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A User Experience Model for Health Data Visualization for Managerial Decision Support

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Background and Purpose: In public health management, decision-making is heavily reliant on data derived from routine health information systems (RHIS). However, the increasing volume of data necessitates the development of decision-support tools to facilitate data visualisation (DataViz). Despite the availability of several tools, the varying requirements of health managers, based on their respective decision-spaces, contexts, content needs and personal attributes, pose a challenge. Drawing on a public health medicine perspective, this study aims to develop a User Experience (UX) model for the Western Cape Department of Health and Wellness to improve the design of RHIS DataViz systems.
Methods: The study involved a comprehensive description of the RHIS policy landscape, structures, and processes to understand the regulatory context. A literature review was conducted to investigate the theories and application of UX in RHIS. A Proposed UX model for RHIS DataViz was developed based on the International Organisation for Standardization's definition of UX, and components from other UX models. The model was tested through a case study involving interviews with 15 health managers, which were subsequently analysed thematically. A focus group was conducted to refine the model, and its final version was evaluated by external subject-matter experts.
Results: The final UX Model for RHIS DataViz emphasises the importance of purposeful storytelling of RHIS data content. However, it also recommends mindfulness of the cognitive load placed on health managers and the range of contextual factors affecting their UX.
Conclusions: The UX Model for RHIS DataViz can be a useful guide for UX practitioners and business analysts while exploring health manager RHIS DataViz requirements. Moreover, the multi-method study, rooted in the design science research paradigm, demonstrates the agility of public health medicine in assimilating innovative research methods.

Keywords: user-centred design, health information systems, routinely collected health data, decision support, design science

1 Introduction

In public health management, decision-making is significantly reliant on data, particularly from Routine Health Information Systems (RHIS) [1]. These systems are designed to support health managers by providing timely, accurate, and comprehensive data to inform decisions on service delivery, resource allocation, and health outcomes improvement. However, as the volume of data collected by RHIS increases so does the complexity of interpreting and utilizing it effectively. Health managers must navigate a wide range of data points, often without adequate decision-support tools to visualize or contextualize this information, making the process overwhelming and time-consuming [2, 3].
Data visualisation (DataViz) helps to convert complex health data into forms that are easier to interpret and use [4]. By providing visual representations of patterns and trends, DataViz can support health managers in drawing insights that may not be immediately evident in raw data [5]. Yet the process of interacting with data is not always straightforward. In the context of RHIS, the usability of DataViz tools plays a significant role in shaping how information is interpreted and whether it informs practical action. Tools that are poorly aligned with users' cognitive processes or decision-making contexts may hinder rather than assist [6].

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Within the Western Cape Department of Health and Wellness (WCDHW), this problem is compounded by the wide range of decisions that managers face. These range from immediate operational responses to long-term service planning, each requiring different forms of data interaction [3]. The entities and facilities under managerial oversight are themselves heterogeneous, ranging from primary health care clinics through district and regional hospitals to central academic hospital complexes, each with distinct scale, case mix, and information requirements. Moreover, the diversity of the management workforce adds another layer of complexity. Not all managers are equally comfortable with digital tools, and levels of data literacy vary considerably across the system. A tool that supports one user group well may present barriers to another. There is a need to better understand how DataViz design choices interact with these varying contexts and capacities, so that RHIS tools can more effectively support managerial work.

One of the persistent challenges in developing RHIS DataViz tools lies in the lack of a deliberate user-centred design approach, particularly in how these tools support the user experience (UX). The ISO 9241-210 standard defines UX as encompassing the perceptions and responses that arise from both the actual and anticipated use of a product, system, or service [7]. These responses extend beyond technical functionality, encompassing a wide range of elements such as emotions, beliefs, preferences, perceptions, and even physical and psychological reactions during use. At its core, UX speaks to how users engage with a system, including dimensions of usability, accessibility, and satisfaction [8]. In practice, when the UX of a DataViz tool is poor, health managers may struggle to interpret the information presented to them or to act on it in a timely manner. The result can be a missed opportunity to improve services or address emerging issues [9]. For this reason, a considerable argument can be made for the development of a UX model that is specifically attuned to the daily realities and challenges of health managers in the WCDHW. Tools that are both practical and intuitive are more likely to be adopted and used in ways that genuinely support data-driven decision-making [9].

RHIS DataViz tools, when well designed, can support more effective decision-making among health managers [5]. A central aim of these tools is to present information in ways that are clear, interpretable, and actionable within the constraints of managers' work environments. In practice, however, many existing tools do not achieve this. Managers are often presented with large volumes of data or complex visual layouts that make it difficult to extract relevant insights [10]. This can reduce the practical value of the information, leaving it underutilised in daily decision-making. The diversity of decision contexts across the health system further complicates tool design. Managers at provincial, district, and facility levels each operate within distinct decision-spaces that require different forms of data support [3]. A district manager, for example, may need high-level population trends to guide strategic resource allocation, while a facility manager may focus on more granular clinical or operational indicators to inform service delivery [9]. Designing DataViz tools that can accommodate such varied needs remains an ongoing challenge.

