



Article

Evaluation of the Factors and Strategies for Water Infrastructure Project Delivery in South Africa

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Abstract: Infrastructure project delivery, specifically the delivery of water infrastructure projects, is a serious challenge in South Africa. Therefore, using the study context of water utility agencies in South Africa, the objective of this study was to examine the challenges that emanate from poor delivery and factors that cause poor delivery of water infrastructure projects in South Africa. Furthermore, it evaluated the various strategies that could enable improvement in water infrastructure project delivery. A survey research method constituting data obtained on the perceptions of relevant stakeholders and ordinal regression modeling were used for conducting the study. Findings suggest that delay in project completion, cost overruns, poor quality of work, poor fund utilization, and poor service delivery are the major challenges of the poor delivery of projects. The major factors that cause such challenges are linked to four aspects of the infrastructure projects such as project management, organization and management, construction and construction management, and sociopolitical. Six-pronged strategic measures, which include capacity building, the appointment of competent and skilled professionals, structuring review and monitoring processes, enhancing collaboration and communication among stakeholders, enabling accountability and transparency, and adopting participative leadership, can assist efficient water infrastructure project delivery in South Africa.

Keywords: construction management; project delivery; project management; organization and management; water infrastructure



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1. Introduction

Infrastructure is considered as the backbone of a country or city to stimulate socio-economic development. Many developing countries including South Africa, China, India, Vietnam, and Thailand to name a few have been found to invest heavily in infrastructure to create or reinforce both the physical and digital infrastructure, specifically in the last two decades. The focus of the creation of infrastructure includes roads, airports, seaports, rail, water, energy, housing, and information and communication technology that would enhance economic development and offer social benefits.

In the context of South Africa, the country had invested heavily during the 1960s and 1970s in various infrastructure sectors to create adequate and efficient infrastructure. However, the lack of adequate and efficient infrastructure in recent years has been considered a constraint for socioeconomic development in many parts of the country. Realizing the importance and linkage between infrastructure creation and economic development [1–4] and observing the gap in infrastructure in different sectors, a concerted effort has been made since the start of this millennium to upgrade the old or create new infrastructure in South Africa [3,5–7]. For example, as indicated from Figure 1, the public sector spending on infrastructure development is more than ZAR 2.2 trillion during the period 1998/99 to 2014/15 as indicated in the National Treasury Budget Review (2016) [8]. The expenditure had increased from ZAR 48.8 billion in 1998/99 to ZAR 259.7 billion in 2014/15, at an average rate of increase of 7.5% per year. A further investment ranging between 275 billion

and 305 billion per year was estimated between the year 2015/16 to 2018/19 [8,9]. In the year 2020, 50 projects with an estimated cost of ZAR 340 billion have been undertaken by the government [10]. These investments are although in absolute terms at the price (value) of respective years, considerations for annual inflation (the inflation rates range between 4.13% and 6.3% except for the years 2003, 2004, and 2007–2009) have been made in the budget estimate. This indicates that a consistent rise in the investment in the infrastructure sector was seen in the country. It was also found that the lion's share of the investment has occurred in three sectors such as transportation and logistics, energy, and water and sanitation.

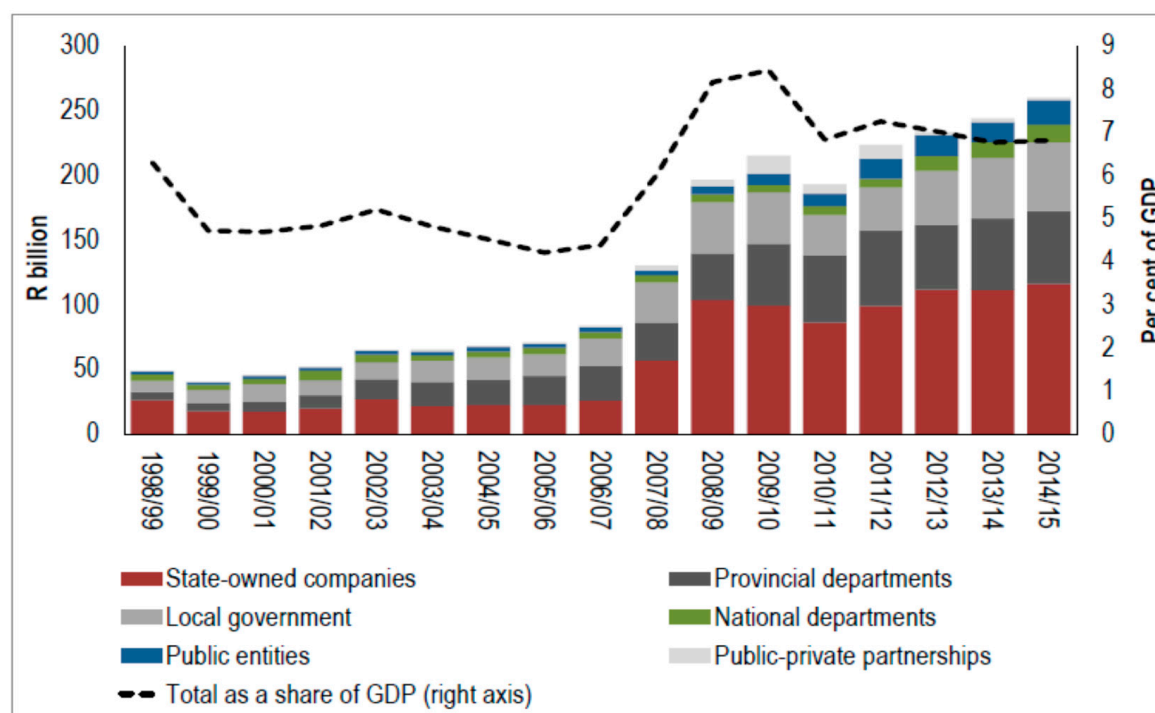


Figure 1. Public sector infrastructure spending 1998/99–2014/15 (National Treasury Budget Review, 2016).

