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Business Intelligence Applications in Water Utility Management: A Case Study Approach

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Abstract

Purpose: This study explores the application of Business Intelligence (BI) tools in the management of water utilities, focusing on how BI supports strategic decision-making, operational efficiency, and service improvement. Despite the abundance of operational data, many water utilities in developing countries struggle to fully integrate BI systems due to technical, cultural, and organizational barriers.

Design/Methodology/Approach: A qualitative case study methodology was used, involving semi-structured interviews with management and technical staff, document analysis, and limited observation. Purposeful sampling identified key informants, and thematic analysis was applied to the collected data to extract recurring themes related to BI applications and outcomes.

Findings: The findings reveal that BI tools—such as dashboards, data warehousing, and reporting systems—are being increasingly integrated into utility management. These tools have enabled real-time monitoring, improved customer insights, and data-informed financial planning. However, challenges remain in the form of technical integration barriers, staff capacity gaps, and cultural resistance to data-driven practices. Despite these challenges, the organization demonstrates a clear commitment to BI as a driver of performance and innovation.

Originality/Value: This research contributes to the limited body of knowledge on BI in public utilities, particularly in developing country contexts. The study offers practical insights into how water utilities can adopt BI effectively and proposes recommendations for improving BI readiness, organizational alignment, and data governance.

Keywords: Business Intelligence, Water Utilities, Case Study, Public Sector Management, Data Analytics, Jordan

Introduction

In recent years, data has emerged as a strategic asset for organizations across a wide range of industries, driving a shift toward more data-informed decision-making processes (Negash, 2004; Shollo & Galliers, 2015). With the rise of digital technologies and the proliferation of smart systems, organizations are increasingly recognizing the importance of harnessing data

not merely as a by-product of operations but as a vital resource for achieving competitive advantage, optimizing performance, and enhancing service delivery (Chen et al., 2012; Watson, 2009).

This transformation is particularly significant in public utility sectors such as water management, where data plays a crucial role in ensuring the sustainability, efficiency, and reliability of essential services (Amankwaa et al., 2021; Dornberger et al., 2024). Water utility companies are responsible for a complex array of functions, including the sourcing, treatment, distribution, and monitoring of water resources, as well as customer service and billing operations. As a result, these organizations generate vast volumes of operational and customer-related data on a daily basis. This data includes, but is not limited to, information on water quality, pressure levels, consumption patterns, system maintenance, customer complaints, and financial transactions.

Despite the abundance of available data, many water utilities continue to face significant challenges in transforming this raw information into meaningful insights that can guide strategic and operational decisions. Limitations in data integration, analytical capabilities, and organizational readiness often hinder the ability to fully capitalize on the value that data can provide (Shollo & Galliers, 2015).

Business Intelligence (BI) offers a promising solution to this challenge. BI encompasses a set of tools, technologies, and methodologies that enable organizations to collect, integrate, analyze, and visualize data in a way that supports evidence-based decision-making (Watson, 2009; Chen et al., 2012). Through dashboards, reporting systems, and advanced analytics, BI applications facilitate real-time monitoring, performance tracking, and trend analysis, thereby helping organizations respond more effectively to emerging issues and long-term challenges.

In the context of water utilities, BI can be instrumental in improving resource management, reducing operational costs, enhancing customer service, and supporting regulatory compliance (Nofal et al., 2022; Hayajneh & Harb, 2023). The integration of BI into water utility management is particularly relevant for countries facing increasing water scarcity, infrastructure limitations, and pressure to improve public services. In Jordan, one of the most water-scarce countries in the world, the need for efficient water utility management is both urgent and strategic (Abdel-Hadi, 2024; GIZ & International Water Association, 2018).

The effective application of BI tools in this sector could contribute significantly to optimizing resource use, reducing waste, improving service delivery, and enhancing institutional accountability. However, there remains a gap in the academic literature regarding how BI is specifically implemented and utilized within the water utility sector in developing countries, particularly at the organizational level.

This study is distinct in that it focuses on a water utility operating in Jordan, one of the most water-scarce countries globally, where institutional challenges, donor-driven reforms, and public service pressures intersect. The case organization is characterized by a semi-public structure, hybrid financing mechanisms, and a growing reliance on performance indicators—a combination that presents a unique context for studying BI adoption.

