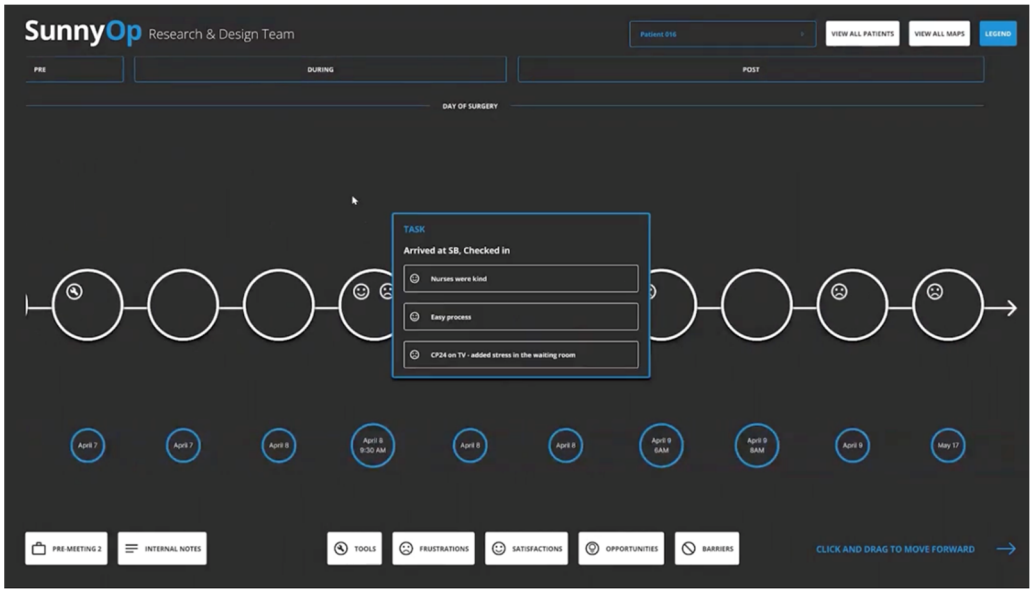

Figure 7. Interactive journey map features phases along the top, time along the bottom, and tasks in the middle, represented by white circular nodes. Clicking a task opens a window with the associated details

The next step would be to communicate the collected data. Information visualization is a powerful tool for representing complex concepts as simplified visuals. By presenting qualitative data in visual formats such as charts, tables, graphs, maps, and diagrams, we can quickly grasp the meaning behind the data and make informed decisions.

To communicate our findings, we analysed the data from both workshops and synthesized it into frustration and solution matrices, aiming to better visualize the gathered information. A matrix table expands both horizontally and vertically, with the number of rows and columns determined by the unique values in the specified fields. These matrices function as "look-up" tables, allowing stakeholders to find specific information by examining the intersections of rows and columns.

We categorized similar frustrations and solutions by their affinities, organizing them by location and time, which allowed us to group and quantify related sentiments from participants. Both matrices were developed using an identical structure: the horizontal axis displays locations such as unspecified/virtual, hospital, waiting room, and appointment room, while the vertical axis represents time periods including pre-appointment, during appointment, post-surgery, and unspecified time. Each category can be further broken down into specific moments, such as scheduling appointments, check-in, or information exchange (Figure 8). For example, if a stakeholder wanted to know how many frustrations occurred in the appointment room, they could navigate to the appointment room column and identify the number of issues and the specific times they occurred by examining the corresponding rows.

