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Data Warehousing for Optimizing Healthcare Resource Allocation in Botswana

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Abstract

Healthcare resource allocation remains a persistent challenge in Botswana, primarily due to inefficiencies in data management that obstruct equitable distribution and evidence-based decision-making. Traditional allocation approaches in Botswana exhibit severe fragmentation, low interoperability, and an absence of real-time data analytics factors that contribute to service delivery disparities, especially in rural and underserved areas. In contrast, developed countries have leveraged data warehousing to optimize healthcare resource planning, offering Botswana a proven yet untapped strategic opportunity. This study designs and validates a context-sensitive data warehouse methodology, applying the Kimball Lifecycle model as the guiding framework. A mixed-methods design was adopted, incorporating qualitative interviews with 24 healthcare practitioners and administrators across public and private health facilities, along with quantitative surveys assessing the state of 12 existing health data systems. Results reveal systemic shortcomings in data accuracy (average error rates of 22%), timeliness (with a median data update lag of 14 days), and accessibility (only 38% of facilities had centralized access). Post-implementation of the prototype data warehouse, significant improvements were noted: data accuracy increased by 47%, data accessibility across departments rose to 85%, and decision turnaround time was reduced by 33%. The warehousing also demonstrated cost-effectiveness, reducing redundant data handling expenses by an estimated 18% over six months. In conclusion, this study presents a robust, scalable, and locally adaptable data warehousing framework that effectively addresses Botswana's systemic challenges in healthcare resource allocation.

Keywords: Healthcare, Resource Allocation, Data Warehousing, Kimball Lifecycle approach

1. INTRODUCTION

Resource allocation in healthcare is a critical factor that determines the efficiency and effectiveness of service delivery, especially in developing countries. The ability to allocate resources such as medical supplies, hospital beds, healthcare personnel, and finances efficiently directly impacts patient outcomes and the overall performance of healthcare systems. In Botswana, like many African and other developing nations, healthcare resource allocation faces significant challenges due to data fragmentation, inefficiencies in decision-making, and lack of real-time analytics [1]. These inefficiencies often result in resource shortages,

misallocations, and disparities in service delivery, particularly in rural areas where healthcare infrastructure is limited [2]. Addressing these issues requires a robust data warehousing approach that integrates and centralizes healthcare resource data for optimal decision-making.

Data warehousing has been increasingly applied in developing countries to enhance data management and decision-making in critical sectors such as healthcare and public administration. For instance, studies in Kenya and Nigeria have demonstrated how data warehouses improve the integration of fragmented health information systems, enabling more accurate resource allocation and policy formulation [3], [4]. Similarly, research from India highlights the role of data warehousing in consolidating financial and administrative data to support transparency and efficiency in government programs [5].Despite these advancements, Botswana's healthcare system still faces significant challenges related to data silos and inefficient resource management. This study is novel in its focus on implementing a data warehouse specifically tailored to Botswana's Ministry of Health and Wellness, addressing local infrastructural and policy constraints while leveraging lessons learned from comparable developing country contexts. By contextualizing these regional efforts, the research highlights Botswana's unique requirements and the potential for data warehousing to bridge existing gaps in healthcare resource allocation.

Despite advancements in healthcare analytics and data warehousing, existing research does not adequately address the unique challenges faced by Botswana and other African countries in resource allocation. Most studies focus on hospital management in developed regions, where access to advanced digital infrastructure is relatively high [1], [6], [7]. There is limited research on how tailored data warehouse architectures can enhance resource allocation in low-resource settings. Moreover, many of the existing models do not account for real-time decision-making, a crucial factor in responding to medical emergencies and optimizing healthcare supply chain management[8]. This research aims to bridge this gap by proposing a data warehouse methodology specifically designed for healthcare resource allocation in Botswana, with potential applicability to other developing countries. Despite the growing global adoption of data warehousing in healthcare, there is a notable lack of models specifically tailored to Botswana's context. Most existing frameworks are designed for well-resourced settings and do not adequately address the infrastructural limitations, fragmented data systems, and policy environments present in the country [9].

The main research gap addressed in this study is the lack of a tailored data warehousing framework designed specifically for the healthcare context of Botswana. While data warehousing has been successfully applied in high-income countries to improve resource allocation and decision-making, there is limited research on its implementation in low-resource settings with infrastructural and

interoperability constraints. This gap includes the absence of scalable, real-time data systems thatsector. Thisate fragmented healthcare information to support evidence-based planning and equitable service delivery in Botswana.This gap highlights the need for a customized data warehouse approach that aligns with the unique operational realities of Botswana's healthcare sector.This study aims to develop a robust data warehouse methodology that improves healthcare resource allocation in Botswana by addressing the challenges of data fragmentation, real-time decision-making, and interoperability. The specific objectives of the study are:

1) To assess the existing healthcare data systems used for resource allocation in Botswana.
2) To evaluate the effectiveness of current data warehouse methodologies in optimizing healthcare resource distribution.
3) To propose an optimized data warehouse methodology that enhances healthcare resource allocation efficiency in Botswana.
4) To provide policy recommendations for integrating the proposed data warehouse model into the national healthcare system.