Existing research has shown that health managers are more likely to adopt RHIS DataViz tools when these systems are aligned with their specific decision-making contexts [9]. However, a lack of user-centred design often results in low adoption rates, with health managers opting to rely on traditional data interpretation methods rather than adopting new technologies [9]. This challenge is further compounded by the varying levels of data literacy among health managers in the WCDHW. A successful UX model must consider these varying levels of familiarity with data analytics tools and provide intuitive, easy-to-use interfaces that minimize the learning curve for users [5].

Despite the growing availability of RHIS DataViz tools, many of these systems have been developed without a nuanced understanding of the user experience of those expected to use them [9]. In the WCDHW, increasing digitisation and harmonisation of RHIS processes have made more data accessible to health managers. Yet this abundance of information, often spread across multiple dashboards, can become overwhelming. Rather than enhancing decision-making, it risks introducing confusion and fragmentation, especially when the design of these tools lacks coherence or alignment with users' cognitive and contextual needs. There is, therefore, a need for a conceptual model that clarifies the factors shaping user experience in RHIS DataViz and can guide the design of more usable, meaningful visualisation tools. The aim of this study is to develop a UX model that will inform the design of routine health information visualisation systems for managerial decision support in the WCDHW.

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2 Methods

2.1 Research Design

This study employed a Design Science Research (DSR) approach to investigate and iteratively refine a conceptual model of UX in the context of RHIS DataViz for managerial decision-making. DSR was selected for its focus on problem-solving through artefact development, making it well-suited for addressing the gap between RHIS tool functionality and user experience in a public health setting [11, 12]. In DSR, an artefact is a constructed output (a construct, model, method, instantiation, or design proposition) that addresses a real-world problem [11]. The artefact developed in this study is the UX model itself, which evolved iteratively through the four DSR phases. The research was situated within the WCDHW, a provincial health system. The system includes 6 districts, 33 sub-districts, 53 hospitals, and over 270 fixed primary care facilities, supported by a layered managerial structure operating at sub-district, district, and provincial levels. This organisational arrangement provided an ideal environment for exploring the intersection between data systems and the decision-making needs of health managers.

The DSR process [Fig. 1] included four iterative phases: problem awareness, suggestion, development, and evaluation. These phases guided the creation of a novel UX model grounded in the real-world experiences of health managers. A mixed-methods design was used to generate, refine, and validate the model. This included qualitative case study methods and structured expert evaluation to ensure both theoretical soundness and practical applicability [12].

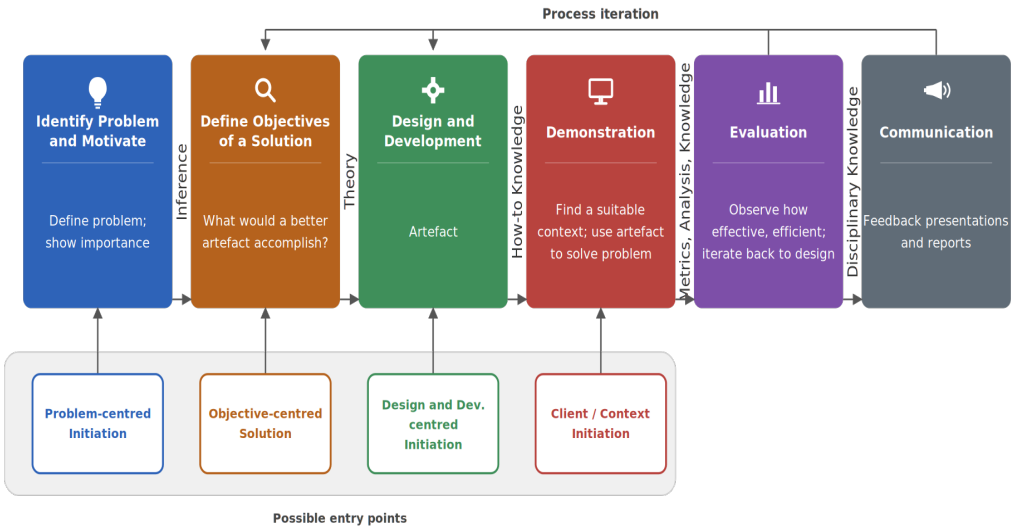

Figure 1: Design Science Research Process. Source: Adapted from Peffers et al.[12]

The study was grounded in an interpretivist epistemological stance, recognising that UX is shaped by users' perceptions, professional values, and contextual realities. The research acknowledged that health managers' experiences with RHIS DataViz are situated, meaning-laden, and shaped by operational constraints. Ontological and epistemological assumptions aligned with the view that these subjective accounts constitute valid knowledge and are essential for designing usable, relevant health information tools. Axiologically, the study aligned with the WCDHW's organisational values of accountability, innovation, and competence, reflecting its strategic commitment to evidence-based service delivery [3, 13].

2.2 Data Collection Methods

Data were collected using multiple qualitative methods to capture a holistic view of managers' UX with RHIS DataViz. These included direct observation, key informant interviews, and a focus group discussion (FGD) in 2020. A purposive sampling strategy was applied to ensure representation across the various levels of management, including participants from both rural and urban settings within the WCDHW.

