Designing Dashboard for Healthcare and Resource Information for CHUK.

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ABSTRACT
Health data and resource management pose significant challenges to healthcare systems in resource-limited settings, such as Rwanda. At the University Teaching Hospital of Kigali (CHUK), outdated paper-based systems and fragmented data sources contribute to inefficiencies in patient care, delayed decision-making, and suboptimal performance. The lack of a centralized dashboard for real-time data access further exacerbates issues related to resource management and patient safety.

Method: To ensure a user-centered design, a structured questionnaire was administered to 162 respondents, including both medical and non-medical staff at CHUK. Key features such as data visualization, accessibility, and integration with the existing OpenClinic Electronic Medical Records (EMR) system were identified as priorities.
The dashboard was developed using Vue.js and Tailwind CSS for the front end, with PHP, Laravel framework for the back end, and MySQL as the database. An iterative development process was used, incorporating stakeholder feedback to continuously refine the prototype and ensure alignment with user needs.

Results: The user assessment identified critical needs for the dashboard, with 86% of users recommending key performance indicators such as the total number of patients per department and disaggregation by diagnosis. The findings also demonstrated a significant positive relationship between the dashboard and stakeholders' data management priorities ($r=0.921, p=0.000r = 0.921$, $p = 0.000r=0.921, p=0.000$), emphasizing its impact on clinical care quality.

Conclusion: In conclusion, the development of a healthcare and resource management dashboard for CHUK represents a transformative opportunity to improve decision-making, reporting accuracy, and overall healthcare delivery. The successful implementation of the dashboard will enhance operational efficiency, and it is recommended that CHUK staff actively support its adoption to maximize its impact.

Keywords: Dashboard, health data, healthcare information, Resource information.

I. INTRODUCTION.

In the past, healthcare systems worldwide, including those in Africa and specifically in Rwanda, faced significant hurdles in data management and decision support due to outdated dashboard designs(Obinna, et al., 2019)(Sulaiman, et al., 2023). These challenges were especially acute in resource-constrained environments, where access to timely and accurate data is paramount for effective healthcare delivery(Prabath & Roshan, 2023). Rwanda, like many other African nations, confronted the dual challenge of enhancing healthcare outcomes while contending with limited resources and infrastructure(Alphonse, et al., 2020).

Research extensively underscored the pivotal role of well-crafted dashboards in global healthcare contexts, highlighting their capacity to streamline data management processes and augment decision support. Studies by (Smith, 2019) and (Johnson, 2021)spotlighted the affirmative influence of user-centered dashboard design on healthcare professionals' proficiency in interpreting and leveraging data efficiently. However, a literature gap exists concerning dashboard design customized to suit the distinctive challenges and contexts of African healthcare systems, including those in Rwanda.

Paper based data management, not only led to dissatisfaction of the administrative managers, excessive tiredness among healthcare

personnel might have negatively impacted patient safety (Beck, 2018). In addition, using data in administrative and clinical procedures was hard due to its huge volume, multiple sources, and lack of structured organizational structure of how data is collected and stored. Inefficient data management and display could have resulted in increased clinical errors (Gunjan, et al., 2024) ,delayed care delivery (Gunjan, et al., 2024), and decreased patient safety (Davis, 2023)

Dashboards served as tools for overseeing organizational performance(Ehsan, et al., 2023) , presenting data amalgamated from various sources to offer a comprehensive view of organizational performance. This eliminated the need for managers to go through multiple reports and compile data themselves (Reza & Sohrab, 2022),providing pertinent, timely insights into business performance to facilitate prompt and appropriate responses to issues(Sudesh & Neha, 2020).By offering a consistent performance view across the organization, dashboards fostered a shared understanding of common goals and enabled alignment towards the same objectives (Sudesh & Neha, 2020).

I.1. Situation at CHUK.

CHUK was one of the facilities, which was the largest referral hospital in Rwanda with 565 beds, and a catchment area of more than 6.2 million people (Rwanda Biomedical Center;, 2020). This hospital faced the challenges of a growing patient population, resource constraints, and a need for enhanced performance.