However, despite the significant investment, it is argued that infrastructure project delivery has been slow. Many projects particularly in the above-mentioned (transportation and logistics, energy, and water and sanitation) sectors have been faced with challenges of delay and cost overruns. Although the national government provides the budget for investment, the various activities for the creation of infrastructure starting from the choice and prioritization of the projects to delivery of the projects are done by various state agencies such as municipalities, state-owned companies, or boards. In the wake of infrastructure delivery challenges faced by the state entities, the national government developed an infrastructure delivery management system (IDMS) that focuses on applying best practices of project delivery methods for infrastructure management within the government sector and state-owned entities [11]. However, the onus of the infrastructure delivery remains with the state entities. Arguments have emerged that the lack of contextualized project management strategies is at the forefront of these challenges, which hinders the smooth execution and progression of the projects. Furthermore, based on this premise the various state entities have developed their project management strategies to deal with the project delivery challenges such as timely completion and delivery of the project and attaining cost efficiency. However, contrary to the envisaged outcomes, the project delivery agencies, are struggling to cope with the challenges of completing or delivering the projects within the estimated budgets and scheduled time. For example, the delivery of large-scale water infrastructure projects in the country has decreased by 30% over the last few years [12].

Some of the major challenges that contribute to the poor project delivery have been argued to relate to inappropriate procurement practices, which initiate, create, and fulfill contracts, the absence of delivery management, and poor identification, assessment, and preparation of the project. Further, poor structuring, management of the tender process, contract management and drafting of contracts, lack of management capacity and proper skills, failures in timely taking and managing decisions, stakeholder identification, internal and external communications, political interference, and unrealistic time scales also contribute to the failures of timely delivery of the projects [9]. Poor project management specifically related to planning and design, poor risk management and stakeholders' engagement during planning, design, and implementation phases is argued to contribute to the failure of the project delivery from the engineering project management point of view [13].

Although the majority of the infrastructure sectors including the most predominant sectors such as transportation and logistics, energy, and water and sanitation are faced with project delivery challenges, water being one of the most important and scarce commodity for the living habitat including people, and water scarcity in many regions of the country is being experienced in recent years, water infrastructure delivery is of paramount importance. Therefore, using the context of water infrastructure project delivery in South Africa, the objective of the study was to identify the various challenges that impede the project delivery, evaluate the various factors, which contribute to the challenges, and assess their impact on various aspects of the project. Followed by various strategic measures that could improve water infrastructure project delivery in the country were evaluated. The study was conducted by considering the study context of public sector water utility companies located in different provinces in South Africa.

1.1. The Study Context

The public sector water utility agencies affiliated with the South African Association of Water Utilities (SAAWU) were considered as the study context for this study. Previously known as the South African Association of Water Boards, SAAWU is a Section 21 company established in March 2001 to represent, endorse, coordinate, and manage the interests of state-owned entities responsible for the delivery of water services in South Africa. Nine water utility agencies such as Amatola Water, Bloem Water, Magalies Water, Mhlathuze Water, Midvaal Water Company, Lepelle Northern Water, Rand Water, Sedibeng Water, and Umgeni Water are affiliated to SAAWU. The detailed profiles of these water utility agencies are presented in Table 1.

The various infrastructure that the water utility agencies needed to build for its smooth operation include dams, abstraction works, pump stations, pipelines, reservoirs, raw water treatment works, and wastewater treatment works. These companies build their infrastructure as per the demand of the situation. To develop each infrastructure, they create projects and follow the project management lifecycle from inception to the project closeout based on the principles outlined in PMBOK. However, it was observed that these companies face significant challenges concerning timely delivery of the projects and therefore undertake remedial measures to overcome the challenges. Umgeni water, for example, implemented Umgeni Water Project Management Plan (2012) [14] to meet the demands of consistent project delivery. The purpose of the Project Management Plan (PMP) was to provide the framework for the execution of the projects and introduce procedures, which are in addition to the PMP, required to run the project. The Umgeni Water PMP methodologies are based around the project management body of knowledge (PMBOK) framework and its implementation strategy is based on a 4-stage project life cycle process, such as initiate, plan and design, execute, and close [14].

Table 1. Water utility agencies in South Africa, their service area, and functions.