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Direct observations were conducted during routine meetings such as district executive, and facility performance review meetings. These occasions offered opportunities to see the use of RHIS DataViz for service monitoring and decision-making. Observations provided insight into real-time use of dashboards, the social dynamics of data interpretation, and contextual factors influencing UX.

Semi-structured interviews were held with 15 health managers. Eligible participants were line managers with direct responsibility for clinical service delivery; corporate or support-function managers (finance, human resources, supply chain, infrastructure, information management) were excluded. These interviews explored experiences of using RHIS DataViz tools, factors that supported or hindered their use, and participants' views on what model components were most relevant. The sample size was guided by data saturation, which was reached after 15 interviews. All direct observations and key informant interviews were conducted by the principal investigator, a public health medicine specialist employed within the WCDHW at the time of fieldwork, in order to maintain consistency of interview technique, prompts, and observational lens across the case study group. Reflexive notes were maintained throughout fieldwork to surface potential biases arising from this insider-researcher role, and these are revisited in the Discussion.

FGDs served to cross-check emerging findings and contributed to the co-refinement of the model. Participants reflected on draft model components, shared feedback, and suggested revisions. This iterative process allowed the study to incorporate perspectives from users who engage with RHIS DataViz in everyday practice.

Interview data were collected over a six-month period and were triangulated with relevant policy documents, internal reports, and strategic frameworks from the WCDHW. This ensured alignment with the organisational context and strengthened the credibility of the UX model.

2.3 Case Study Approach

This study was conducted within the WCDHW, a provincial health system in South Africa with a longstanding emphasis on health information systems innovation [14]. A case study approach was adopted to provide an in-depth understanding of health managers' experiences with RHIS DataViz in this context. This method allowed detailed analysis within a specific, real-world context, offering insight into the model's practical relevance and applicability. The framework by Rashid et al. guided this case study, providing a structured approach that included foundational preparations, pre-fieldwork, fieldwork, and reporting [15].

The case was set in a provincial health system with a mix of urban and rural service platforms, a defined operational hierarchy, and an established digital health reporting infrastructure. This made it a relevant and information-rich context for examining how DataViz tools are used by health managers to support routine decision-making. Pre-fieldwork included obtaining ethical and operational approvals, developing a case protocol, and defining the unit of analysis. The case focused on collective managerial experience rather than individual perspectives, reflecting how RHIS DataViz is typically discussed and applied during team meetings and strategic planning.

The case study findings informed the iterative refinement of the UX model. Triangulation with policy documents and strategic plans added depth and credibility to the interpretation process. The case also served as a practical environment for assessing the model's relevance and for eliciting user feedback on preliminary components prior to expert evaluation.

2.4 Model Development and Evaluation

Model development followed the iterative process outlined in Figure 2, drawing on the approach by Becker et al. [16, 17]. An initial UX model was synthesised from the literature, incorporating constructs relevant to RHIS DataViz and UX design. This preliminary model was iteratively refined through user feedback obtained during interviews and focus group discussions with health managers.

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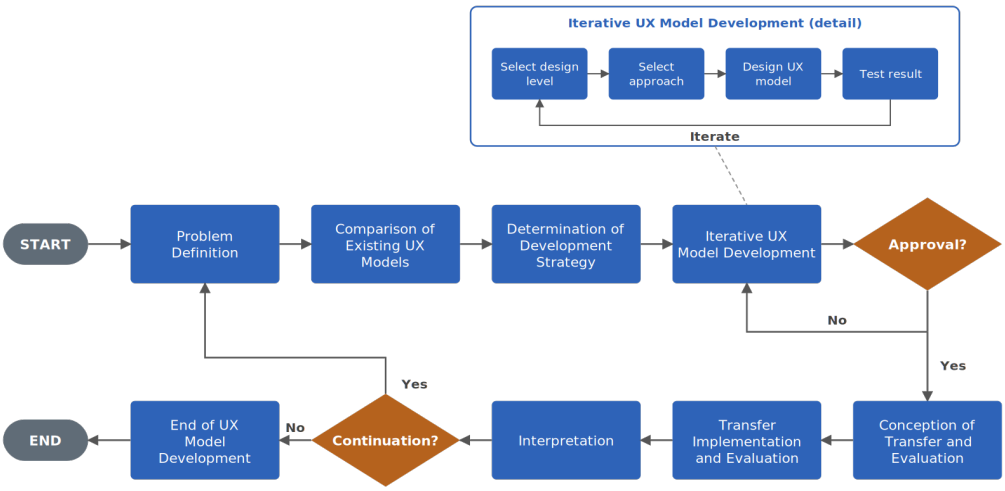

Figure 2: Procedure for Developing a Model for RHIS DataViz. Source: Adapted from Becker, Knackstedt, Pöppelbuß [16, 17]

After a pause in research activities caused by the COVID-19 pandemic, the refined model underwent evaluation in 2022 by eight external experts specializing in user experience, routine health information systems, and data visualisation. Using a structured digital instrument, reviewers rated the usefulness of each component and provided qualitative commentary. Their feedback informed further refinements, resulting in a final UX model tailored to RHIS DataViz in managerial decision-making contexts [16]. The expert evaluators were selected for their independence from earlier research phases and their demonstrated expertise in areas such as UX, health information systems, data visualisation, health management, and decision support. They included public health professionals, policy analysts, human-computer interaction scholars, and business analysts with experience in the South African health system context.