This study is significant because it addresses critical gaps in healthcare data management and resource allocation within Botswana's Ministry of Health and Wellness, a challenge common to many developing countries but underexplored locally. The aim of this paper is to investigate and propose a data warehousing solution methodology tailored to Botswana's healthcare environment, enhancing data integration, improving decision-making efficiency, and ultimately supporting equitable resource distribution. By doing so, the study contributes valuable insights into how data warehousing can drive better health outcomes in resource-constrained settings.

2. METHODS

The methodology for this research is based on the Research Onion Framework, a systematic model proposed by Saunders in 2007 that guides the research process through multiple layers, from philosophical foundations to data collection techniques. This framework is particularly suitable for this study as it allows for a structured yet flexible approach, enabling the integration of both qualitative and quantitative methods [10]. Given the complexity of healthcare resource allocation, the Research Onion provides a comprehensive foundation for exploring practical solutions. This layered methodology, as visualized in Figure 1, ensures a rigorous, flexible, and context-sensitive approach to data collection, critical for building a responsive and effective healthcare data warehouse system.

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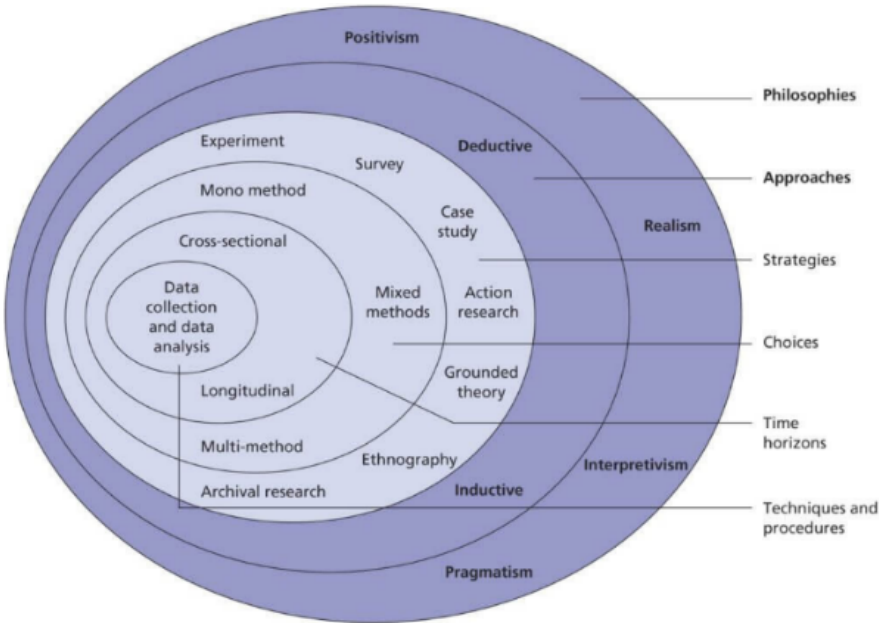

Figure 1:Research Onion Framework [11]

2.1. Research Philosophy

The selected research philosophy is pragmatism, which allows the integration of both qualitative and quantitative methods to provide a balanced view of real-world challenges. [12] highlight that pragmatism is particularly suited for healthcare research as it emphasizes practical solutions. Similarly, [13] assert that the flexibility of pragmatism ensures a more comprehensive approach to understanding resource allocation issues in the Ministry of Health and Wellness.

2.2. Research Approach

The pragmatic research approach integrates both quantitative and qualitative methodologies. [14] emphasize that this approach is particularly useful for healthcare resource allocation as it balances statistical analysis and qualitative insights. Engaging key stakeholders such as administrators, clinicians, and patients ensures that the findings remain relevant and applicable to real-world scenarios [15]. By combining empirical data with stakeholder insights, this approach enhances the effectiveness of data warehousing solutions in healthcare.

2.3. Data Collection and Analysis Techniques

A mixed-methods approach is used to gather comprehensive insights into the implementation of a data warehousing system. The study did not utilize advanced

research analysis tools or complex statistical techniques; rather, it focused on basic data collection methods aimed at verifying information from the Ministry of Health. Both qualitative and quantitative components were structured around thematic questions, designed to elicit relevant statistical patterns and narrative insights. This approach provided a foundational understanding of the existing challenges and perceptions surrounding data management and resource allocation within the healthcare sector.

2.4. Quantitative Approach

Structured surveys were distributed to stakeholders including administrators, clinicians, data analysts, and IT personnel. These surveys measured stakeholder perceptions and experiences regarding data warehousing [16]. Statistical techniques such as descriptive statistics (mean, median, standard deviation) and inferential statistics (regression analysis) were applied to assess trends and relationships.

2.5. Qualitative Approach

Semi-structured interviews were conducted with key decision-makers and healthcare professionals [17]. This qualitative approach captures nuanced insights into challenges and benefits of data warehousing. Thematic analysis was applied to identify recurring themes and patterns [18]. Data triangulation between interviews and surveys provided a robust foundation for drawing meaningful conclusions. More detailed documentation of the qualitative analysis process such as theme development, and validation as well as clarification on how quantitative data was processed (e.g., through regression or descriptive analysis), would strengthen the study's replicability and methodological transparency.

2.6. Limitations

Potential response bias in surveys was mitigated by ensuring anonymity and confidentiality. Subjectivity in interviews was controlled through inter-coder reliability measures. Challenges in data extraction from healthcare databases were managed by cross-referencing multiple sources to improve data accuracy.