Agency	Province	Service Area	Function
Amatola Water	Eastern Cape	Controls 11 plants and 7 subregional, bulk distribution networks in an assigned services area of 45,794 km ² .	Delivery of bulk water supply and sanitation services. It affords comprehensive contract services to municipalities for water abstraction, treatment, bulk supply and water quality observation for domestic, industrial and agricultural use.
Bloem Water	Free State	7 water treatment works in Mangaung Metro Municipality, Mantsopa Local Municipality, Naledi Local Municipality, and Kopanong Local Municipality.	It supplies potable water to a population of more than 1.2 million people.
Magalies Water		Magalies Waterworks in a region of 42,000km ² across 3 provinces being North West, Limpopo, and Gauteng in the two key catchments area of the Crocodile and the Pienaars River.	Magalies Water delivers quality bulk water and secondary services directly to municipalities, mines, and other industries.
Mhlathuze Water	KwaZulu-Natal	Mhlathuze Water's region of supply covers 37,000km ² stretching from the uThukela River in the South and up the East Coast to the Mozambique and Swaziland borders, around Vryheid and back to the uThukela River.	It is a regional water and wastewater service provider. It constructs, operates, and maintains an interbasin transfer scheme, a major water treatment plant, an offshore wastewater disposal pipeline, and manages water treatment and sewerage plants on an agency basis for industry.
Midvaal Water Company	North-West Province	Midvaal Water Company is a water service provider supplying bulk potable water to the Klerksdorp, Orkney, Stilfontein regions and attends to an area of 900 km ²	It procures raw (untreated) water from the Department of Water Affairs and Forestry and after purification, supplies to consumers.
Lepelle Northern Water	Limpopo	Three operating regions, namely, the Capricorn, Sekhukhune, Mopani, and Waterberg areas in the province of Limpopo.	It provides water services to other water service institutions within its region of service. The organization presently operates 20 water treatment schemes and 5 waste waterworks.
Rand Water	Gauteng	Metropolitan Municipal Councils—City of Joburg, City of Ekurhuleni, City of Tshwane; 13 Municipalities—Emfuleni, Govan Mbeki, Lesedi, Madibeng, Merafong, Metsimaholo, Midvaal, Mogale City, Ngwathe, Randwest, Rustenburg, Thembisile Hani, Victor Khanye; Royal Bafokeng Administration; 40 Mines; and 926 industries and direct customers.	Its supplies network embraces over 3056 km of large diameter pipeline, serving 58 service reservoirs.
Sedibeng Water	The Free State, North West and Northern Cape.	It is serving the Nama Khoi Local Municipality (Steinkopf, Okiep, Concordia, Carolusberg, Nababeep, and Springbok) including mines in the arid north-western part of the Northern Cape, and Pelladrift and Botshelo area.	Potable water supply to the regions mentioned of the three provinces.
Umgeni Water	KwaZulu- Natal	eThekweni Metropolitan Municipality, iLembe District Municipality, Ugu District Municipality, Harry Gwala District Municipality, uMgungundlovu District Municipality, and Msunduzi Local Municipality.	It is the leading bulk water supplier in KwaZulu-Natal and has developed into the second-largest water utility in South Africa, supplying over 453 million cubic meters of bulk potable water annually.

However, a mismatch between the PMP and the operating functions and procedures of departments within the organizations was observed, which necessitated developing appropriate strategies to identify inefficiencies and shortcomings and offer remedial solutions

for efficient delivery of the infrastructure projects. Therefore, this study was undertaken to explore the challenges, and the influential factors contributing to poor project delivery and to develop appropriate strategies to improve project delivery.

1.2. Infrastructure Project Delivery Challenges: A Perspective from Literature

Infrastructure development is vital for the socioeconomic development of a nation, which is well acknowledged across the world. The socioeconomic benefits accrue only when adequate provisions and delivery of infrastructure is made [13,15,16]. According to Babbie (2010) [17], without adequate infrastructure provision and delivery, the major functions of a nation or human habitations are likely to suffer. For example, there could be an increase in road traffic congestion leading to unsustainable transportation in the absence of adequate road infrastructure, communication might suffer because of poor telecommunication infrastructure and a scarcity of electricity and water because of poor water and power infrastructure.

Governments are making concerted efforts through the undertaking of focused programs and schemes to boost infrastructure development. One of the major efforts made by the governments seems to be an increase in investment through domestic and foreign direct investment (FDI), and private sector participation by the adoption of public–private partnerships (PPPs) in public infrastructure delivery [18–20]. However, planning, policy, and investment generally work at the macro level. The majority of infrastructure projects are either delayed or suffer from poor delivery at the micro or the project level.

According to scholars, several challenges emanate from poor infrastructure development and delivery, which are caused by many factors. Some of the challenges, which are the consequences of poor infrastructure delivery, could be cost overruns, delayed completion of the projects, poor quality, poor fund utilization, and poor societal benefits in terms of service delivery [13,20,21]. These challenges emanate from a plethora of socioeconomic, technological, and management factors, especially at the project or organizational level [13,21]. For example, according to Kudumela (2015) [22], insufficient skills capacity at the municipal level, lack of funding, and political instability and corruption are the major factors that create challenges for infrastructure development and delivery in developing countries. Similarly, Senyakoe (2011) [21] argued that sectoral planning and program management are major issues, specifically in countries such as South Africa. Arguments have emerged that the lack of technical, management, and administrative capacity of organizations that are entrusted with infrastructure development to plan, execute, operate, and maintain infrastructure projects are among the major challenges, which hinder the success of project delivery [14,23–26]. Furthermore, insufficient investment laws, limited access to loans and other debt financing institutions, insufficient municipal revenues from taxes and tariffs and unreliable planning and procurement processes used to carry out public projects also influence the delay and poor delivery of infrastructure projects [26]. Moreover, it was also argued that social and environmental considerations should be prioritized to facilitate adequate and efficient project delivery. Coordination among the various stakeholders and involved organizations are also essential to enable project delivery [20,27].

These challenges and factors are almost similar in every spectrum of infrastructure and valid for water infrastructure sectors. The Department of Water and Sanitation (DWS), water boards (for each province), municipalities (water service authorities), and special-purpose vehicles (for example, Trans-Caledon Tunnel Authority and Komati Basin Water Authority in South Africa) are engaged to regulate water and its safe delivery in the water sectors in South Africa [28,29]. In other words, the sustainability of water infrastructure and safe delivery of water through the development and delivery of water infrastructure is the prime responsibility of these public sector organizations. However, despite the efforts of the governments at the national and provincial levels, water infrastructure projects in the country are suffering from different challenges that include delay, conflict, and cost overruns. Moreover, although studies at the macro and conceptual level have been made to explore the various reasons for the poor delivery of water infrastructure projects

and policies thereof to meet the challenges [9,12,13], detailed studies at the microlevel or at the organizational level have been limited. Therefore, this study was conducted by considering the study context of water utility agencies in the public sector engaged in water infrastructure development and delivery to explore the challenges created because of poor infrastructure delivery and why such challenges occur and what strategic measures could enable efficient infrastructure project delivery, which seems to be a significant gap in the literature not only in the South African context but also in the context of many developing countries in Africa. In other words, the study will examine the various factors from the project management, organization and management, construction and construction management, and sociopolitical aspects at the organizations level (as shown in Figure 2), and their influence on the project delivery and exploring remedial strategies.