FRUSTRATION MATRIX *(highlighting key areas where frustrations are recorded)*

		UNSPECIFIED / VIRTUAL	HOSPITAL (NOT PAC)	WAITING ROOM	APPOINTMENT ROOM	TOTAL
PRE-APPOINTMENT	Scheduling Appointments	10			1	11
	Testing / Surgery Prep	1	10	1	3	18
	Information Exchange	5	1			6
	Check-In			4		4
DURING APPOINTMENT	Information Exchange	10	2		6	18
	Writting / Reviewing Documentation				4	4
POST SURGERY	Side Effects / Healing Process		2			2
	Asking For Assistance		1			1
UNSPECIFIED TIME	Communication Between Systems		1			1
	Using myChart	4				4
TOTAL		30	17	5	14	66

Data Hotspot

Numbers refer to amount of participant frustrations at a specific time, phase, and location

For more in-depth information, view the Participant Matrix spreadsheet below:
https://docs.google.com/spreadsheets/d/1DfIsWgrGelh01WJvsqAYtme7sGstRvmzEFLfB_E-opY/edit?usp=sharing

Figure 8. The frustration matrix highlights the frequency and context of frustrations, allowing stakeholders to pinpoint specific issues within the pre-surgical process by cross-referencing the corresponding rows and columns

The matrices were further complemented by rose charts—radial graphs that overlaid all the quantified data. While the matrices provided high-level overviews, the rose charts offered a more detailed means of examination. One chart was created for each role, with an additional chart combining data from all participants (Figure 9). The size of each section in the chart corresponded to the number of sentiments expressed. These sections were further divided by the number of people expressing those sentiments and colour-coded to identify their roles. This approach allowed us to break down the different roles expressing certain frustrations or solutions, along with the number of participants who shared the same sentiments.

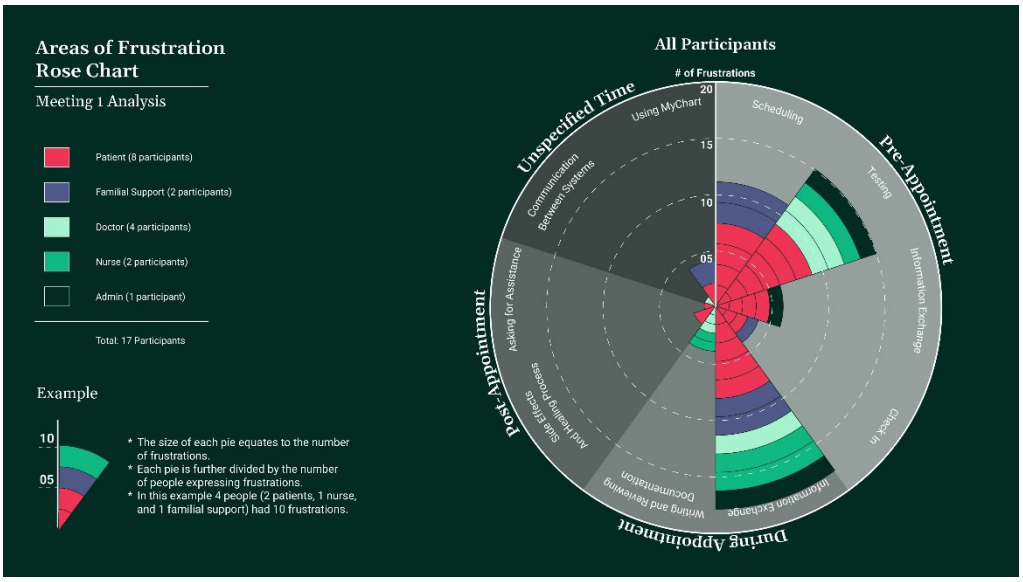

Figure 9. Rose chart overlaying frustrations. Each group is categorized by their affinities and phases. The size and density clearly identify areas of focus

Design thinking deals with scale and time, looking at both the big picture and the fine details. When it comes to examining these systems, services, and products, we often rely on the ability to compare. These tools and methodologies were developed to offer a different means of comparison.

4. FINDINGS

With a comprehensive understanding of the presurgical process our focus shifted towards developing interventions to address key frustrations within the pre-surgical care system. This phase involved exploring design solutions through workshops and ideation sessions. These methodologies allowed us to delve deeper into the findings, informing our design ideation phase. Supported by insights from user feedback, we explored targeted solutions and high-level systemic approaches involving multiple integrated products and services.