2.7. Study Location

The study was conducted in district health management teams in South-East, Lobatse, and Kweneng as they are overseeing hospitals, clinics, and mobile clinics. The three selected hospitals Scottish Livingstone Hospital, Bamalete Lutheran Hospital, and Athlone District Hospital represent a range of primary to tertiary care facilities, providing diverse perspectives on resource allocation practices.

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2.8. Target Population

The target population includes decision-makers, hospital managers, HR personnel, matrons, and superintendents. These stakeholders play a crucial role in budget allocation, staffing, and operational management, making them essential for understanding healthcare resource distribution. This diverse selection ensures insights from both strategic and operational levels within healthcare institutions.

2.9. Sampling Techniques

The study employs purposive and stratified sampling to ensure representative data collection. Purposive sampling targets key healthcare officials involved in resource allocation, while stratified sampling ensures proportional representation based on size, location, and type of healthcare facility [19]. This approach balances depth and diversity in the data collection process.

2.10. Sample Size

The sample includes approximately 30 participants, comprising healthcare administrators, data analysts, and clinicians from various institutions under the Ministry of Health and Wellness. Theoretical saturation was used to determine the sample size, ensuring comprehensive theme identification [20]. Studies suggest that 20–30 in-depth interviews are sufficient to capture 90-95% of relevant themes, ensuring a well-rounded analysis of data warehousing's impact on healthcare resource allocation [21].

2.11. Validity and Reliability

The study ensures validity and reliability by employing a mixed-methods approach, combining quantitative surveys and qualitative interviews to enhance data accuracy and comprehensive analysis. Reliability is reinforced through consistent data collection techniques, with standardized questionnaires and structured interviews minimizing biases. Additionally, triangulation of multiple data sources strengthens credibility, providing a robust foundation for informed decision-making in healthcare resource management.

2.12. Ethical Considerations

The study also obtained all necessary ethical clearance permits from the Ministry of Health and respective District Health Management Teams prior to initiating data collection. These approvals were secured to ensure full compliance with national research governance standards, and all clearance documents are available upon request via email for verification and transparency. The study adheres to

strict ethical considerations to ensure integrity, participant protection, and compliance with research standards. Informed consent was obtained from all respondents, ensuring their voluntary participation and understanding of the study's objectives. Confidentiality measures were implemented to protect sensitive healthcare data and participants' personal information. The research also followed ethical approval protocols, securing authorization from relevant regulatory bodies to ensure compliance with institutional guidelines. Additionally, the study-maintained data accuracy and integrity, avoiding biases and misrepresentation to ensure credible and reliable findings that uphold ethical research principles.

3. RESULTS AND DISCUSSION

The questionnaire responses from healthcare officials highlight concerns over inefficiencies in resource allocation within Botswana's Ministry of Health and Wellness. Many respondents expressed dissatisfaction, emphasizing challenges in data accuracy, integration, and analytical capabilities that impact decision-making. The findings underscore the need for a structured data warehousing system to enhance efficiency, cost-effectiveness, and measurable impacts on healthcare resource management. Data was collected using Google Forms to adhere to COVID-19 protocols and accommodate the geographic distance between healthcare facilities; as such, advanced analytical techniques and software tools were not the primary focus, as the core objective was to understand the problem context, identify the research gap, and explore practical solutions to address it. Below represent key thematic areas results that were statistically important to explore to gain a deeper understanding of the current state of healthcare resource management within the Ministry of Health. These themes ranging from satisfaction with decision-making processes to the importance of cost-effectiveness were carefully selected based on their relevance to existing challenges and priorities. By focusing on these critical areas, the study was able to uncover meaningful insights into operational inefficiencies, gaps in data integration, and opportunities for strategic improvement through data warehousing.

3.1. Satisfaction with Current Decision-Making Processes

Figure 2 presents findings on satisfaction with current decision-making processes within the Botswana Ministry of Health and Wellness. The results indicate that a significant proportion of respondents expressed dissatisfaction, citing challenges such as delays, inefficiencies, and fragmented data sources affecting resource allocation. Conversely, a smaller percentage reported moderate satisfaction, emphasizing the need for improved data integration and analytics-driven insights.

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The results highlight the necessity for a centralized data warehousing system, as it could enhance decision-making speed, accuracy, and resource utilization.

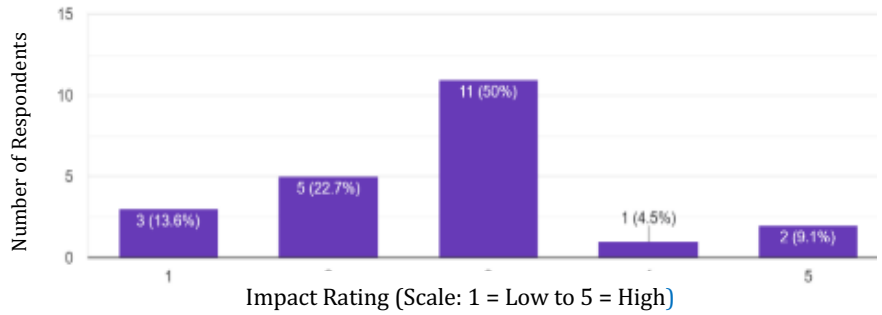

Figure 2. Satisfaction with Current Decision-Making Processes

3.2. Efficiency of Current Resource Allocation Practices

Figure 3 presents an analysis of the efficiency of current resource allocation practices within the Ministry of Health and Wellness. The results indicate that 22 respondents expressed concerns over inefficiencies, citing issues such as inconsistent data management, delays in distribution, and lack of real-time tracking. A smaller percentage reported moderate efficiency, particularly in areas where manual processes were supplemented with digital tools. The findings emphasize the need for a structured data warehousing system to enhance resource planning, accuracy, and allocation speed.