In the dynamic landscape of healthcare, CHUK faced challenges in optimizing data resource management for informed decision-making and efficient healthcare delivery. The absence of a comprehensive dashboard system as a tool for data resource management might have resulted in inefficiencies, hindered access to critical information, and potentially compromised the accuracy and timeliness of healthcare data.

The University Teaching Hospital of Kigali faced challenges in efficiently managing and accessing critical healthcare data. Currently, it lacked a comprehensive dashboard system that could provide real-time insights into patient care, resource allocation, and operational efficiency. As a result, healthcare providers and administrators struggled to make informed decisions promptly, leading to potential delays in patient care, inefficient resource utilization, and suboptimal hospital performance.

CHUK had traditionally relied on paper-based systems where data was scattered across patient files, registers, and open clinics, creating significant gaps in data management. This fragmented approach hampered the hospital's ability to deliver high-quality patient care, as healthcare professionals struggled to access and utilize critical information effectively. The lack of centralized and real-time data insights hindered decision-making processes, impeded the hospital's ability to monitor key performance indicators, and delayed responses to emerging healthcare trends.

Designing a customized dashboard for CHUK was therefore essential to bridge this critical gap. The dashboard would have integrated and visualized healthcare and resource information in real time, empowering the hospital to make data-driven decisions, enhance operational efficiency, and improve patient outcomes(Fatemehi, et al., 2021).

Healthcare dashboards are categorized into three main types: operational, tactical, and strategic. Each type serves distinct purposes and targets different levels of decision-making within healthcare organizations(Anon., 2009). Operational dashboards focus on the day-to-day activities and real-time operations within a healthcare facility. They provide immediate insights into the performance of clinical and administrative functions, such as patient flow, staff allocation, and resource utilization (Kamel Boulos, 2023). Tactical dashboards are used for mid-term planning and decision-making, typically focusing on metrics and performance indicators over a span of weeks or months. They help managers and department heads to assess the effectiveness of ongoing projects and initiatives (Dixon, 2022). Strategic dashboards are designed for high-level, long-term planning and decision-making. They offer an overview of the organization's performance in relation to its long-term goals and strategic objectives

I.2. Healthcare Dashboards, real time data analysis and their impact.

Dashboards in healthcare settings have been adopted for their potential to enhance operational efficiency and patient care in general. According to a study by (Kamel Boulos, 2023), healthcare dashboards improved clinical workflows by providing real-time data on patient metrics, resource utilization, and operational performance. This real-time access enabled healthcare professionals to make informed decisions quickly, thereby optimizing patient outcomes and resource management. Similarly, a review by (Jzerman,

2022) revealed that dashboards facilitated better monitoring of key performance indicators (KPIs) and supported evidence based practice.

Real-time aggregated data availability on dashboard plays a crucial role in healthcare by enabling immediate insights and actions that enhance patient care and operational efficiency. At department level, It allows healthcare providers to continuously monitor patient vital signs, track the status of ongoing treatments, and manage hospital resources dynamically(Patrick, et al., 2019). According to (Kamel Boulos, 2023), real-time data facilitates early detection of adverse events, timely adjustments in treatment plans, and rapid responses to changes in patient conditions, thereby improving overall clinical outcomes and operational effectiveness.

In addition to benefiting patient care, real-time insights are crucial for effective resource management within healthcare settings. By continuously monitoring resource utilization, such as bed occupancy, staff allocation, and equipment availability, real-time data helps hospitals optimize their operations and reduce inefficiencies. (McGonigle, 2022), highlight that real-time dashboards enable healthcare administrators to make data-driven decisions regarding resource allocation, identify potential shortages, and streamline workflows. This proactive approach not only improves the operational efficiency of healthcare facilities but also contributes to cost savings and better overall management of resources, ensuring that patient care is delivered effectively and efficiently.