4.1 Ecosystem Map

The purpose of the ecosystem map is to provide a high-level overview of the surgical process and enable the design team to extract valuable insights. The map illustrates the intricate relationships and dependencies among elements within the surgical system. Like pillars supporting the load of a building, intersection points may also reveal the stress inflicted on one specific part of the system. By detecting patterns and identifying areas where more knowledge is needed, the final map uncovers potential points of intervention. It visually represents the extensive data exchange required for a successful operating system and reflects the complexity of the surgical process.

Viewing the ecosystem map at the macro level reveals its complexity, including hubs, patterns (such as repetitions, proximity, symmetry, and intersections), shortcuts, dead ends, and other intricate paths (Figure 10). The patient had the highest number of inputs and outputs, suggesting that the system might be particularly complex for this user. Much of this complexity results from redundant tasks, such as repeatedly collecting medical histories at various stages of the pre-surgical process. This redundancy adds a burden to both the system and the user experience.

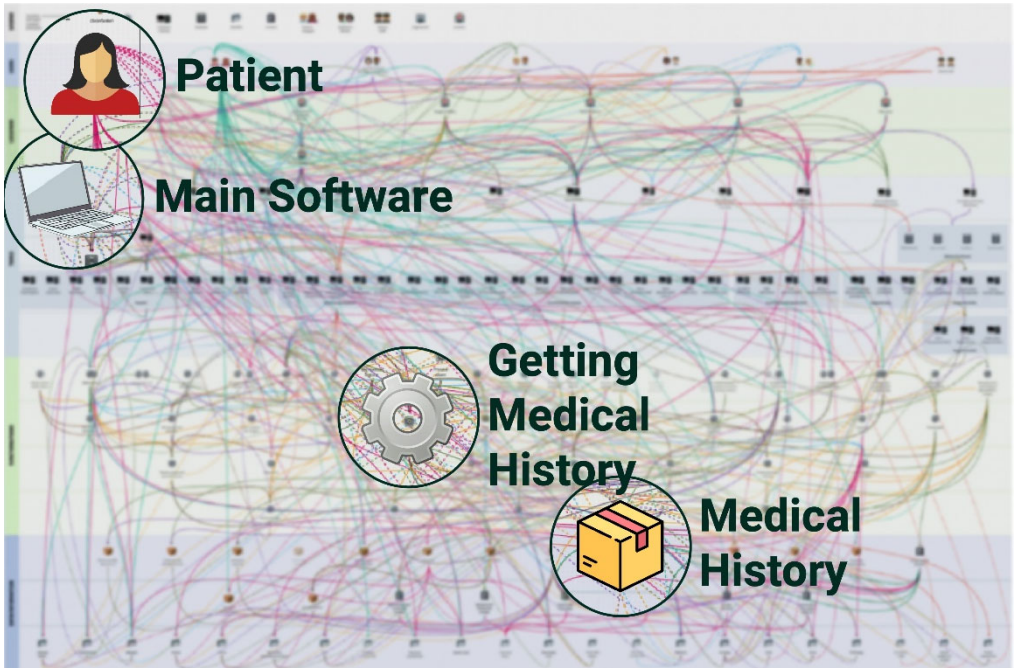

Figure 10. Ecosystem map highlights areas with a high volume of connections, enabling us to identify users, tools, tasks, and data with significant complexity, dependency, or redundancy

One of the most important observations made was that there are minimal connections at the interface level compared to the rest of the map. This could indicate one of two options: (1) the design team's lack of understanding of how these interfaces relate to the rest of the system, or (2) shows the complete dependence the surgical system has on a single software application alone. This application is a database accessed by clinicians as a viewer, searcher, and for query of information. As mentioned earlier, the copious number of lines leading to this tool could reveal stress inflicted to this part of the system. This then prompts the design team to explore if the intersection point should be bypassed with a parallel journey leading to a new product and service, or if shortcuts should be designed to ease the user experience leading up to an existing product and service.