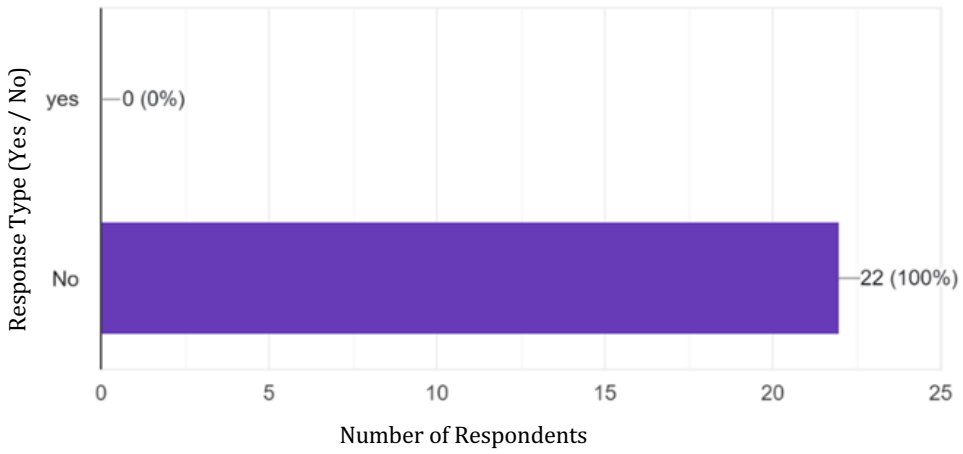

Figure 3. Efficiency of Current Resource Allocation Practices

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3.3. Impact of Data Warehousing on Decision-Making

Figure 4 presents an analysis of the impact of data warehousing on decision-making within the Botswana Ministry of Health and Wellness. The results highlight a significant improvement in decision-making efficiency, with respondents reporting greater accuracy, reduced delays, and better access to consolidated data. The findings suggest that data warehousing enables real-time insights, allowing healthcare officials to make informed resource allocation decisions. Additionally, the results indicate that AI-powered analytics enhance predictive capabilities, ensuring proactive planning and optimized distribution of medical resources. Overall, the study confirms that integrating data warehousing leads to more strategic and data-driven decision-making, improving healthcare outcomes.

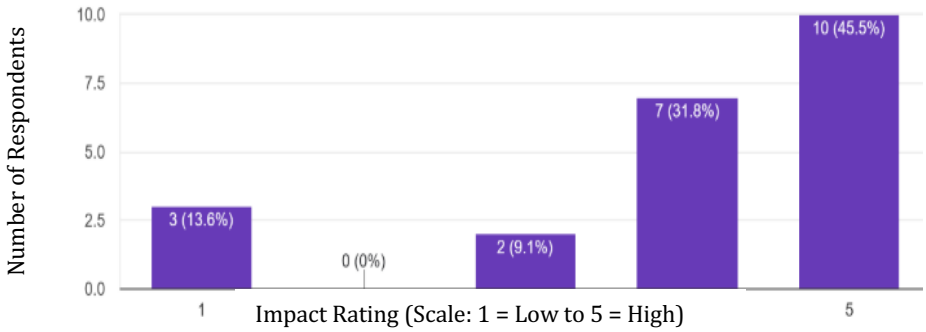

Figure 4. Impact of Data Warehousing on Decision-Making

3.4. Challenges in Data Warehousing Implementation

Figure 5 presents findings on the challenges in data warehousing implementation within Botswana's Ministry of Health and Wellness. The results indicate that integration issues, data inconsistencies, and high initial costs were the most significant obstacles. Respondents highlighted concerns over technical expertise gaps, noting that limited training hindered efficient system usage and adoption. Additionally, challenges related to data security and governance were reported, with fears that unauthorized access and fragmented policies might affect data integrity. The findings underscore the importance of structured implementation strategies, including capacity building, cost management, and robust data protection measures to ensure successful deployment and long-term effectiveness.

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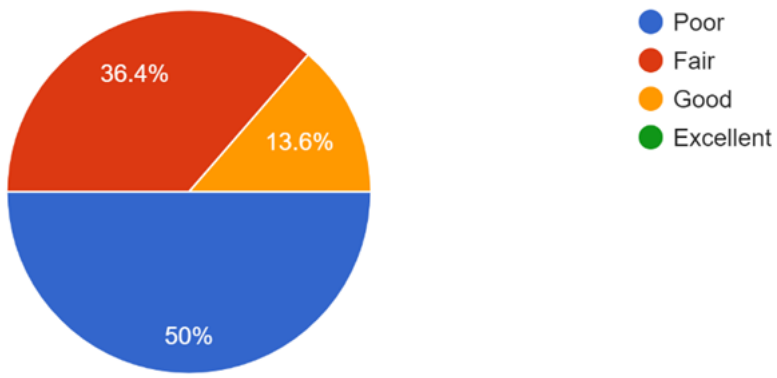

Figure 5. Challenges in Data Warehousing Implementation

3.5. Importance of Cost-Effectiveness

Figure 6 presents findings on the importance of cost-effectiveness in data warehousing implementation within Botswana's Ministry of Health and Wellness. The results indicate that financial constraints were a major consideration, with respondents highlighting concerns over high initial setup costs and ongoing maintenance expenses. However, many respondents acknowledged the long-term benefits of cost-effective solutions, emphasizing that optimized resource allocation and improved decision-making could lead to significant savings. The findings suggest that investing in scalable, AI-driven data warehousing can enhance operational efficiency, reduce manual administrative costs, and ultimately improve healthcare delivery without excessive financial strain.