This study aims to address this gap by exploring the role of Business Intelligence applications in enhancing the management practices of water utility organizations. Using a case study approach, the research will focus on a local water utility in Jordan to examine how BI tools are

adopted, what challenges are encountered, and what benefits are realized. The case study method is appropriate for this inquiry as it allows for an in-depth understanding of the context, processes, and outcomes associated with BI implementation in a real-world setting (Yin, 2018). By shedding light on the practical experiences of a water utility organization, the study seeks to provide insights that can inform both academic discourse and managerial practice in the field of data-driven utility management.

Literature Review

The concept of Business Intelligence (BI) has undergone significant evolution since its inception. Initially rooted in decision support systems developed during the mid-20th century, BI was primarily concerned with generating reports and queries on historical data to assist managerial decision-making. The term itself was popularized in the late 1980s and early 1990s, marking a shift towards more systematic and structured approaches to data analysis (Chaudhuri et al., 2011). Over time, BI has transitioned from basic descriptive analytics to incorporate more advanced functionalities such as predictive and prescriptive analytics, driven by technological advancements in big data, cloud computing, and artificial intelligence (Negash, 2004; Wixom et al., 2014). This evolution reflects a growing recognition of data as a strategic organizational asset, enabling not only retrospective insights but also forward-looking, actionable intelligence. Consequently, modern BI platforms empower a wider range of users within organizations, fostering a data-driven culture that supports decision-making at strategic, tactical, and operational levels. However, despite these advances, challenges remain, including issues of data quality, governance, and cultural resistance, which can impede the effective adoption and integration of BI systems across organizations (Popovič et al., 2012).

The technological foundation of BI consists of several key components and tools that facilitate the extraction, processing, and analysis of data. Central to BI architecture are data warehouses, which serve as repositories consolidating data from multiple sources into a unified, structured format (Inmon, 2005). These data warehouses rely on ETL (Extract, Transform, Load) processes to cleanse, transform, and organize data, enabling efficient querying and analysis. Online Analytical Processing (OLAP) tools allow users to interact with data multidimensionally, exploring trends and patterns across various attributes. At the front end, visualization tools such as dashboards and reporting platforms transform complex data sets into accessible and actionable insights (Watson, 2009). Popular tools like Tableau, Power BI, and QlikView provide interactive and customizable interfaces that facilitate real-time monitoring and decision support. The advent of self-service BI platforms has further democratized data access, allowing non-technical users to independently analyze and interpret data (Wixom et al., 2014). Moreover, the integration of BI with emerging technologies—such as machine learning for predictive analytics and the Internet of Things (IoT) for real-time data acquisition—has expanded BI's capabilities and relevance, particularly in sectors that rely on continuous monitoring and complex infrastructure (Chen et al., 2012; Turcu, Turcu, & Gaitan, 2018).

In the context of public utilities and infrastructure management, BI has emerged as an essential enabler for addressing operational complexities and improving service delivery. Utilities face numerous challenges, including aging infrastructure, increasing demand, stringent regulatory environments, and the imperative to optimize resource utilization (Pettit et al., 2012). BI applications contribute to overcoming these challenges by enhancing asset management through predictive maintenance, which allows for timely identification and resolution of equipment issues, thereby reducing downtime and maintenance costs (Hazen et al., 2014).

Additionally, BI supports customer service by providing detailed analytics on consumption patterns, billing accuracy, and complaint management, which in turn improves customer satisfaction and operational transparency. Resource optimization is a critical area of impact, where BI facilitates the detection of water loss, demand forecasting, and efficient energy use in water treatment and distribution (Gohar et al., 2013). Reports from leading organizations in the water sector highlight tangible benefits realized through BI adoption, including improved operational efficiency, regulatory compliance, and customer engagement (Khatri & Brown, 2010). Nevertheless, the implementation of BI in utilities is often constrained by challenges such as legacy system integration, data silos, and workforce readiness. Successful BI initiatives depend heavily on organizational factors such as leadership commitment, data governance frameworks, and capacity building to foster an environment conducive to analytics-driven decision-making (Yeoh & Koronios, 2010).

Similarly, the electricity sector has leveraged BI and smart grid technologies to enable load forecasting, outage prediction, and demand management. Utility companies such as National Grid UK and various North American providers exemplify how BI-driven analytics support infrastructure resilience and customer service enhancements (Williams, 2016). Beyond utilities, government initiatives such as Singapore's Smart Nation illustrate the role of BI in facilitating data-driven governance, urban planning, and public service optimization (Tan et al., 2016). These cross-sectoral applications underscore the transferability of BI methodologies and tools, offering valuable lessons for the water utility sector. Given the analogous challenges related to infrastructure monitoring, service quality, and customer engagement, adapting best practices from healthcare, electricity, and public administration can accelerate the effective adoption of BI in water utilities, particularly in resource-constrained contexts (Amankwaa et al., 2021; Atwater et al., 2016; Watson, 2009).