These insights would not have been possible without ecosystem mapping, which provided a visual representation of the complex system. This approach made the process easier to understand, allowing the design team to uncover gaps and identify opportunities for improvement within the surgical process. Ultimately, the ecosystem maps provided a high-level overview of the user experience from a systems-scale perspective.

4.2 Participatory Design Workshops

Conducting the participatory design workshops allowed us to explore the problem space in greater depth and start developing solutions. To begin, we aimed to capture diverse perspectives. Engaging with users facilitated a truly multidisciplinary collaboration, which is fundamental to user-centered design.

The first workshop focused on journey mapping. These maps provided a detailed account of the pre-surgical experiences of real-world users and outlined the effects of healthcare systems on the individual scale (Figure 11). These maps allowed the design team to understand what users were thinking and feeling during their experience. The moments of frustration could indicate areas of opportunity for intervention, meanwhile moments of satisfaction could indicate areas where things were working smoothly. Furthermore, this exercise led to the output of interactive journey maps. A tool the design team used internally to directly compare user experiences. This provided a different way to analyse the information. We were able to see whether participants experienced the same frustrations or if certain complexities within the system were isolated incidents. By comparing the different individual experiences, we gained crucial insight into specific challenges and sources of frustration. These journey maps would become the foundation the design team would use to build and imagine scenarios with different outcomes.

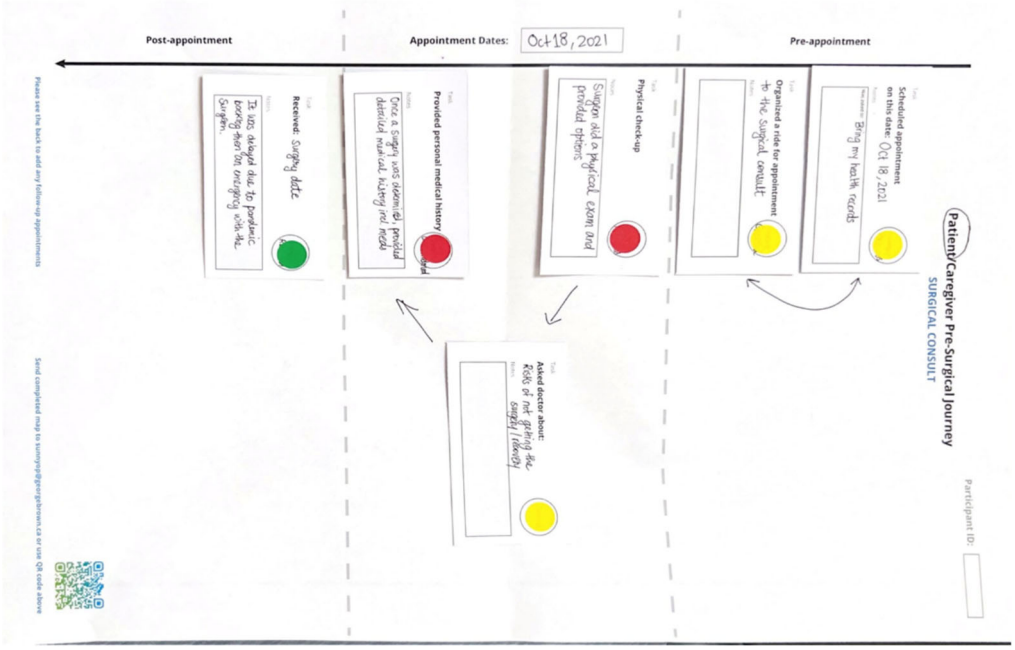

Figure 11. Map template filled in by a patient using task cards and colour-coded stickers to denote difficulty. During the pre-appointment phase, this patient experienced moderate frustrations scheduling their appointment noting that they needed to bring their medical records

Workshop two also contributed to this scenario building exercise. Participants generated a plethora of suggestions about how the process could be made better (Figure 12). As participants examined the maps, they had the opportunity to see the perspective of other roles. One key factor was the deliberate omittance of frustrations on the maps. This was to eliminate any bias and allow ideation based purely on the pre-surgical process. This encouraged thinking through the lens of pace, relationships, and being human.