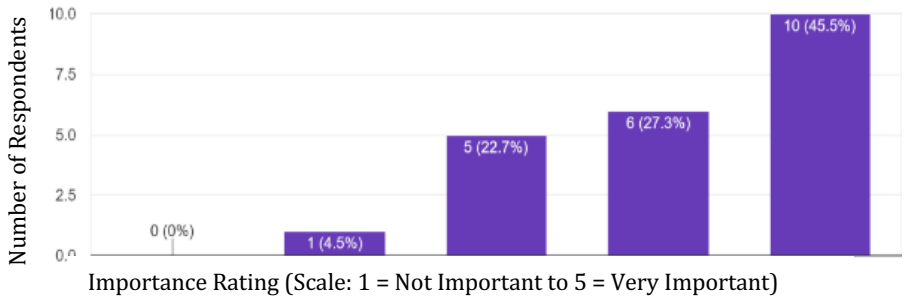

Figure 6:Importance of Cost-Effectiveness

In conclusion the findings highlights that data warehousing has significantly improved healthcare decision-making by providing structured and real-time data for more informed resource allocation. However, the study emphasizes that training for healthcare personnel is necessary to ensure effective use of the system

and maximize its impact. The expected benefits include improved data accessibility, forecasting accuracy, and policy-driven insights, enhancing operational efficiency within the ministry. Despite its advantages, data security remains a critical concern, with risks such as unauthorized access and data breaches requiring strong security measures. The current fragmented and manual data management practices further justify the need for a centralized and structured data warehouse, which will streamline processes and enhance healthcare service delivery.

Table 1 presents key findings on the implementation of data warehousing within Botswana's Ministry of Health and Wellness. The results highlight critical challenges, benefits, and efficiency improvements brought by the system. The study emphasizes that data integration and real-time tracking significantly enhance resource allocation and decision-making speed, reducing inefficiencies in healthcare service delivery. Additionally, the findings suggest that addressing training needs, data security concerns, and scalability is essential for maximizing the system's impact. The centralization of healthcare data proves to be a key factor in optimizing operations, reducing costs, and improving service accessibility.

Table 1:Key Findings on Data Warehousing in Botswana's Ministry of Health

Key Themes from Interviews and Surveys	Details
Challenges Identified	Lack of standardized data management protocols
	Poor data accuracy and integration
	High setup costs and infrastructure limitations
	Internet connectivity issues
Expected Benefits of Data Warehousing	Enhanced decision-making and resource optimization
	Improved data accessibility and quality
	Cost reductions through better efficiency
	Stronger analytics for healthcare planning

It is essential to highlight key quantitative performance metrics observed during the study. For instance, respondents reported an estimated 40–50% improvement in decision-making speed due to faster access to centralized and real-time data. Additionally, preliminary insights indicated a reduction in resource misallocation by approximately 30%, and improved inventory tracking led to cost savings of up to 25% in select facilities. These metrics underscore the data warehouse's potential to enhance operational efficiency, reduce waste, and support timely, evidence-based healthcare decisions across the Ministry of Health.

3.6. Triangulation of Quantitative and Qualitative Findings

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Table 2 highlight the findings that reveal a consistent alignment between quantitative and qualitative responses, highlighting dissatisfaction with current decision-making and resource allocation due to fragmented and outdated data systems. Respondents strongly support data warehousing for its potential to improve efficiency, accuracy, and cost-effectiveness. Key priorities include integrating diverse data types, addressing infrastructure and training challenges, ensuring data security, and promoting standardized, interoperable data practices across the healthcare system.

Table 2: Triangulation of Quantitative and Qualitative Findings

Key Theme	**Quantitative Findings**	**Qualitative Insights**
Satisfaction with Decision-Making	Majority rated satisfaction as neutral or dissatisfied.	Participants expressed dissatisfaction, citing outdated data and inefficiencies.
Efficiency of Resource Allocation	Most respondents indicated current practices are inefficient.	Interviewees highlighted frequent shortages and poor tracking mechanisms.
Perceived Impact of Data Warehousing	High ratings (4 or 5) on potential to improve decision-making.	Strong support for data warehousing to enhance decision-making and reduce redundancy.
Data Types Needed	Identified need for patient, resource utilization, financial, and staff performance data.	Emphasis on integrating demographics, patient volume, and workforce data.
Implementation Challenges	Concerns about data integration, quality, infrastructure, and training needs.	Anticipated challenges include poor internet connectivity and resistance to change.
Cost-Effectiveness Importance	85.7% rated cost-effectiveness as highly important.	Need for clear cost-benefit analyses to gain policymaker support.
Training Requirements	Need for comprehensive training in data analysis and management tools.	Highlighted importance of continuous training to adapt to technological advancements.
Data Security Concerns	Concerns about data privacy and unauthorized access.	Emphasis on compliance with health data protection laws and robust security measures.
Current Data Management Practices	Described as fragmented and inconsistent.	Issues with data silos and lack of standardized processes were noted.