II. METHODOLOGY.

This study is comprised of two main components. The first component aimed to quantify the existing gaps in data management at the University Teaching Hospital of Kigali (CHUK) and to comprehensively understand user needs for the proposed dashboard system. To achieve this, a structured questionnaire was developed to gather quantitative data. The questionnaire focused on assessing user requirements related to dashboard design, usability, and user-friendliness, as well as workflows involving patient tracking, data entry processes, and methods for data storage and retrieval.
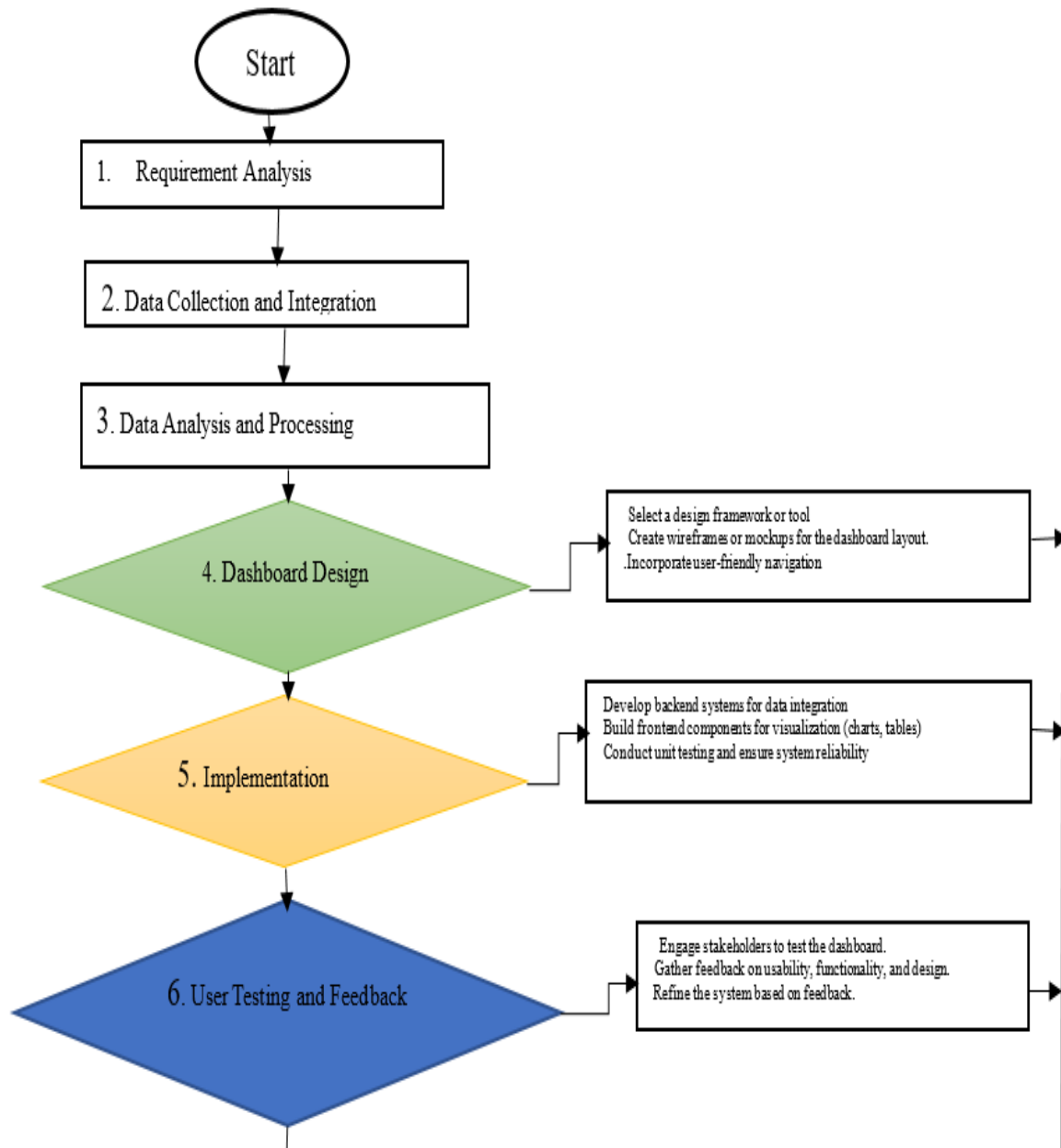
This study employed a descriptive research design, utilizing standardized research questionnaires and SPSS V.23 for data analysis, highlighting the analytical approach taken. Stratified sampling was used to select a representative sample from the entire population of CHUK, which included student researchers, data managers, IT help desk personnel, nurses, and medical doctors.