In sum, the literature reveals that BI has matured into a critical strategic capability across multiple sectors, including public utilities. While the water utility sector faces unique challenges, the adoption of BI tools offers significant opportunities to enhance operational efficiency, customer satisfaction, and resource management (Chen et al., 2012; Wamba et al., 2017). However, realizing these benefits requires addressing technical, organizational, and cultural barriers (Shollo & Galliers, 2015; Hayajneh & Harb, 2023). This literature review establishes a foundation for examining the implementation of BI in the water utility sector in Jordan, where the intersection of resource scarcity and growing service demands necessitates innovative data-driven management solutions (Abdel-Hadi, 2024; GIZ & International Water Association, 2018; Nofal et al., 2022).

Methodology

This study employs a qualitative case study approach to examine the implementation and utilization of Business Intelligence (BI) applications within water utility management. The case study methodology is particularly suitable for conducting in-depth investigations of contemporary phenomena in real-life contexts, especially when the boundaries between the phenomenon and its context are not clearly defined (Yin, 2018). In this research, the case study facilitates a comprehensive exploration of how BI tools are adopted and used in a local water utility in Jordan, the challenges faced during their implementation, and their perceived effects on both operational and managerial outcomes.

Research Approach

A single-case, embedded design was chosen to offer a comprehensive understanding of BI practices within the organization, while enabling the examination of multiple stakeholder perspectives, including those of management and technical personnel. The qualitative approach aligns with the study's exploratory goals, allowing the collection of rich, contextual insights that are not easily attainable through quantitative methods alone (Bryman, 2016).

Data Collection

Multiple data sources were utilized to ensure data triangulation and enhance the credibility of the findings. The primary data collection method involved semi-structured interviews with key personnel from both management and technical departments within the water utility. These interviews followed a structured protocol aimed at exploring perceptions of BI implementation, specific use cases, organizational readiness, challenges encountered, and benefits realized. Semi-structured interviews provided a balance between consistency across respondents and the flexibility to probe deeper into emerging themes (Braun & Clarke, 2006).

In addition to interviews, document analysis was performed on internal reports, strategic plans, performance dashboards, and other relevant materials that demonstrate how BI tools are embedded in organizational processes. Where feasible, observational data—such as shadowing staff during BI system usage or attending pertinent meetings—were also incorporated to provide richer contextual understanding and to validate self-reported information.

Sampling Strategy

The study employed a **purposeful sampling** strategy to identify participants with direct knowledge and experience related to BI systems within the utility. Key informants included decision-makers, IT specialists, data analysts, and department heads responsible for planning, operations, and customer service. The aim was to capture a range of perspectives that reflect the diverse ways BI tools are used and understood within the organization. The sample size was determined based on the principle of data saturation, where additional interviews no longer yielded new insights.

Data Analysis

The collected qualitative data were analyzed using **thematic analysis**, which involves identifying, analyzing, and reporting patterns (themes) within the data. The analysis followed the six-phase process recommended by Braun and Clarke (2006): familiarization with data, initial coding, theme generation, theme review, theme definition, and final reporting. Both inductive and deductive coding strategies were employed—inductive to capture emerging themes from the data, and deductive to examine pre-identified themes such as BI applications, challenges, and organizational impacts.

To enhance the reliability of the analysis, coding was conducted using qualitative analysis software (e.g., NVivo or MAXQDA), and an audit trail was maintained throughout the process. Where applicable, triangulation was used to compare findings across different data sources (interviews, documents, and observations) to validate and enrich the interpretation of results.

Findings

The findings from this qualitative case study are organized around four key thematic areas that emerged from the data analysis: (1) current applications of Business Intelligence (BI) within the utility, (2) perceived benefits and impacts, (3) implementation challenges, and (4) organizational readiness and future directions. These themes reflect the perspectives of both management and technical staff and are supported by data gathered through interviews, document analysis, and observations.

1. Current Applications of Business Intelligence

BI tools are actively used across multiple functional domains within the utility. Operational monitoring is one of the core areas, where dashboards enable near real-time tracking of water distribution, pressure levels, and service interruptions. This allows engineers and supervisors to detect and respond quickly to anomalies.