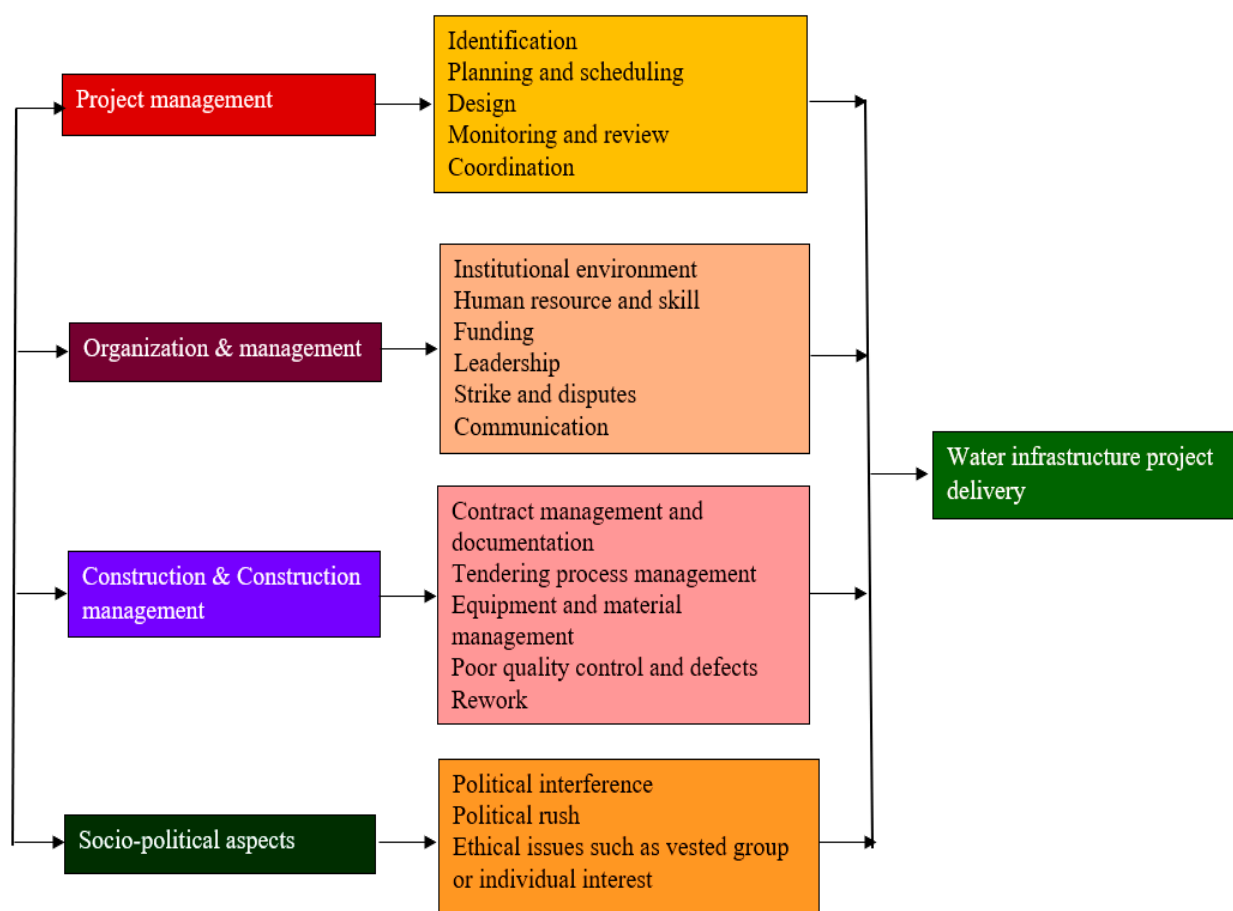


Figure 2. Conceptual framework of different aspects and factors influencing water infrastructure project delivery.

2. Research Methods

The focus of the study was to explore the factors that create project delivery challenges in water infrastructure and evaluate the various strategic measures that could assist in improving the infrastructure delivery situation in South Africa. Commensurate to this aim of the study, a survey research method was adopted. A survey was conducted to collect data followed by descriptive and inferential statistical methods and an ordinal regression modeling approach that were adopted to analyze data.

2.1. Data Collection

A survey among the stakeholders was conducted to collect data. A stakeholders' perception survey was essential as no structured statistical data to evaluate and analyze the challenges and factors that influence infrastructure project delivery were available. This

data collection method was deemed suitable and as stakeholders can provide insights to the various aspects of the projects and project delivery challenges and the plausible strategic improvement measures because of their engagement with the project related activities at the grassroots level. The study relied on the perceptions of the various stakeholders engaged in the water infrastructure project delivery system in South Africa.

A list of the stakeholders was compiled for this survey. The compilation of the list of the stakeholders was conducted based on a set of criteria that includes the professional engagement of the stakeholders, involvement in water infrastructure-related projects, level of education, and experience in different aspects of the projects. For example, the respondents should have in some way participated or engaged or be responsible for the decision-making, initiation, planning, execution, construction, management, administration, or maintenance of water infrastructure-related projects. The sampled stakeholders were selected from the KwaZulu-Natal, the Free State, and the Eastern Cape provinces within South Africa. These provinces were selected because major water utility agencies are located there, the researchers have access to the water infrastructure projects and the willingness and availability of the respondents. After the compilation of the list, the stakeholders were contacted via email or personal contacts, or telephonically to invite them to take part in the survey. Based on the availability and willingness of the stakeholders, the final sample respondents were selected. However, while selecting the respondents, care was taken to not to discriminate based on race, gender, nationality, and age to avoid biased responses. The survey was conducted among a total of 220 respondents; however, 181 responses were received with a return percentage of over 82%, which was found to be adequate for a credible study [30]. The stakeholders included project managers, civil engineers, planning engineers, quantity surveyors, environmental project managers, servitude administrators, and technical staff and professionals from the civil society having engagements with water infrastructure.