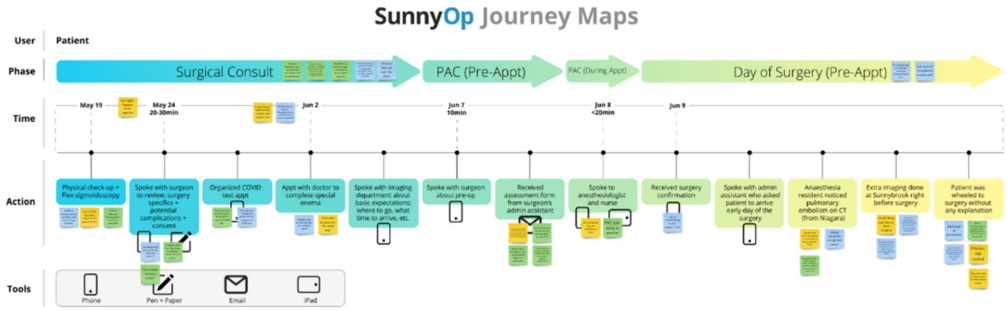

Figure 12. Simplified patient journey map covered in sticky notes. Each sticky note is a thought, comment, or idea from the workshop participant and is categorized by colors to represent themes of time, tools, or empathy

To organize the information from these brainstorming sessions, the team used a tool called affinity mapping. By combining the inputs from the different individuals based on commonalities, groups of similar ideas were identified and new relationships between ideas began to form. The suggestions of participants directly informed our own ideation sessions. As we brainstormed solutions, the connections and relations to participants ideas gave validity to our ideas. This ensured we were designing products and services that were more holistic to the user, creating experiences they desire, expect, and deserve.

The advantage of participatory design is the ability to leverage the strength of collective groups at recognizing the value of ideas. This is a highly effective tool that helps designers build for the end user and not for themselves. The design workshops engaged participants from various roles ensuring a diverse range of perspectives and expertise. This fostered collaboration and ensured that resulting interventions addressed the needs and concerns of all stakeholders involved.

4.3 Qualitative Data Analysis and Information Visualization

Qualitative data analysis was used as an aid for understanding complex human experiences, behaviors, and perspectives in the pre-surgical process. It offers depth and context to research findings, providing nuanced insights in ways that quantitative methods alone may overlook.

Throughout our research, comparing and analysing the experiences of specific participants was essential to determine whether certain pain points were isolated incidents or reflective of broader systemic issues. For instance, if a patient experienced frustration during the check-in process, we could use the tool to "view all patients" and display their journey maps simultaneously (Figure 13). This functionality greatly enhanced the efficiency of our analysis. In this case, by overlaying patient journey maps, we could easily identify the frequency and location of recurring issues within the pre-surgical phase. Additionally, the tool allowed us to

compare patient experiences with those of doctors, nurses, and familial support. This comprehensive analysis from multiple perspectives enabled us to craft more effective interventions that addressed the pain points of all involved parties.

Figure 13. Interactive journey map showing all patient journeys at once for comparison. Each journey includes visual details of the participant's time, location, tasks, tools, and frustrations. Users also have the ability to compare these aspects with those of doctors, nurses, or familial support side by side

The development of interactive journey maps allowed us to go beyond the limitations of traditional, static visualizations. They became invaluable tools for real-time analysis and comparison, enabling us to focus on specific user journeys and overlay them by various factors, such as frustrations, satisfactions, barriers, and participants. This approach to qualitative data analysis allowed us to examine the pre-surgical system at both individual and systemic levels.