2.5 Data Analysis

The data collected during this study were analysed through both thematic analysis and expert evaluation methods, providing a robust foundation for refining the UX model for RHIS DataViz.

2.5.1 Thematic Analysis of Case Study Data.

Thematic analysis was applied to the data gathered from direct observations, key informant interviews, and focus group discussions with health managers, following the six-step framework outlined by Kiger and Varpio [18]. The steps involved familiarization with the data through repeated readings of interview transcripts and observation notes, generating initial codes using ATLAS.ti™ software, and identifying significant themes related to UX in RHIS DataViz. These themes were reviewed and refined, with names assigned to encapsulate key aspects of managers' experiences. Themes that emerged from this analysis were directly mapped to components of the proposed UX model and provided insights that guided the model's iterative development.

2.5.2 Model Evaluation Analysis.

The refined UX model was then subjected to expert evaluation by eight external reviewers with backgrounds in UX, RHIS, and Data Visualization. Each expert was asked to assess the model's components using a 3-point Likert scale (Useful, Neutral, Not Useful) and provide narrative feedback. Responses were analysed qualitatively by categorizing expert recommendations and comments, focusing on their alignment or divergence from the model's components.

The distribution of responses across the Likert scale was reviewed to identify components rated as particularly useful or needing adjustment. Key insights were extracted from the experts' narrative comments to inform final modifications to the model. This feedback process allowed the integration of

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expert perspectives on RHIS and decision-support contexts, enhancing the model's relevance and practical applicability for health managers.

Together, these analyses contributed to a well-rounded evaluation of the UX model, incorporating both in-depth thematic insights from case study data and validation from expert reviewers.

2.6 Ethical Considerations

This research was approved by the Stellenbosch University Health Research Ethics Committee (Reference No: S18/05/095) and adhered to national and international ethical guidelines, including the Declaration of Helsinki 2013. Written informed consent was obtained from all participants, and efforts were made to minimize disruption to routine managerial duties during data collection sessions. Access to interviewees was arranged through WCDHW's senior management to ensure minimal operational impact.

3 Results

3.1 Case Study Findings on RHIS Data Visualization for Health Management

3.1.1 Organizational Structure and Participant Characteristics.

This study was conducted within the WCDHW, a provincial health system in South Africa with a longstanding emphasis on health information systems innovation. At the time of the study, the WCDHW had implemented a number of digital tools for routine health information, including public- and manager-facing dashboards, yet faced persistent challenges in translating these data into improved service delivery at facility and district levels.

Health managers in this context operated within a complex, multi-tiered governance environment. Their responsibilities spanned from responding to immediate operational issues, such as medicine stock-outs or human resource shortfalls, to aligning services with provincial targets and strategic priorities. These decision-making responsibilities unfolded under pressure from resource constraints, performance mandates, and service delivery expectations, all of which shaped how managers engaged with RHIS data and visualisations.

Fifteen health managers were purposively sampled to represent a range of roles and decision-making levels, including facility-, subdistrict-, district-, and provincial-level management. All 15 participants were line managers with direct responsibility for clinical service delivery; corporate or support-function managers (finance, human resources, supply chain, infrastructure, information management) were excluded by design, as their data needs and information systems differ materially from those of service line managers. Participants were drawn from both urban and rural substructures. Most were experienced users of RHIS tools and had prior exposure to dashboard visualisations, although their technical literacy and comfort with data interpretation varied. The sample included 10 female and 5 male participants, reflecting the gender composition of the provincial management workforce at the time.

Rather than being passive recipients of data, these managers were observed to be active interpreters, interrogating the meaning of indicators, assessing implications for their services, and using visualisations to justify actions or identify gaps. Their feedback revealed a range of contextual, cognitive, and emotional factors that shaped the UX of RHIS DataViz tools. These real-world experiences provided a critical empirical foundation for the iterative development of the UX model.

3.1.2 User Perceptions and Responses to RHIS Data.

RHIS DataViz was consistently valued as a core tool for evidence-based decision-making across all managerial levels. However, participants emphasized that the trustworthiness of the data was paramount for fostering constructive decision-making processes and collaborative relationships. For instance, district-level managers articulated how data-driven accountability forms a cornerstone of WCDHW's ethos. As one participant explained:

"Our intention is to be a recognized leader in health system strengthening and health systems development. To meet that commitment and to influence other systems, it very often comes back to the relationships with people. But you must build that relationship. We need to have a deeper understanding

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of the issues and tap into making the connections with other people. This is based on the fact that everybody is accountable for something." – **Participant 10**

The case study indicated that RHIS data plays a dual role: on one hand, it reinforces accountability by documenting service performance; on the other hand, it can foster or undermine relationships depending on its perceived purpose. Several managers expressed concern that RHIS data might sometimes be perceived as punitive, as it could be used to critique performance rather than facilitate shared problem-solving. As one manager noted:

"In one example, the HbA1c data of diabetic patients was problematic. When I highlighted this to health care workers on site visits, they felt threatened. 'She's coming here to find something wrong and not listen to us first!' So how do I make sure that the data doesn't become a hindrance in relationships? Data should just be one of the inputs for your understanding the system performance." – **Participant 10**

These findings underscore the importance of transparency and support within the RHIS DataViz systems to enable managers to interpret data without fearing repercussions, thereby fostering a data culture focused on mutual understanding and service improvement.