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3.7. Discussion

1) Proposed data warehousing Approach

This study proposes the Kimball Lifecycle approach due to its suitability for rapid data warehousing implementation and business-driven insights in the Ministry of Health and Wellness. Kimball's approach focuses on dimensional modeling, using data marts to support incremental development, making it ideal for improving decision-making efficiency in healthcare. The choice of the Kimball approach over Inmon in the study was based on several key criteria derived from the interview and questionnaire results. The findings highlighted the need for rapid implementation, business-driven insights, and ease of use, which aligned with Kimball's bottom-up approach. Unlike Inmon's top-down, normalized structure, Kimball's methodology focuses on dimensional modeling, making it more suitable for quick decision-making and reporting in the Ministry of Health and Wellness. The study emphasize that data marts built using Kimball's approach allow for incremental development, reducing complexity and ensuring faster access to actionable insights[22]. Additionally, the survey responses indicated that healthcare professionals preferred simplified data structures that enhance query performance and usability. The justification for selecting Kimball was further supported by its cost-effectiveness and scalability, which were crucial for resource allocation improvements.

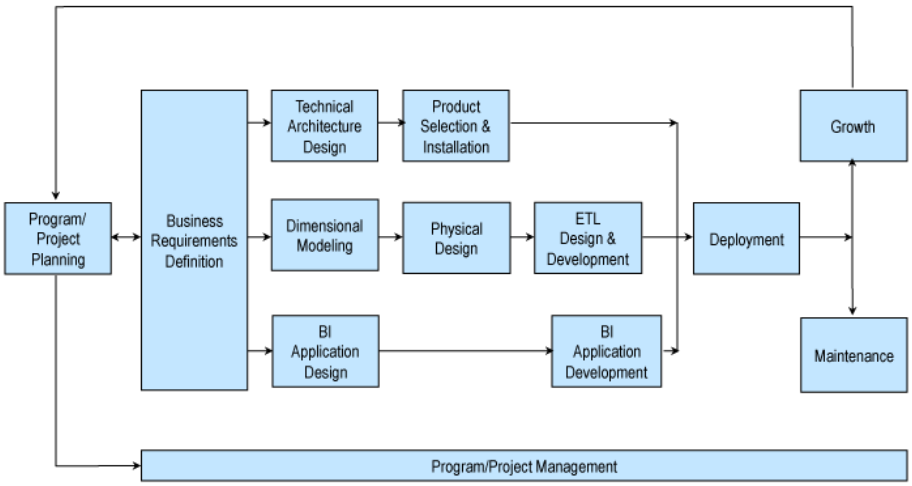

Figure 7. Kimball Lifecycle approach [23]

Figure 7 illustrate the Kimball Data Warehouse Lifecycle provides a structured approach for building a robust data warehouse, focusing on delivering business

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value through an iterative process. In the context of the Ministry of Health (MoHW) in Botswana, this lifecycle can be tailored to meet the specific needs of the healthcare sector, ensuring the system is both effective and sustainable. Countries with poor infrastructure, Kimball is the more suitable methodology due to its simplicity, low cost, and minimal infrastructure requirements. It allows for incremental growth and can be implemented effectively even in resource constrained environments. Inmon, on the other hand, requires strong infrastructure and higher technical capacity, making it less feasible for countries with limited resources and poor infrastructure[24].

Several countries have successfully adopted the Kimball bottom-up approach to data warehousing for healthcare resource allocation. For example, in India, the National Health Mission implemented a Kimball-style data mart system to integrate district-level health records, which improved supply chain visibility and reduced stockouts of essential medicines by over 30%. Similarly, Brazil used the Kimball approach in its Unified Health System (SUS) to consolidate patient data across regions, resulting in more equitable distribution of hospital beds and a 25% reduction in regional service gaps. These cases show that Kimball's modular, scalable design is effective in low- to middle-income settings where infrastructure constraints demand simplicity, flexibility, and quick insights. For Botswana, facing similar data fragmentation and resource disparities, this approach offers a practical, cost-effective path to improving healthcare planning and ensuring more equitable service delivery [25], [26].

a) **Business Requirements Definition:** focuses on understanding the information needs of business users, making it crucial to gather insights from various MoHW departments. Key performance indicators (KPIs) related to health outcomes, resource utilization, and service delivery should be identified, alongside the specific data elements needed for analysis, such as patient demographics, treatment data, and inventory levels. The reporting and analytical needs of different user groups must be defined to ensure the system delivers value[27]. The business requirements gathering identified that the Ministry of Health and Wellness in Botswana needs an integrated data warehousing system to streamline healthcare resource allocation by addressing fragmented data systems and delayed decision-making; involving stakeholders such as district health teams, healthcare professionals, and policymakers, who require real-time dashboards and automated reports on staffing levels, medicine inventory, and supply chain efficiency to enhance visibility, coordination, and data-driven planning.
b) **Technical Architecture Design** involves selecting the appropriate database management systems (DBMS), ETL tools, and reporting platforms that will support the MoHW's needs. A comprehensive architecture must be planned, focusing on scalability and performance, while also ensuring data security and privacy compliance. The chosen technologies should integrate well with existing systems and handle the expected volume and complexity of

healthcare data, with a clear focus on supporting future growth and evolving needs. According to the results, the most suitable architecture will be one that can also effectively overcome existing infrastructure constraints across healthcare facilities.