As we delved into ideation, we revisited our data to identify recurring themes. Regardless of participant, phase, or location, the issue of time consistently emerged. Hospital staff were overwhelmed with redundant tasks due to system inefficiencies, while patients faced repetitive questions that detracted from meaningful interactions. To address these time constraints, we expanded our exploration beyond traditional health tech solutions.

Our investigation led us to examine how airport systems manage the flow of people and how blockchain technology handles information flow. We ultimately envisioned a decentralized system with centralized information accessible to doctors, nurses, residents, patients, and family members based on their credentials.

The development of this concept was greatly supported by the interactive journey maps. However, acknowledging that UX and service design tools can be complex for non-designers, we adapted our approach to communicate insights more effectively through information visualization. This led to the creation of matrices and rose charts. The solutions matrix provided a high-level overview of system issues, and a detailed account of what frustrations were being addressed along with what proposed solutions were being acknowledged and by whom (Figure 14).

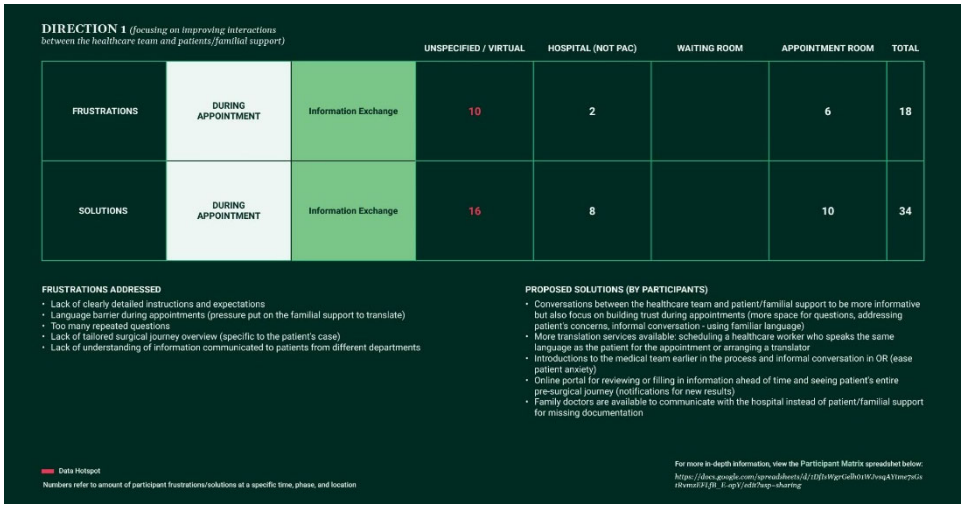

Figure 14. Solutions matrix illustrating potential directions for addressing areas with significant frustration. The matrix highlights the locations of frustrations, presents the proposed solutions, and provides a detailed breakdown of participant insights

The matrices served as a foundation for developing targeted interventions, while the rose charts were valuable for overlaying and isolating quantified data, breaking down various roles and sentiments, and highlighting areas with high volumes of issues. For example, by isolating the perspectives of patients and doctors, the rose charts visually depicted the severity and location of frustrations, allowing stakeholders to quickly identify and understand problem areas without needing to review individual journey maps (Figure 15).