3.1.3 Task Context: Managing Service Delivery and Corporate Functions.

The WCDHW requires managers to engage with RHIS data across a range of responsibilities, from direct patient service delivery to corporate functions like finance and HR. This dual focus created unique task demands that shaped participants' interactions with RHIS DataViz tools. At the facility and district levels, managers cited substantial challenges in accessing data needed to fully understand the local burden of disease. This was particularly evident among managers responsible for developing business cases for service expansion or improvement, where data was often incomplete or required a patchwork of information from multiple sources.

"*We knew the burden of disease in our community was really heavy. We did not previously have access to public health specialists when building the business case, but I knew it was a community with significant burden of disease both in infectious diseases such as HIV and TB as well as high interpersonal violence, and substance use mainly alcohol-driven violence based on EMS [Emergency Medical Services] data*." **– Participant 15**

In contrast, corporate functions such as *people management* and *finance* required managers to adopt a different analytical lens, which some participants found challenging given their clinical backgrounds. For example, Participant 4 described feeling underprepared for analyzing people management and finance data:

"*My staff are not actually skilled and equipped to analyse that data for me. I am struggling with other datasets like finance and HR. They're on top of the Quality Assurance data. But finance and HR data is a bit of a struggle for me. And to make decisions on that, I only have the APL [Approved Post Listing] which is numbers… I struggle actually to make sense of HR data."* **– Participant 4**

The findings suggest that RHIS DataViz tools must be versatile and accommodate both clinical and corporate data analysis to meet the varied needs of health managers effectively.

3.1.4 Social and Organizational Contexts.

The role of RHIS data in promoting transparency and collaboration was repeatedly emphasized by participants, who highlighted that data transparency can bolster trust across different management levels and with external stakeholders. However, managers expressed concerns that data misuse could strain relationships within the health system, especially when data is perceived as a means of oversight rather than improvement.

Participant 2 illustrated this trust-building potential by discussing how community stakeholders viewed data as an "equalizer" in establishing shared goals:

"*The Health Committee can also engage the data and say that 'Wow, now we have a narrative between us to say that we really are happy with what you guys have been doing.' And I think data can actually play a very important role as being the equalizer especially with the conflict-ridden space like Health."* **– Participant 2**

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Participant 10 echoed this sentiment, emphasizing that while data is essential for fostering accountability, it should be positioned as one of many inputs in decision-making rather than as a performance metric that could strain relationships.

3.1.5 Presentation, Data Quality, and Data Storytelling.

The presentation of data and its storytelling capacity were key themes in participants' experiences with RHIS DataViz. Several participants emphasised that data must "tell a story" to effectively support decision-making, suggesting that raw numbers alone are insufficient. Managers, particularly at the district and provincial levels, underscored the importance of following a coherent narrative, referred to as the "golden thread", to ensure that data insights align with the WCDHW's strategic goals.

"C*ertain data elements are more important than others. These tell a more strategic story. One needs to discover that story. And whether that story is linked to the strategy of the Department."* **– Participant 10**

Furthermore, data quality was highlighted as a concern, with participants indicating that inconsistent or fragmented data undermines decision-making and hinders trust. Managers were often cautious when assessing data quality and would cross-reference information to verify accuracy before making critical decisions.

3.1.6 Cognitive Load and Interactive Flexibility.

Participants repeatedly expressed concerns regarding the cognitive load imposed by the volume and complexity of data indicators required for routine reporting. While the Provincial Indicator Workgroup had made efforts to streamline these indicators, managers still found the sheer volume of information to be overwhelming.

"*I come from an office space where you work with data, where you see data, you're sitting in these types of meetings. But I think clinicians can only..., for the large part, most managers are old clinicians. They can only take in a certain amount of information*." **– Participant 2**

Additionally, participants noted that RHIS DataViz tools would benefit from interactive features allowing them to tailor data presentations to suit specific reporting needs. For example, managers expressed a desire for functionality that enables them to calculate indicators directly within RHIS tools to reduce manual data handling.

"Why can't they work on an indicator report where you don't have to do that [calculate manually]? Although I think it's a good exercise because then you will understand how the indicator is built. You need to know what must be divided by what to get the information." **– Participant 8**

3.2 Adjustments to the UX Model for RHIS DataViz based on the Case Study Findings

3.2.1 Managers' Insights on Model Components.

The UX Model's components resonated with participants across several dimensions, including User Perceptions and Responses, Context of Use, Interaction with RHIS DataViz, and User Internal & Physical State. Key themes that emerged as crucial to managers' RHIS DataViz experiences included Emotions and Comfort, Cognitive Load, Social and Organizational Contexts, and Data Quality. Participants provided feedback suggesting that the model accurately reflected their interactions with RHIS DataViz but recommended additional elements, such as data storytelling, to better capture the complexities of managerial decision-making.