The survey was conducted using a pretested questionnaire. First, a questionnaire that constituted questions related to the major challenges of infrastructure project delivery, and the factors that influenced project delivery was developed. Questions related to plausible strategic measures to improve the project delivery system were also included. The respondents were asked to provide their response on a five-point (1–5) Likert scale. The pointers in the Likert scale were given in terms of the significance of the influence of the challenges and factors on project delivery. The same scale was also used for evaluating the influence of strategic measures. The Likert scale adopted for the purpose is as follows:

- (1) Very low;
- (2) Low;
- (3) Average;
- (4) High;
- (5) Very high.

The questions were sent to the respondents by email, which they have returned by the use of the same platform.

2.2. Data Analysis

Several methods of data analyses and modeling approaches could be useful for this type of studies. Analytical methods, such as regression analysis including ordinal regression modeling, principal component analysis (PCA), generalized linear models (GLM), etc., can be used to observe the relationship between various variables influencing project delivery and project delivery success. Similarly, multicriteria decision-making models (MCDMs), such as the analytical hierarchy process (AHP), data envelope analysis (DEA), technique for order of preference by similarity to ideal solution (TOPSIS), etc., can also be applicable. However, the suitability of these methods depends on the availability and type of data. Since the data was collected in an ordinal scale in the absence of the availability of structured statistical data, and the ordinal regression model offers opportunities to evaluate the influence of various factors and strategies comparatively among each other or to a

reference, this modeling technique in addition to other relevant descriptive and inferential statistical methods were found suitable and therefore used in the study.

Both descriptive and inferential statistics were used to analyze and evaluate the responses received from the respondents. IBM-SPSS, V.27 statistical package was used for data analyses. The demographic profile of the respondents was analyzed using descriptive statistics. The challenges of project delivery were evaluated by use of a perception index developed based on the mean score of the Likert scale responses. Standard deviation and z-test (*p*-values) were also used to support the evaluation of the challenges made by using the perception indices.

Ordinal regression models were used to assess the relative influence of the various factors on the project delivery and the plausible strategic measures, which would improve the situation. The ordinal regression model is generally used to forecast the behavior of the ordinal dependent variable (whose values exist on an arbitrary scale) with a set of independent variables [31–33]. The dependent variable should be the order response category variable and the independent variables may be categorical or continuous variables. It focuses on the strength of the relationships between two or more variables and assumes a dependence or causal relationship between one or more independent variables and one dependent variable [31–33]. Furthermore, ordinal regression models offer the advantage to make full use of ranked data [34–36].

In this study, as the data were collected on an ordinal scale and the relative influence of different factors and strategies was evaluated, this model was found relevant and most suitable. In this context, the model was used to assess the effect of the various factors and plausible strategies on the water infrastructure project delivery. In other words, the model used to estimate the influence of various factors and strategies on project delivery success.

The log-linked ordinal regression model was used to develop the model and estimate the parameters. The model is represented by Equation (1).

$$\ln\left(\frac{\gamma_i^{(j)}}{1 - \gamma_i^{(j)}}\right) = \ln\left(\frac{P(Y_i \leq j | x_1, x_2, x_3, \dots, x_p)}{1 - P(Y_i \leq j | x_1, x_2, x_3, \dots, x_p)}\right) = \tau_j - (\beta_1 x_1 + \beta_2 x_2 + \dots + \beta_p x_p) \quad (1)$$

where Y is the response variable with k ordered categories

$j = 1, 2, \dots, k - 1$;

$\gamma_i^{(j)}$ is cumulative probability $P(Y \leq j) = P(Y = 1) + P(Y = 2) + \dots + P(Y = j)$ for $j = 1, 2, \dots, k - 1$.

$\gamma_i^{(k)} = (Y \leq k) = 1$, so it should not be modeled;

Y_i are dependent observations which are statistically independent $i = 1, 2, \dots, n$;

x_1, x_2, \dots, x_p are p explanatory variables;

$\beta_1, \beta_2, \beta_3$, etc. correspond to the regression coefficients for the respective independent variables;

τ_j are the cut-off points between categories.

The goodness of fit, likelihood ratio, Nagelkerke (pseudo R square), and test of parallel lines were used to assess the validity and robustness of the models [34,37,38].

3. Results

Three vital aspects concerning the infrastructure delivery were analyzed and discussed in the following sections. These aspects are challenges experienced in project delivery, factors, and their relative influence that cause the challenges, and strategic measures to improve the scenario.

3.1. Demographic Profile of the Respondents

The demographic profile of the respondents is presented in Table 2. The demographic profile includes professional engagement, number of years of experience, and participation in water utility-related projects. This was necessary to understand the sufficiency and validity of the responses of the respondents. As observed in Table 2, the type of professional engagement ranged between 4.97% (quantity surveyor) and 23.76% (other professionals).

However, there was a significant share of the important stakeholders, such as project managers (11.05%), contractors (11.60%), consultants (10.50%), civil engineers (7.73%), planning engineers (6.63%), technical staff (15.47%), etc., indicating the proportional distribution of the participation of stakeholders in the survey. The majority of the stakeholders (51.93%) had experience between 5 and 10 years and more than 21% of respondents had 11–15 years of experience. Similarly, 8.84% of the respondents had more than 15 years of experience. Therefore, more than 80% of the respondents had significant professional experience. It was also found that more than 76% of the respondents had direct or indirect experience with water projects, and about 24% did not have water infrastructure project experience; yet are experienced in other infrastructure projects. Thus, the demographic profile indicates that the sample used for the survey is diverse and suitable.