"We started using dashboards mainly to track billing performance and complaints. It helps us react faster, but not everyone trusts the data yet."
— Interviewee 3, Customer Service Manager

In customer service, BI tools are used to analyze billing records, monitor complaint trends, and detect consumption irregularities indicative of leaks or faults. Interviewees described a transition from reactive to proactive management, using BI to identify service issues before they escalate.

Financially, BI supports revenue monitoring, expense tracking, and reporting, giving senior managers the insights needed for budgeting and resource allocation.

2. Perceived Benefits and Impacts

Participants agreed that BI tools have enhanced transparency and accessibility of data. Managers and field staff now have better visibility into performance metrics, improving timeliness and accuracy of decision-making.

"The system is powerful, but many of our staff are not trained to interpret the analytics. They still prefer Excel."
— Interviewee 1, IT Department

BI has also contributed to reducing operational costs by optimizing maintenance and reducing water losses through data-driven targeting. Moreover, automated performance reporting has improved accountability both internally and in communications with donors and regulators.

3. Implementation Challenges

Challenges remain despite these successes. Integrating legacy systems that use incompatible data formats was frequently cited as a technical obstacle. Consolidating and cleansing data for use in BI platforms remains time-consuming and error-prone.

Another recurring issue is the low analytical capacity of many staff members. While IT specialists can manage the platforms, most frontline users lack the training to extract and interpret data meaningfully.

"Sometimes, we have the data, but we don't know what questions to ask. That's where we struggle."
— *Interviewee 5, Operations Supervisor*

Resistance to change also emerged, particularly among older staff who view BI with skepticism or as a threat to established routines.

4. Organizational Readiness and Future Directions

The utility's leadership has shown strong interest in expanding BI capabilities through investments in digital tools and staff development. A formal BI strategy is being drafted, with plans to introduce predictive analytics and GIS-based decision-making tools.

Participants were optimistic about the future, but emphasized the need for more structured training, better data governance, and enhanced collaboration between technical and operational units. The utility is also exploring mobile BI applications for field staff.

"BI helped us reduce unaccounted-for water by visualizing leaks and consumption anomalies. But integrating all systems is still a headache."
— *Interviewee 2, Technical Manager*

Furthermore, efforts are underway to build partnerships with universities and international organizations to strengthen innovation and institutionalize a culture of data-driven management.

Table: Summary of BI Applications and Outcomes

BI Application	Use Case	Observed Outcome
Operational Dashboards	Monitoring water distribution and pressure	Faster anomaly detection and service restoration
Customer Analytics	Tracking billing and complaints	Improved responsiveness and customer satisfaction
Financial BI Tools	Monitoring revenue and expenditures	Better budgeting and resource allocation
Data Warehousing	Consolidating diverse data sources	Improved data accessibility and historical analysis
Performance Reporting	Automated reporting to stakeholders	Increased accountability and cross-departmental awareness

Table 1. Summary of BI Applications and Their Outcomes in the Case Utility

Discussion and Interpretation

This study sets out to explore the role of Business Intelligence (BI) applications in water utility management using a qualitative case study approach. The findings reveal that while BI tools are being utilized in several critical domains, including operational monitoring, customer service, and financial reporting—their implementation is shaped by both organizational enablers and structural constraints. These findings align with and expand upon existing literature on BI adoption in public sector infrastructure management.

The study confirms the growing relevance of BI in improving operational efficiency, a theme widely documented in the literature (Wixom & Watson, 2010; Sharda et al., 2019). Within the case utility, the use of dashboards and performance monitoring tools has led to more timely responses to service disruptions and greater visibility into system performance. This supports previous research suggesting that real-time analytics enhance utility responsiveness and service reliability (AWWA, 2020). The case also demonstrates how BI facilitates proactive management by enabling early detection of problems, such as abnormal consumption patterns, which can signal leaks or fraud—paralleling findings from electricity and healthcare sectors where BI has improved operational forecasting and preventive interventions (Chen et al., 2012).

The reported organizational benefits, including improved data transparency and accountability, reflect the transformative potential of BI to support governance and compliance—especially in utilities that operate under public scrutiny or international donor frameworks. These outcomes resonate with studies emphasizing the role of BI in fostering a culture of evidence-based decision-making (Popovič et al., 2012; Amankwaa et al., 2021).