3.2.2 Recommendations for Model Refinement based on the Case Study Findings.

Based on the case study findings, specific refinements to the Proposed UX Model were suggested:

a) Incorporate Data Storytelling: Develop a narrative element that guides managers through data insights to support cohesive decision-making.
b) Prioritize Cognitive Load Reduction: Limit data indicators to essential metrics, with options to drill down selectively, thereby minimizing cognitive strain.

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c) Highlight Data Quality Assurance: Ensure that RHIS DataViz tools enable managers to access high-quality, integrated data sources to build trust in the decision-making process.
d) Enhance Interactivity: Incorporate functionality that allows managers to customize data presentations, including automated calculations and the option to generate tailored reports.

These refinements aimed to enhance the utility of the UX Model for RHIS DataViz and better align it with WCDHW's unique operational needs, as voiced by the participants.

3.3 Evaluation of the Refined Model

A total of eight expert evaluators were invited to participate, of whom six provided informed consent and completed the evaluation.

The four main branches of the model: (1) User Attributes, (2) Interaction with RHIS DataViz., (3) User Perceptions & Responses, and (4) Context of Use, were generally evaluated as useful. Five of the six responding evaluators affirmed the overall usefulness of these components. For instance, Evaluator 1 said, *"All four components of the UX are important and will impact on the UX and thus the benefit of the information to the manager and therefore ultimately to the health system as a whole."* Similarly, Evaluator 5 remarked, *"The main components of the model are useful … exactly what will be needed when developing a tool to assist managers who are making the decisions."*

There was, however, critical engagement with certain subcomponents. The "Brand Image" subcomponent received neutral to negative feedback and was ultimately removed from the model. Evaluator 1 commented, *"The brand image doesn't fit in … and could well be left out without any negative impact."*

Conversely, support was strong for the inclusion of "Cognitive Load." Evaluator 3 emphasised, *"'Cognitive load' brings to mind 'Less is more'—it is true for art and data presentation alike."*

The evaluation process led to targeted refinements, including the renaming of "Big Picture" to "Level of Abstraction" and the removal of overlapping or less clearly defined subcomponents such as "Situational" and "Training."

Finally, all six respondents endorsed the model in its entirety. Evaluator 3 stated, *"This is an extremely comprehensive model … the research generated by implementing this model could lead to the development of guidelines that could transform the eHealth software space."* Evaluator 6 added, *"It does not replace the need for input from knowledgeable domain experts … but it does provide the potential for improved communication between developers and domain experts."*

This expert evaluation affirmed the relevance and applicability of the model and informed the final iteration of the UX Model for RHIS DataViz., marking the conclusion of the model development process.

3.4 Final UX Model for RHIS DataViz

The final UX model [Fig. 3] defines UX as health managers' perceptions and responses that arise from interacting with RHIS Data Visualisation tools. These experiences are influenced by four main components: User Attributes, Context of Use, Interaction with RHIS DataViz, and User Perceptions and Responses.

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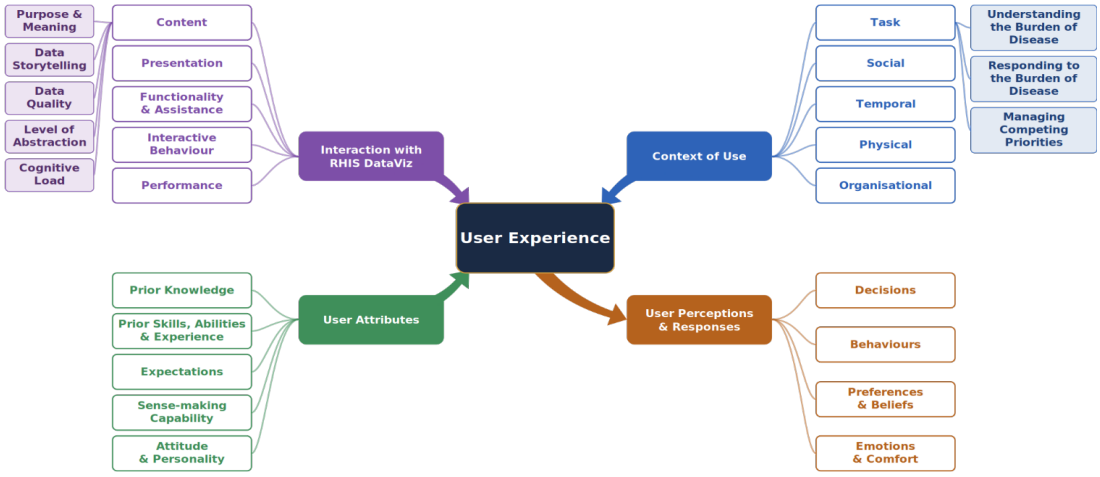

Figure 3: User Experience Model for Health Data Visualization for Managerial Decision Support

3.4.1 User Perceptions and Responses.

These refer to the outcomes before, during, or after interacting with RHIS DataViz.

- *Decisions*: Actions taken after interpreting data, such as allocating resources or adjusting priorities.
- *Behaviours*: Changes in managerial habits (e.g. increased engagement with staff or reports).
- *Preferences and Beliefs*: Evolving views about visual design or trust in data sources.
- *Emotions and Comfort*: Feelings ranging from frustration to reassurance during interaction.