Table 2. Profile of the respondents.

Respondents	Frequency	% Share
Professional engagement		
Project Managers	20	11.05
Civil Engineers	14	7.73
Planning Engineers	12	6.63
Quantity Surveyors	9	4.97
Environmental Project Manager	7	3.87
Servitude Administrators	8	4.42
Technical staff	28	15.47
Contractors	21	11.60
Consultants	19	10.50
Other related professionals (water quality technologist, hydrologist, geologist, mechanical, electrical engineers, Information Communication Technologist, etc.)	43	23.76
Years of experience		
<5 years	32	17.68
5–10 years	94	51.93
11–15 years	39	21.55
>15 years	16	8.84
Participation in water projects		
Directly participated in water projects	64	35.36
Indirect association with water projects	74	40.88
Not associated with water projects but experience in other infrastructure projects	43	23.76

3.2. Challenges in Project Delivery

Several challenges are argued to plague the infrastructure project delivery system in South Africa. Table 3 presents the challenges faced in the project delivery system in the water sector. The most prominent challenge found was the cost overrun (PI = 3.70, p -value ≤ 0.05). In other words, most of the water-related infrastructure projects exceeded the initial estimated budget, which was also evidenced by other studies [9,13]. This challenge is followed by three other important challenges such as poor quality of work (PI = 3.41, p -value ≤ 0.05), poor fund utilization (PI = 3.36, p -value ≤ 0.05), and delay in project completion (PI = 3.30, p -value ≤ 0.05). Moreover, these challenges are intertwined [9,39]. For example, a delay in project completion leads to cost overruns and vice versa. Additionally, poor quality of work sometimes leads to rework, consequent upon which delays in project completion and cost overruns occur. Furthermore, poor fund utilization is both a cause and effect for the delay in project completion and cost overruns [9,40]. Moreover, poor service delivery was also a major challenge (PI = 3.13, p -value ≤ 0.05), which could be a consequence of the other four challenges. Therefore, the combined effect of these five challenges play a crucial role in poor project delivery of water infrastructure projects and adversely impacts the societies in South Africa.

Table 3. Challenges of project delivery.

Challenges	PI	SD	Z-Test <i>p</i> -Value	Significance
Delay in project completion	3.30	1.22	0.00065953	Statistically significant
Cost overruns	3.70	1.06	5.84477×10^{-19}	Statistically significant
Poor quality of work	3.41	1.09	3.75063×10^{-7}	Statistically significant
Poor fund utilization	3.36	1.01	7.91158×10^{-7}	Statistically significant
Poor service delivery	3.13	1.11	0.034	Statistically significant

3.3. Factors and Their Relative Impacts on Project Delivery

Factors under four specific categories such as (1) project management (PM), (2) organization and management (OM), (3) construction and construction management (CCM), and (4) societal aspects (SA) were evaluated to examine their influence and relative impact on water infrastructure project delivery by use of the ordinal regression model. However, before the model was developed, the reliability of the data was checked using the Cronbach α test. A Cronbach α value of 0.77 indicates significant reliability of the data.

Prior to the analysis of the model results, the validity of the model was established by verifying the model validation parameters. The model validation parameters are presented in Table 4. It was found that the model fitting parameter was significant (p -values ≤ 0.05), and the goodness of fit value was 0.994 (p -value > 0.05). Similarly, the test of parallel lines value was 0.164 (p -value > 0.05) and the Nagelkerke (pseudo R square) value was 0.765 (> 0.7). Thus, these four parameters had acceptable values indicating the robustness and validity of the model and thus the model parameters estimates could be used to analyze the factors that impact project delivery.

Table 4. Model validation parameters.

Parameter	Chi-Square Value	<i>p</i> -Values	Acceptable Values	Validity
Model fitting parameter (Likelihood test)	238.15	0.000	≤ 0.05	accepted
Goodness of fit	262.36	0.994	> 0.05	accepted
Test of parallel lines	67.34	0.164	> 0.05	accepted
Nagelkerke (Pseudo R square)		0.765	≥ 0.7	accepted

The model estimates and the factors that cause major challenges in water infrastructure delivery in South Africa and their relative impacts are presented in Table 5 and discussed in the following sections.

3.3.1. Project Management

Table 5 presents the project, management-related factors, and their relative impact on the project delivery. The various factors analyzed include identification, assessment, and preparation of project, planning and scheduling, design, monitoring and review, and coordination. While analyzing the significance and their relative impact, implementation of a proper project management system was considered as the reference factor. As evidenced from Table 5, planning and scheduling, monitoring and review, and coordination are the three most significant factors that influence water infrastructure project delivery in South Africa. Among these factors, planning and scheduling ($B = 5.214$) had the highest impact followed by coordination ($B = 3.182$) and monitoring and review ($B = 2.017$) in that order. In other words, poor planning and scheduling is the most important factor that ensues barriers in project delivery. Additionally, coordination among various stakeholders and activities and monitoring and review play crucial roles. However, factors such as

identification, assessment, and preparation of a project, and design were found to be statistically insignificant, thus were not likely to influence project delivery significantly. These findings are in concurrence with the findings from previous studies [9,11].

Table 5. Factors and their relative impact on the project delivery.