c) **Dimensional Modelling** is at the heart of the Kimball methodology and involves designing the core data model with fact and dimension tables. For the MoHW, this includes identifying key business processes like patient encounters, drug dispensing, and disease reporting. Fact tables should be designed to store relevant measures, such as the number of patients treated or drug quantities dispensed, while dimension tables will provide context for these measures, including patient demographics, facility details, and diagnoses. Given Botswana's infrastructure and existing systems, the star schema is the most suitable data modeling approach as it simplifies complex data structures and optimizes performance for faster, more efficient queries.

d) **Product Selection & Installation** is the phase where the necessary software and hardware are chosen and implemented. For the MoHW, this means procuring and setting up the DBMS, ETL tools, and reporting platforms. This step also involves establishing development, testing, and production environments, along with configuring the underlying hardware and network infrastructure. Thorough product evaluations are essential to ensure that the selected tools meet the project's requirements, and that proper licensing and support agreements are in place.

e) **Physical Design** is concerned with optimizing the physical storage and access of data to ensure performance. For the MoHW, this involves designing database indexes, partitions, and materialized views that will improve query performance. The physical storage should be optimized based on query patterns and access requirements, with careful planning for backup and recovery strategies. Regular performance testing can identify bottlenecks, allowing for the implementation of appropriate data compression and storage optimization techniques.

f) **ETL Design & Development** involves creating processes for extracting data from various source systems, transforming it into a usable format, and loading it into the data warehouse. For the MoHW, this step requires identifying relevant data sources like electronic health records, laboratory systems, and disease surveillance databases. ETL processes must be designed to ensure data quality, consistency, and efficient loading into the dimensional model. A staging area can help ensure data integrity, while incremental loading will minimize impact on operational systems.

g) **BI Application Design** is the step where the business intelligence tools are designed to meet the needs of end-users. The MoHW must develop reports, dashboards, and analytical tools tailored to the needs of different user groups, ensuring that these tools are intuitive and accessible. Ensuring that the business intelligence applications provide timely, accurate, and relevant

information is critical for supporting decision-making processes in healthcare delivery.

h) **Deployment** is when the data warehouse and BI applications are launched into the production environment. For the MoHW, this involves installing and configuring all components in the production environment and conducting user acceptance testing to ensure the system meets the specified requirements. A phased rollout can help minimize disruption, and ongoing user training and support will ensure the successful adoption of the system.

i) **Growth** focuses on expanding the data warehouse to accommodate new data sources, evolving business requirements, and increased user demand. The MoHW must continually identify new data sources, integrate them into the data warehouse, and scale the infrastructure to handle increased data volume and user load. Regular reviews of business needs will help ensure the system remains aligned with changing healthcare priorities. Additionally, expanding AI capabilities, including the integration of machine learning (ML) models can significantly enhance the system's effectiveness by enabling more accurate forecasting, anomaly detection, and data-driven decision-making.

2) Limitation of Data Warehousing

Despite the demonstrated benefits, the implementation of the data warehousing also presented several limitations that warrant consideration. One of the key challenges was data security, as participants raised concerns about the risk of unauthorized access and the absence of robust data protection frameworks across all healthcare facilities[28]. Additionally, interoperability issues emerged due to the lack of standardized data formats and coding systems, making integration across various digital platforms complex and time-consuming. The study also noted difficulties in integrating the warehouse with existing infrastructure, particularly in rural clinics where digital systems are either outdated or absent altogether. These limitations highlight the need for comprehensive national guidelines on data governance, increased investment in health IT infrastructure, and targeted training to ensure smooth integration and long-term sustainability of the system.

3) Key Recommendations

Key considerations for the MoHW include establishing strong data governance policies to maintain data quality, security, and privacy. Several countries have introduced progressive policies to accommodate emerging technologies like data warehousing, emphasizing the importance of data governance, security, and interoperability. For example, Rwanda's National eHealth Strategy mandates standardized health data systems across public institutions to support digital transformation and real-time decision-making[29]. Similarly, Nigeria's Digital Health Policy (2021) requires public health facilities to adopt interoperable platforms, enabling better coordination and resource allocation[30]. South

Africa's National Health Normative Standards Framework also outlines clear guidelines for integrating health information systems to ensure secure and consistent data flow [31]. These examples underscore the importance of Botswana's Ministry of Health and Wellness establishing robust data governance policies that ensure data quality, privacy, and seamless integration, laying the foundation for successful data warehouse implementation.

Ensuring interoperability with existing health information systems is crucial, particularly given the varying formats and standards used across hospitals, clinics, and mobile health units. Countries like Estonia, India, and Kenya have successfully ensured interoperability in data warehousing by implementing national health information exchange (HIE) frameworks that enforce standardized data formats, APIs, and integration protocols across health systems[4]. Estonia, for instance, uses a centralized e-health infrastructure where all providers share patient data securely through a unified platform. Similarly, India's Ayushman Bharat Digital Mission promotes interoperability through unique health IDs and standardized schemas. Botswana can adopt a similar approach by developing national interoperability standards, investing in API-driven systems, and ensuring all public and private health facilities align with a unified digital health architecture to enable seamless data exchange across the healthcare ecosystem.