3.4.2 Interaction with RHIS DataViz.

This includes the design and functional elements of the system that shape the user's experience.

- *Content*: The indicators or data elements visualised, including:
  - *Purpose and Meaning*: Clear rationale for data visualisation.
  - *Data Storytelling*: The narrative quality of the information.
  - *Data Quality*: Completeness, accuracy, and reliability.
  - *Level of Abstraction*: Ability to drill up/down through data layers.
  - *Cognitive Load*: The mental effort needed to interpret the visuals.
- *Presentation*: How data is displayed (e.g. charts, maps, infographics).
- *Functionality and Assistance*: Features that support use, such as filters or tooltips.
- *Interactive Behaviour*: How the system responds to user actions.
- *Performance*: Speed and responsiveness under typical working conditions.

3.4.3 Context of Use.

This refers to the broader setting in which the tool is used.

- *Task Context*: The work involved in understanding and responding to the burden of disease, and in balancing competing service priorities.
- *Social Context*: The interpersonal dynamics that shape interaction with data in team or oversight settings.
- *Temporal Context*: How long the user has been exposed to the tool, influencing comfort and ability.
- *Physical Context*: The physical environment and devices used (e.g. office desktop vs tablet in clinic).
- *Organisational Context*: The values, policies, and strategic imperatives that influence the user's framing of data.

3.4.4 User Attributes.

These refer to characteristics that influence how users interpret and interact with data.

- *Prior Knowledge*: Familiarity with indicators, systems, and decision-making roles.
- *Prior Skills, Abilities and Experience*: Tacit or practical knowledge relevant to RHIS data use.

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- *Expectations*: Expected functionality based on previous digital tools.
- *Sense-making Capability*: Capacity to derive meaning from diverse data inputs.
- *Attitude and Personality*: Individual differences in engagement, trust, and analytical preference.

4 Discussion

4.1 Insights from Iterative Model Development in a Public Health System Context

The application of the UX model to RHIS DataViz surfaced valuable insights about the realities of managerial data use in a provincial public health system. The case study revealed that health managers work within a context shaped by competing priorities, fluctuating workloads, and differing levels of data literacy. These contextual nuances had direct implications for how users engaged with visualised information, how they derived meaning from data stories, and how they acted upon insights. For instance, health managers found that features such as interactive drilldowns and layered data summaries enhanced usability, but only when aligned with their information needs and cognitive bandwidth. These findings affirm the need for user-centred RHIS design that is not only technically functional but also cognitively ergonomic [6, 10].

The concept of "cognitive load" emerged as a recurring theme. Several managers reported feeling overwhelmed when presented with dashboards that included large volumes of data or lacked narrative structure. This finding supports the inclusion of "data storytelling" and "level of abstraction" as core model components [19, 20]. Moreover, emotional responses to data, ranging from frustration to pride, highlighted the affective dimensions of UX in health systems, echoing earlier literature that calls for a broader conceptualisation of UX beyond mere usability [8, 21].

Evaluation feedback from expert reviewers further reinforced the model's practical relevance. Reviewers highlighted that contextual subcomponents, such as organisational priorities and physical environment, were often overlooked in existing health IT implementations. The refined model's attention to these aspects was viewed as an important corrective. For example, the component "managing competing priorities" was praised for capturing the dilemma of balancing local service needs with provincial or national targets, a reality previously documented in South African PHC contexts [3].

The usability of the model itself also came under scrutiny. Reviewers appreciated the layered structure and the descriptive clarity of components but recommended refinements in terminology to make the model more accessible to non-specialist users. Consequently, several terms were revised. For instance, "Big Picture" was renamed to "Level of Abstraction", to improve resonance with target users. These adaptations illustrate the iterative nature of DSR and the importance of continuous user feedback in artefact refinement [11, 12].

Overall, the model proved useful in bridging the gap between technical data design and managerial decision-making practice. It clarified how users make sense of visual data under real-world constraints and illuminated factors that promote or hinder effective use. These insights confirm the value of integrating UX theory into RHIS design and suggest that the model has utility beyond the specific case setting, particularly in other LMIC health systems undergoing digital transformation.

A further consideration concerns the relationship between trust in DataViz and trust in upstream data collection. Well-designed visualisations cannot generate confidence in decision support if managers doubt the accuracy or completeness of the underlying records. Visualisation features such as data lineage display, quality flags, and drill-down to source records can support trust at the point of use, but their effect is contingent on a functioning data assurance ecosystem upstream of the dashboard. The UX model therefore needs to be read as one component within a broader information quality system rather than a stand-alone solution.

A second consideration concerns the practical tension between standardisation and context-specific visualisation. Dedicated UX support for each manager is impractical at scale within a public health system. Generative AI and natural language query interfaces offer one possible direction, allowing managers to interrogate a common dataset through plain-language questions and receive visualisations shaped to their specific decision context. Realising this potential will depend on careful attention to UX design principles, governance arrangements, and data privacy safeguards, and warrants further investigation.

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4.2 Contribution to Theory and Practice

This study contributes a novel theoretical model of UX tailored to the RHIS data visualisation needs of health service managers. While existing UX models tend to emerge from consumer, web-based, or product design contexts [8], this model foregrounds the cognitive, contextual, and managerial demands of decision-making in public health systems. The model draws on the ISO definition of UX [7] but extends it by including context-specific subcomponents such as "managing competing priorities," "sense-making capability," and "level of abstraction." These elements were confirmed to be important by evaluators and distinguish the model from general UX frameworks.