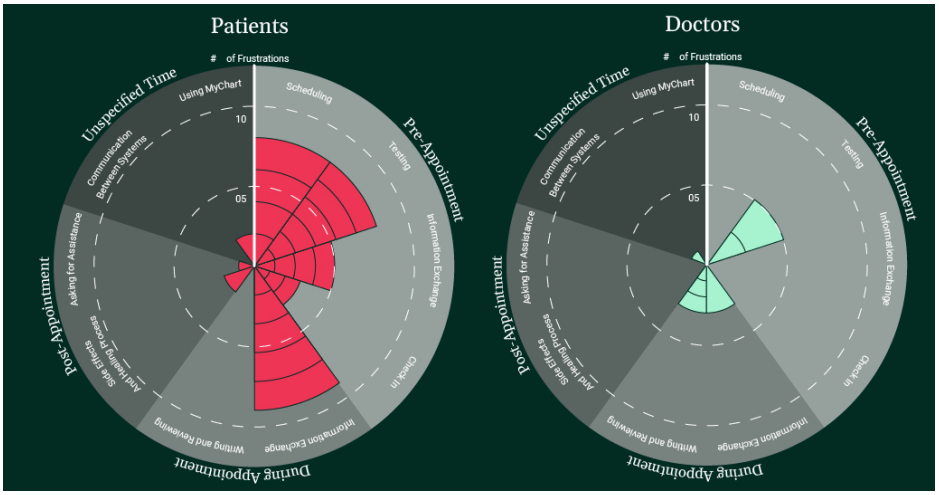

Figure 15. Rose chart illustrating an isolated view of patient and doctor experiences. This visualization enables users to assess the number and location of frustrations encountered by each participant during the pre-surgical phase. By providing this detailed insight, stakeholders can make more informed decisions about deploying targeted solutions

By presenting data through interactive journey maps, matrices, and rose charts, we provided clear and concise representations of complex information. Each method contributed to understanding how the process could be made safer and was crucial in communicating findings to stakeholders. Projects like this, involving large institutions, often require regular strategic reviews to confirm or realign goals. Such decisions can be challenging and time-consuming, significantly impacting the project's future direction. These visualizations facilitate a clear understanding of the data for all parties involved.

5. REFLECTION

Early on, we realized that the traditional design stages of 'discover, define, develop, deliver' would not work for our research project. Healthcare systems are inherently complex—challenging to navigate as designers and even more so for users. In the first phase, we analysed the system comprehensively and developed a roadmap, only to find that the complexity hindered the emergence of a better system.

In response, we shifted our focus in the second phase to human experience, leading us to create customized tools—interactive journey maps, matrices, and rose charts—specifically tailored for this project. These tools provided a deeper understanding of potential interventions and detailed data analysis.

Design methodologies proved an effective way of finding areas of opportunity and interventions within the healthcare system. By combining systems design with user-centered design principles, we forged an interdisciplinary strategy that not only drives innovation but also creates experiences that truly resonate with people. At its core, this process places humans at the center of it all.

6. CONCLUSION

The Canadian healthcare system, plagued by underfunding and understaffing, creates a vicious cycle where healthcare workers are burdened with tasks that do not align with their skills, preventing them from focusing on their core responsibilities. Meanwhile, patients experience the system's shortcomings as they struggle to receive the meaningful human interaction they should expect. This underscores the systemic issues impacting both healthcare workers and patients alike.

This paper introduces a novel approach to solving these issues by combining established systems design and user-centered design methodologies to explore the complex socio-technical system of pre-surgical care. This approach and the following methods can be applied for future use-cases when identifying opportunities and informing design guidelines for systems improvement.

Recommendations include: 1) involving multidisciplinary perspectives ranging from engineering, health sciences and education, health care delivery improvement, and health care technologies 2) methodologies with quantitative and qualitative approaches 3) integration of sociotechnical systems with a focus on human-technology interactions 4) the design of person-centered systems taking into account human needs and recognition of the impact of

social disparities and inequities on health. This last point requires a methodology such as user-centred design which places humans at the center of healthcare delivery.

Designing for healthcare is fundamentally about prioritizing human-centered design before technology. Throughout the process, we discovered a lack of humanity within the system, which drove our commitment to elevating the human experience rather than merely focusing on building dashboards or reducing forms. Human factors play a crucial role in this endeavor as they aim to optimize work systems and the interaction between social and technical elements. Combining both human factors' systems engineering with user-centred design practice ensures a more interdisciplinary methodology. It connects socio-technical systems, human-technology interactions, and the practice of designing from a person-centred lens. This approach ensures that our solutions are both effective and genuinely aligned with the desires of the people they serve.

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