The study population at this hospital was 278 staff who interact with data at least at one data cycle step. At a Confidence Level (CI) of 95% and precision level of 5%, Cochrane formula (Singh & Masuku, 2014)was used to get the number of sample participants which we can better represent whole population. Where n is the desired sample, n0 is the initial sample size, Nthe total number of finite population .

$$n = \frac{n_0}{1 + \frac{(n_0 - 1)}{N}}$$

Equation 1. Cochrane's Formula

Using convenience sampling technique, a total of 162 participants, including both clinical and non-clinical staff, were recruited from five departments within the hospital. Participants were provided with the questionnaire via Google Forms to facilitate data collection. Responses were filled in a Googlesheet only accessible to the researcher then downloaded as a csv file which was imported in SPSS version 18 for descriptive analysis. The insights gathered from the user needs assessment informed the iterative design and development process of the dashboard. The dashboard was designed to be user-centered, focusing on simplicity, efficiency, and real-time data accessibility to address the operational challenges identified in the initial phase.

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    │ 2. Data Collection and         │
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4. Dashboard Design

Select a design framework or tool
Create wireframes or mockups for the dashboard layout.
.Incorporate user-friendly navigation

5. Implementation

Develop backend systems for data integration
Build frontend components for visualization (charts, tables)
Conduct unit testing and ensure system reliability

6. User Testing and Feedback

Engage stakeholders to test the dashboard.
Gather feedback on usability, functionality, and design.
Refine the system based on feedback.

i. System design flowchart.

The front end of the dashboard was developed using Vue.js for its dynamic and reactive user interface capabilities, complemented by Tailwind CSS for efficient and responsive styling. The back end was built with PHP-Laravel, a robust framework well-suited for developing scalable and secure web applications. Data storage and management were handled using a MySQL database, selected for its reliability and compatibility with the chosen technologies.

III. RESULTS.

In the initial phase of this study, ideas and suggestions from potential users in the hospital were collected. Among 162 participants who were eligible and accepted to respond the questionnaire, the majority (101, 62.3%) were female, while occupy the rest. Considering the profession, there was a slight difference between clinical and non-clinical where clinical professionals occupied a high number (95, 58.6%). We were also interested to know about the features decision support that they wish to have. Regarding the general features

of the dashboard, the respondents highlighted that the hospital dashboard will solve most the problems they usually meet in reporting. High number of respondents (131, 80.9%) showed that they wish to have tool that has customizable reporting feature as it is described on Table1.

Supporting features	Frequency	Percent	Cumulative Percent
Real-time data monitoring	6	3.7	3.7
Automated data analysis	17	10.5	14.2
Customizable reporting	131	80.9	95.1
User-friendly data visualization	8	4.9	100.0
Total	162	100.0	

Table 1. Preferred decision support features.

They also responded to questions related to the general importance of digital dashboard design in daily hospital operations. They (144, 88.9) further showed that they expect that a dashboard will help them to keep and share clear and simple information within the hospital. Table 2 describe this in details.

Importance of dashboard	Frequency	Percent	Cumulative Percent
Clarity and simplicity of information	144	88.9	88.9
Customizability of dashboard layout	18	11.1	100.0
Total	162	100.0	

Table 2. Importance of Dashboard

Asked about the best practices of dashboard design, the majority (144, 88.9%) said that they wish a dashboard that use clear and concise visualizations. Only 1.9% proposed a dashboard with responsive design on various devices on type and size. Table 3 describes more.