Theoretical value lies in the way this model bridges the fields of UX, health informatics, and systems thinking. It integrates both human-computer interaction (HCI) principles [22] and health governance [3, 13], presenting UX as an emergent phenomenon situated in complex, resource-constrained environments. This is especially pertinent for low- and middle-income countries (LMICs), where managerial decisions must often be made with imperfect data, limited time, and competing demands [23].

In practical terms, the model provides development teams and public health stakeholders with a structured yet flexible framework to assess, design, and procure RHIS data visualisation tools. Its language, refined through expert feedback, supports better alignment between software design and managerial workflow. For instance, the revision of "Big Picture" to "Level of Abstraction" made the concept more intuitive and technically applicable for both users and developers. Moreover, the model can inform procurement specifications, design requirements, and formative evaluation during RHIS dashboard development. The removal of less relevant components (such as "Brand Image") shows the importance of contextual relevance and responsiveness in model development. These practical implications underscore the value of DSR in producing artefacts that are not only theoretically rigorous but also aligned with real-world implementation needs [11, 16].

The model also complements emerging local research on the UX of digital health systems in the Western Cape. Recent work on the UX of electronic medical records in the Western Cape public health sector highlights similar challenges of cognitive burden, contextual complexity, and the need for user-centred design [24]. Together, these studies suggest that UX theory can offer a unifying perspective for advancing the design of both RHIS and clinical information tools in this setting. The present model extends this agenda by providing a structured framework specifically tailored to RHIS DataViz and decision-support contexts, with potential application across other LMIC health systems.

4.3 Study Limitations

This study's scope and method present several limitations that should be considered when interpreting the findings. The empirical component was limited to a single provincial health system in South Africa. Although WCDHW has demonstrated significant investment in health information systems and digital initiatives [14, 25], the organisational arrangements, levels of digital maturity, and governance structures in this setting may differ from those in other South African provinces or low- and middle-income countries (LMICs). While the study offers in-depth contextual insights, the broader applicability of the findings would require additional adaptation and validation in diverse settings [6, 9].

The case study and model evaluation primarily involved operational and strategic health service managers. While this user group was appropriate for the RHIS DataViz use case, perspectives from other potential users such as policymakers, data capturers, analysts, or clinical teams were not explored in depth. Similarly, patients and community stakeholders were excluded, even though their inclusion is increasingly valued in user-centred digital health design [23].

Although the expert evaluation confirmed the model's relevance, face validity, and clarity, it relied on structured survey instruments rather than real-world implementation or usability testing. The model was not instantiated into a working prototype, and its application to live RHIS dashboards remains to be evaluated. Future studies should empirically assess how applying the model influences users' comprehension, decision-making quality, or system usability [26].

Although cognitive load and contextual complexity were recognised as influential components of UX, this study did not systematically quantify these constructs during evaluation. Their influence was inferred from qualitative interviews and expert feedback. Further research could benefit from incorporating validated instruments for measuring these dimensions [10].

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The principal investigator's insider position offered familiarity with the organisational context, established relationships of trust with participants, and an understanding of the operational pressures under which managers worked. It also carried the risk of confirmation bias and of participants moderating their responses in the presence of a fellow employee. These risks were mitigated by maintaining reflexive notes throughout fieldwork, by triangulating observational and interview findings against the policy review and the subsequent expert evaluation, and by securing access to participants through senior management rather than through the principal investigator's own service relationships.
Despite these limitations, the study offers a rigorous and contextually grounded contribution to understanding UX in RHIS Data Visualisation for managerial use, and a foundation for future applied research and design.

5 Conclusion

This study contributes a novel, theory-informed, and contextually grounded model of UX RHIS data visualisation, designed to support managerial decision-making in a public health setting. By applying DSR methodology, the model was iteratively developed, refined, and evaluated through empirical engagement with health managers and expert reviewers. It advances current understanding of UX in RHIS applications by explicitly incorporating the contextual realities, user attributes, and cognitive processes unique to public sector decision-making.
The model's strength lies in its relevance to operational and strategic health managers who must interpret complex health data while navigating multiple organisational demands. It provides a practical and theoretically robust foundation for improving data use in health governance, offering value not only to system designers but also to implementation teams seeking to enhance dashboard usability, policy alignment, and service responsiveness. While the model is rooted in a specific provincial context, its components reflect broader challenges and dynamics present across many health systems globally, particularly in low- and middle-income countries. Future work should explore its application in different digital maturity settings, assess its influence on decision quality, and examine its adaptability to participatory or patient-facing RHIS tools.
In an era of increasing data availability, strengthening the usability and uptake of health data remains a strategic imperative. This model represents a step toward more human-centred, context-aware digital health systems that enable meaningful engagement with data for better health outcomes.

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Statement on conflicts of interest

RD and HM were employed by the WCDHW at the time of the study, which constitutes a potential conflict of interest. Mitigation measures are described in the Study Limitations. DvG declares no competing interests.

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