However, the challenges identified, particularly related to legacy system integration, staff capacity, and cultural resistance, highlight persistent barriers that can undermine BI effectiveness. These obstacles are consistent with barriers documented in previous research and suggest that technical solutions alone are insufficient without concurrent organizational change management (Anderson, 2021; Shollo & Galliers, 2015). The limited analytical skills of end-users underscore the need for comprehensive training and support to democratize BI usage beyond IT specialists. Additionally, resistance from senior staff may require targeted change management initiatives that communicate BI benefits and involve stakeholders in system design and implementation.

The utility's proactive steps toward a formal BI strategy, infrastructure investments, and capacity building are promising and align with best practices for sustainable BI adoption (IWA, 2022; Gartner, 2021). The exploration of mobile and predictive BI tools indicates a forward-looking orientation, which may further enhance operational agility and customer engagement. Partnerships with external organizations for innovation and training are critical to overcoming internal capacity gaps and can leverage global expertise adapted to local needs.

In the Jordanian context, where water scarcity and infrastructure challenges are acute, the integration of BI into water utility management offers a pathway to optimizing limited resources and improving service delivery. This case study provides empirical evidence that such integration is feasible but contingent on addressing both technological and human factors. Future research could expand on this work by conducting comparative studies across multiple utilities or by quantitatively assessing BI's impact on performance metrics.

Conclusion and Recommendations

This study examined the application of Business Intelligence (BI) tools within a local water utility in Jordan, employing a qualitative case study approach to understand how BI is integrated into operational processes, the benefits realized, and the challenges faced. The findings indicate that BI has become an essential component of the utility's management framework, supporting functions such as operational monitoring, customer service, and financial planning. The use of dashboards, reporting tools, and data integration platforms has enhanced the organization's ability to make timely and informed decisions, improve service quality, and ensure greater accountability.

However, the study also revealed several persistent barriers that hinder the full realization of BI's potential. These include technical challenges related to legacy system integration, organizational issues such as limited analytical capacity among non-technical staff, and cultural resistance to data-driven practices. Despite these constraints, the utility demonstrates strong leadership commitment to expanding BI capabilities, signaling an encouraging level of organizational readiness for digital transformation.

The case reinforces the notion that successful BI implementation in public utilities is not solely a technological issue, but a socio-technical challenge that requires coordinated efforts across infrastructure, people, processes, and governance. The experience of the utility highlights the importance of aligning BI initiatives with institutional goals, fostering a culture of data literacy, and investing in the human capital necessary to support advanced analytics.

Based on these findings, the following **recommendations** are proposed:

1. Invest in Capacity Building and Data Literacy

Utility management should prioritize the development of staff competencies in data analysis and interpretation. Tailored training programs and continuous professional development opportunities can empower non-technical staff to engage meaningfully with BI tools and outputs. Encouraging a culture of learning and experimentation will help reduce dependence on a limited pool of technical experts.

2. Develop a Comprehensive BI Strategy

A formal BI strategy that aligns with the utility's overall objectives should be developed and regularly reviewed. This strategy should outline the goals of BI use, define key performance indicators, establish data governance protocols, and identify responsible units for implementation. A clear roadmap can ensure coherence and accountability across BI initiatives.

3. Strengthen Data Infrastructure and Integration

To address the challenges posed by fragmented and outdated systems, the utility should invest in modernizing its data architecture. This includes adopting interoperable platforms, standardizing data formats, and automating data flows to improve consistency and reduce manual errors. Enhanced data infrastructure will enable more advanced analytics and improve data-driven decision-making.

4. Promote Organizational Change Management

Given the observed resistance to change, leadership must actively manage the cultural aspects of BI adoption. This includes clear communication of BI's purpose and benefits, involving staff in system design and decision-making, and recognizing and rewarding data-informed behaviors. Building trust in BI systems is essential for long-term success.

5. Explore External Collaborations and Innovation Partnerships

Collaborating with academic institutions, technology providers, and international organizations can provide the utility with access to expertise, research, and funding. Such partnerships can support pilot projects in areas like predictive analytics or mobile BI and facilitate knowledge transfer on emerging practices in utility management.

6. Conduct Further Research and Comparative Studies

This study provides a contextualized understanding of BI implementation in a single water utility. Future research should explore comparative cases across multiple utilities or countries to identify broader patterns and best practices. Quantitative studies may also complement qualitative insights by measuring the tangible performance outcomes of BI adoption.

In conclusion, Business Intelligence represents a valuable pathway toward more efficient, transparent, and responsive water utility management. While the journey toward full BI integration is complex and multifaceted, the case study illustrates that with strategic planning, organizational commitment, and targeted investments in people and infrastructure, public utilities can leverage data to drive transformative improvements in service delivery.

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