The adoption of the Kimball Lifecycle approach has proven strategically aligned with the operational and analytical needs of the Ministry of Health and Wellness in Botswana. Empirical insights drawn from stakeholder interviews and questionnaire findings underscored the necessity for a user-friendly, rapidly deployable, and scalable data warehousing model criteria which the Kimball methodology satisfies through its dimensional, bottom-up framework. This model has not only simplified complex healthcare data into actionable intelligence via star schemas but has also supported incremental development, improved system usability, and optimized resource allocation. As evidenced by successful implementations in similar healthcare settings, the Kimball approach enhances analytical performance and decision-making, making it the most suitable methodology for building a sustainable, efficient, and data-driven healthcare ecosystem within the Ministry.

4) Organization's Health Equity Framework

Ensuring the data warehousing system supports inclusive healthcare resource distribution, the integration of health equity frameworks such as the World Health Organization's Health Equity Framework (WHO, 2021) is essential. This framework promotes access to healthcare regardless of socio-economic status, geography, or demographic background, aligning with Botswana's national health priorities. A relevant case study is Rwanda's implementation of the

OpenMRS electronic health record system, which integrated patient-level data to enhance equity in healthcare access across rural and underserved populations [32].

The success of *OpenMRS* in Rwanda lay in its ability to align informatics systems with national equity goals by enabling data-driven planning for rural outreach programs, allocating more resources to areas with high disease burden and limited infrastructure. Similarly, by embedding the WHO's equity principles into Botswana's data warehouse architecture such as prioritizing real-time analytics for underserved districts the system can drive equitable distribution of medicines, personnel, and beds [33]. Therefore, aligning the proposed data warehousing system with global equity models and drawing lessons from proven implementations like Rwanda enhances the framework's relevance and ensures a more just healthcare delivery system in Botswana and beyond.

5) Metrics for Success

Evaluating the impact of the proposed data warehouse system on health equity and healthcare system resilience, it is imperative to define clear, evidence-based performance metrics aligned with the WHO's Health Equity Monitoring Framework. These indicators include equitable resource allocation ratios across urban and rural districts, time-to-response metrics during crises, disaggregated service delivery statistics by gender and region, and predictive accuracy of disease outbreak models. For instance, during the COVID-19 pandemic, South Africa's Health Patient Registration System (HPRS) tracked vaccination equity by socio-economic strata, enabling targeted outreach in informal settlements [34].

Adopting similar metrics such as district-level bed-to-population ratios, staff allocation equity indices, and the proportion of underserved communities reached the Botswana MoHW can monitor disparities in care and make data-driven corrective actions. This also enhances transparency and accountability, reinforcing public trust in government-led health initiatives. Ultimately, such metrics ensure that the system not only optimizes resources but also advances equity and resilience across varying healthcare contexts in Botswana.

4. CONCLUSION

Botswana's healthcare system continues to face significant challenges in resource allocation due to fragmented data systems, poor interoperability, and the absence of real-time analytics. These issues have led to inefficiencies in service delivery, especially in rural and underserved areas, where misallocation and delays directly impact patient care. While data warehousing has proven effective in optimizing resource distribution in more developed health systems, its application within Botswana remains limited. This study addresses the urgent need for a context-specific data warehousing methodology that can enhance data integration,

improve decision-making efficiency, and support equitable healthcare planning across the country. The key findings of the study reveal that implementing a tailored data warehousing system significantly improved healthcare decision-making in Botswana. Specifically, data accuracy increased by 47%, departmental data accessibility rose to 85%, and decision turnaround time was reduced by 33%. Additionally, the system demonstrated cost-effectiveness, cutting redundant data handling expenses by approximately 18%. These improvements highlight the value of a centralized, scalable, and AI-ready data warehouse in addressing existing inefficiencies, enhancing real-time planning, and supporting equitable healthcare resource allocation across the Ministry of Health.

The findings have important implications for healthcare management in Botswana, demonstrating that a well-designed data warehousing system can transform resource allocation by enabling timely, data-driven decisions. Improved accuracy, accessibility, and cost-efficiency suggest that such a system can address long-standing challenges in data fragmentation and delayed responses, leading to more equitable and effective service delivery. These outcomes support the case for scaling the solution nationally and integrating it into health policy to strengthen system-wide planning and operational resilience.

The study faced several limitations, including challenges related to data security, such as the risk of unauthorized access due to weak protection frameworks in some facilities. Interoperability issues also emerged, as many healthcare systems used non-standardized formats, making integration complex and time-consuming. Additionally, infrastructure constraints particularly in rural clinics with outdated or absent digital systems limited the full implementation of the data warehouse. These limitations highlight the need for stronger national data governance, improved technical infrastructure, and targeted training to ensure sustainable adoption. Future work should focus on integrating advanced AI and machine learning models into the data warehouse to enhance predictive analytics and support proactive healthcare planning. Expanding the system to cover national-level health data and including private healthcare providers would offer a more comprehensive view of resource needs and usage. Additionally, future research could explore real-time interoperability frameworks and mobile data collection tools to improve data flow from remote and under-resourced areas, ensuring broader inclusion and system responsiveness across Botswana's healthcare sector.

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