Factors	Parameter Estimates (B)	EXP (B)	Wald	Upper Bound	Lower Bound	p-Value	Significance
Project management							
Identification, assessment and preparation of project	1.414	4.11	3.510	−0.065	2.893	0.061 *	Not Significant
Planning and scheduling	5.214	183.83	34.527	3.475	6.954	0.000	Significant
Design	−0.590	0.55	0.703	−1.969	0.790	0.402 *	Not Significant
Monitoring and review	2.017	7.52	5.696	0.361	3.674	0.017	Significant
Coordination	3.182	24.09	15.002	1.572	4.792	0.003	Significant
Implementation of the proper project management system (Reference)	0				1		
Organization and management							
Institutional environment	2.342	10.40	6.122	0.487	4.198	0.013	Significant
Human resource and skill availability	3.471	32.17	18.754	1.900	5.042	0.000	Significant
Funding	3.218	24.98	18.870	1.766	4.670	0.000	Significant
Leadership	3.015	20.39	16.609	1.565	4.465	0.000	Significant
Strikes and disputes within the organization	3.089	21.96	14.391	1.493	4.686	0.000	Significant
Both external and internal Communication	2.436	11.43	8.730	0.820	4.052	0.003	Significant
Competent O&M (reference)	0				1		
Construction and construction management							
Contract management and documentation	1.599	4.95	5.584	0.273	2.926	0.018	Significant
Tendering process management	0.605	1.83	0.522	−1.036	2.246	0.470	Not significant
Equipment and material	2.282	9.80	14.321	1.100	3.464	0.000	Significant
Poor quality control and defects	1.861	6.43	6.600	0.441	3.281	0.010	Significant
Rework	0.876	2.40	1.130	−0.739	2.490	0.288	Not significant
Construction management practices (reference)	0				1		
Sociopolitical aspects							
Political interference	2.872	17.67	11.294	1.197	4.548	0.001	Significant
Political rush	3.609	36.93	20.149	2.033	5.185	0.000	Significant
Ethical issues such as vested group or individual interest	2.068	7.91	8.461	0.675	3.462	0.004	Significant
Congenital sociopolitical environment (reference)	0				1		
Cronbach α				0.77			

* Indicates Statistically not-significant.

3.3.2. Organization and Management

Organization and management factors play very important roles in the success of project delivery or any organization. The factors that included under organization and management are institutional environment, human resource and skill availability, funding, leadership, strikes and disputes within the organization, and external and internal communication as shown in Table 5. The influence of these factors in the project delivery of water infrastructure in South Africa was evaluated in reference to the competent organization and management factor. From the model results, it was found that all the six factors were

statistically significant and therefore were likely to influence project delivery of water infrastructure in South Africa. Moreover, it was found that human resource and skill availability ($B = 3.471$) and the availability of funding ($B = 3.218$) were the two most vital factors for the success of the project delivery. In the absence of both factors, the successful and timely delivery of projects becomes a challenge. Furthermore, these two factors are followed by two more crucial factors such as strikes and disputes within the organization ($B = 3.089$) and leadership ($B = 3.015$). Leadership essentially drives the organization and offers direction to the project delivery activities whereas strikes and disputes within the organization act as a barrier for the smooth functioning and management of the organization and management of the project delivery. The study also revealed that communication (both external and internal) ($B = 2.436$) and institutional environment ($B = 2.342$) were major obstacles in the success of project delivery of water infrastructure projects in South Africa although to a relatively lower extent.

3.3.3. Construction and Construction Management

Five factors such as contract management and documentation, tendering process management, equipment and material, poor quality control and defects, and rework were evaluated under construction and construction management to assess their influence on the project delivery. However, the influence of these factors was evaluated in reference to competent construction management practices (Table 5). The results evidenced that challenges with regards to equipment and material ($B = 2.282$) and poor-quality control and defects ($B = 1.861$) are the two major influential factors that hamper the delivery of water projects. These two factors were followed by poor contract management and documentation processes ($B = 1.599$). Tendering process management and rework may have some impact on project delivery, but they are not statistically significant. Thus, there is a need to improve the equipment and material management and quality management system. Furthermore, contract management and documentation processes should be improved [9,11].

3.3.4. Sociopolitical Aspects

Society and politics (governance system) are the two most important spectra of stakeholders of the infrastructure projects although both are external to the organizations engaged in project delivery. However, they influence directly and indirectly the decision making and functioning of the project delivery system and the management of the organizations responsible for such activities. The various factors in the sociopolitical aspects include political interference, political rush, and ethical issues such as vested group or individual interest or corruption. The impacts of these factors were analyzed in reference to the congenital sociopolitical environment (non-interference and observing ethical behavior). From the model results, it was evidenced that political rush ($B = 3.609$) and political interference ($B = 2.872$) are the two most important factors, which impede or create obstacles in the project delivery (Table 5). This happens because of a lack of understanding and non-alignment of the political entities with the feasibility, technical aspects and management of the project delivery systems adhered to by the organizations engaged in the infrastructure project delivery [11]. Furthermore, it was found that ethical issues such as unethical behavior of the vested groups or individuals and corruption ($B = 2.069$) is a major barrier. This finding concurred with the findings of previous studies by Hartig (2008), Jerome (2011), Bond et al. (2012), Oyedele (2012), and Verma (2016) [26,41–44]. Thus, as evidenced by this study, sociopolitical factors influence the success of project delivery significantly.

3.4. Strategic Measures for Efficient Project Delivery

Nine strategic measures (SMs) to overcome the challenges were evaluated for their plausible influence to improve the efficiency of water infrastructure project delivery in South Africa. These nine strategies were evaluated with reference to the current system of infrastructure delivery as measured by the results of the ordinal regression model developed based on the responses of the various stakeholders surveyed. Table 6 and Figure 3 present the strategies and their relative influence on the plausible delivery of waster infrastructure projects. However, the results of the models on the nine strategies were discussed with several stakeholders to verify their validity. It was found that all the strategies were not adopted in any of the projects or organizations in their entirety or concurrently, although they were used sporadically depending upon the situation and context with varying results. For example, capacity building was adopted and prioritized in some of the organizations with positive outcomes. Overall, the stakeholders' opinions were found to concur with the model results. The nine strategies, therefore, are discussed as follows:

Table 6. Strategic measures and system thinking framework to efficient project delivery.