Dashboard design	Frequency	Percent	Cumulative Percent
Use of clear and concise visualizations	144	88.9	88.9
Consistent and intuitive navigation	5	3.1	92.0
Responsive design for various devices	3	1.9	93.8
Ability to drill down into specific data points	10	6.2	100.0
Total	162	100.0	

Table 3. Best Practices for dashboard design.

Clinicians, who form the majority of the sample (95, 58.6%), offer first-hand knowledge of the clinical data and decision-support features necessary for improving patient care. Non-clinicians contribute insights into administrative needs, resource management, and system

integration, which are essential for the dashboard to function effectively across the hospital.

II. Dashboard design and Indicators selection.

In the second phase, the key indicators to be displayed on the dashboard were identified based on input from respondents. They suggested presenting data specific to each department. Within each department, users can navigate through reports for individual units and subunits.

The 14 suggested departments to be visible on the dashboard include: Internal Medicine, Gynecology and Obstetrics, Pediatrics, Intensive and High Dependency Units, Accident and Emergency, Radiology, Laboratory, Pharmacy, Outpatient Department, Private Rooms, Orthopedics, and Mental Health.

Users are assigned roles based on their responsibilities and the departments they work in. This ensures that each user has access only to the data of their respective department. By logging in with a confidential username and password in the designated department's space, users can access specific summary data indicators related to their specialty.Detailed indicators on each departments are shown in Table 4.

On the main dashboard page which shows the general hospital structure, the administrators with such privileges are able to explore the indicators which shows the clinical situation and operational efficiency of the hospital. The user here is able to customize the dashboard by specifying the period he wants. The indicators on this page are : the number of admissions , the bed occupancy rate which further detail to show that rate in each department , it also show the number of patients who are in each department in real time, then finally shows the disease conditions that the hospital is currently managing and their frequencies.
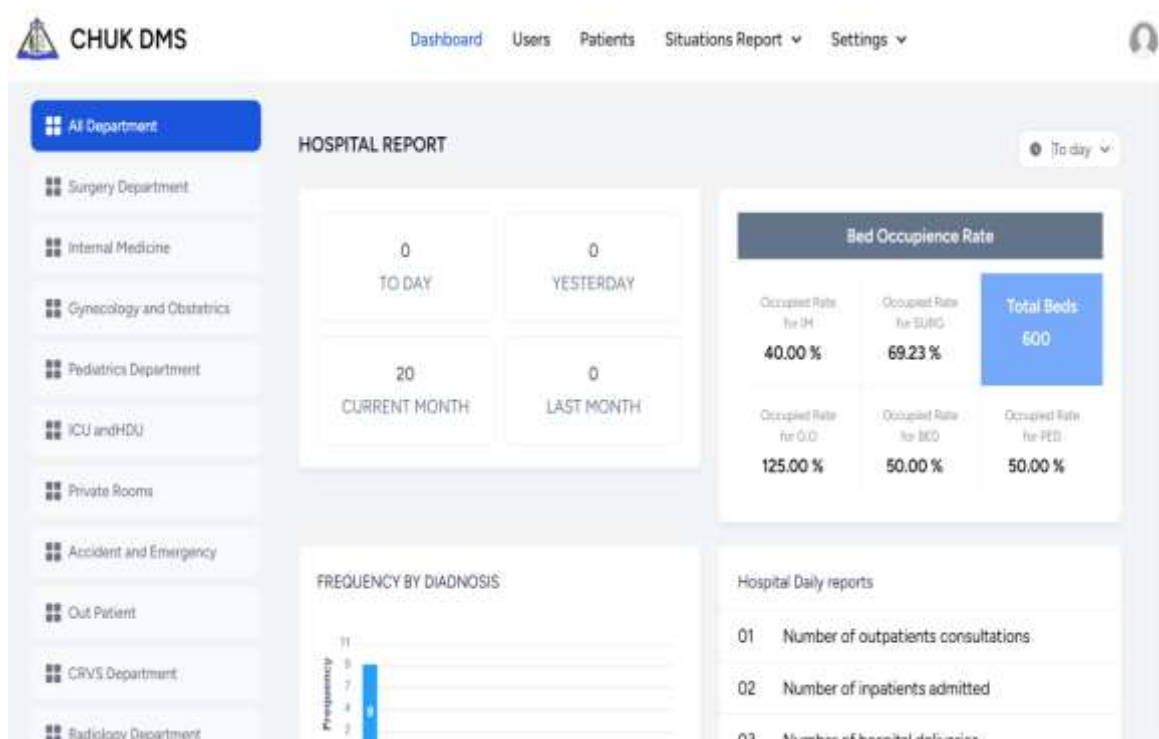

Figure 2. Overview of the general hospital overview.

To mention one, in the space of ICU / HDU department, the dashboard displays the number of patients in each subunits: patients in ICU and number of patients in HDU. It also details the number of patients disaggregated by their district of origin, which is important in studying the geographical distribution of disease in community.

IV. DISCUSSION.

This study aimed to design the hospital dashboard which is important in monitoring some of the hospital KPIs and inform the operational department. To understand the user needs, a questionnaire was distributed to collect the key elements that that they expect to have on the dashboard(Jessica, 2020). The design process followed the User-centered design which was recently proved as an effective approach in modern system design to ensure user acceptance, adoption and satisfaction(Sylvain & Noemie, 2023)(Donald , 2012)

Most research conducted aiming to design the healthcare institution dashboard adopted UCD, an approach by which designers focus on the users and their needs during the design process(Jaydon, et al., 2020)(Holly, et al., 2015)(Annete, et al., 2009). Health regulatory agencies and international health organizations, including the WHO, also recommendadoption of the UCD approach in the design of health information systems(WHO, 2016)(Gavriel & Waldemar , 2021). This model was preferred in this study because of its flexibility to be used in diverse dashboards.

Some other studies, have used other approaches like user interviews, iterative multiple cycles of the design. Others have used behavioral theory approachto understand how people perceive, process and respond to information which is not only important in making visually appealing dashboard but also drive action and decision making(Jenifer, et al., 2023).

By the end of our quantitative data analysis, we noted that 73% of the proposed and accepted indicators were process, operational and information management KPIs. Process indicators are sets of clinical actions which inform the clinicians about diagnosisactions, treatment and the best ways of follow-up of the patients. Availability of these indicators on the dashboard, make them easily accessible and hence improved quality of healthcare received by the patients, which aligns with one of the hospital's aims of providing high quality care in Rwanda(Maartj, et al., 2017). In his study across 8 European countries, H Flattenreported that 63% of the quality indicators of ICU were all clinical indicators, though the indicators were not perceived the same way throughout the countries where study conducted (Flateen, 2012)

Another group package of indicators (22%) of this study, were related to the outcome of medical and clinical actions. This set of indicators are mostly used to measure the effect of healthcare service provided on and describe any possible change to the patients which include readmission and complication (Audrey, et al., 2020)

UCD helped identify and gather existing issues in the data management process, along with recommendations for improvement. For instance, 89% of our participants recommended a customizable reporting system. Implementing this system is expected to greatly reduce the time spent on generating routine reports and minimize errors that typically arise from manual reporting. This expectation is shared with(Caroline , et al., 2018)in Mali, who found that dashboard is a good tool for monitoring the performance of community health and primary health workers and timely collect errors that they may make. Furthermore, Similar findings were observed by Naseem(Naseem , et al.,

2020)in his study, which aimed to use a dashboard to reduce turnaround time in the laboratory. He further emphasized that dashboards can provide real-time, automated reports.

The indicators selected for display on the dashboard are mostly department-specific. To provide an overall view of the hospital, the dashboard includes data such as the total number of patients served on the current day, the previous day, the following day, as well as for the current month, next month, and last month. Additionally, it shows the number of available beds in each department along with the bed occupancy rate. The dashboard also displays the number of diagnoses managed and their frequencies within the selected time period.

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