SM ID	Strategic Measures (SM)	Related Challenges	Parameter Estimate (B)	EXP (B)	Wald	Upper Bound	Lower Bound	p-Value	Significance
1	Capacity building	PM, OM	2.140	8.50	6.958	0.550	3.730	0.008	Significant
2	Appointment of competent and skilled professionals	PM, OM	2.911	18.38	9.131	1.023	4.798	0.003	Significant
3	Structuring review processes and compliance	PM, OM	1.872	6.50	4.272	0.097	3.647	0.039	Significant
4	Enhancing collaboration and communication among stakeholders	PM, OM	2.109	8.24	6.185	0.447	3.772	0.013	Significant
5	Enabling accountability and transparency	PM, OM, SA	2.499	12.17	5.979	0.496	4.502	0.014	Significant
6	Adopting Participative leadership	OM, SA	1.399	4.05	4.008	0.029	2.769	0.045	Significant
7	Adopting Total Quality Management system	PM, CCM	0.887	2.43	1.357	−0.605	2.379	0.244 *	Not significant
8	Adopting material and equipment management system	PM, CCM	0.822	2.28	1.320	−0.581	2.225	0.251 *	Not significant
9	Reinforcing contract and documentation management	PM, CCM	1.123	3.07	1.814	−0.511	2.758	0.178 *	Not significant
0	The current system of infrastructure delivery		0				1.00		
	Cronbach α		0.83						

* Indicates statistically not-significant.

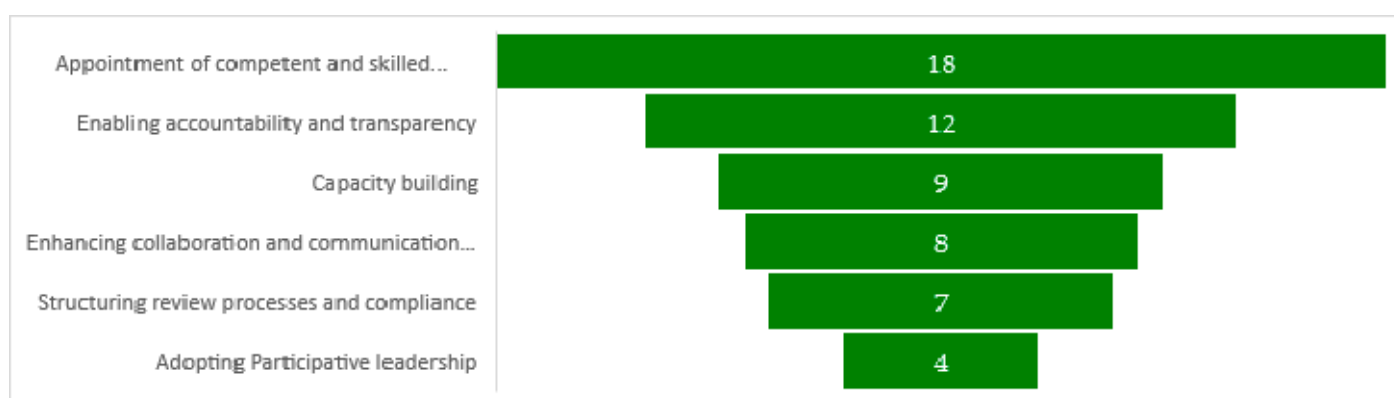


Figure 3. The relative impact of different strategic measures.

SM 1: Capacity building

Capacity building is one of the strategic measures used generally to build or to enhance knowledge, skill, and competency through education, training, hands-on experience, and exposure to real-life situations. As observed from Table 6, capacity development was statistically significant with the improvement of the water infrastructure project delivery and was one of the top three strategic measures ($B = 2.140$), which needs to be adopted. Capacity building was linked to the factors related to both project management and organization and management, which influenced the successful and efficient delivery of projects. For example, as evidenced by this study, project management factors such as planning and scheduling, monitoring and review, and coordination need improvement can be achieved by enhanced competency and skill or capacity building. Similarly, capacity building is essential to improve organizational factors such as efficient human resources, leadership, communication, and dispute resolution. Therefore, the capacity building could help to overcome the project management and organization and management problems that are experienced in the water infrastructure project delivery systems in South Africa.

SM 2: Appointment of competent and skilled professionals

The appointment of competent and skilled professionals was found to be the most important strategic measure ($B = 2.911$) that could enhance the efficiency of water infrastructure project delivery (Table 6). This strategy could resolve the problems faced because of project management and organization and management-related factors. This strategy is in fact linked to the capacity development of the organizations. For example, capacity development can be attained in two ways, such as enhancing knowledge, skill, and competency and by appointing competent and skilled professionals. This strategy becomes more important when there is a lack of competent and skilled professionals and when the enhancement of knowledge, skill, and competency takes a long time to be realized in an organization. Therefore, concurrent to capacity development, which is a continuous effort and time consuming, the appointment of competent and skilled professionals is essential to meet the challenges of project management and organization management, and improve the efficiency of project delivery.

SM 3: Structuring review processes and compliance

Review and compliance form an important part of the organizations to ensure accountability and take remedial measures in case the projects veer off course. Every organization follows a specific form of review and compliance system. In the delivery of water infrastructure projects, review and compliance are linked with both project management and organization and management aspects. As found out from Table 6, this strategic measure was statistically significant with efficient project delivery and the fifth most important strategy ($B = 1.872$) that should be adopted to improve project delivery in South Africa.

SM 4: Enhancing collaboration and communication among stakeholders

It was observed that communication both external and internal is one of the major challenging organization and management factors that impact project delivery. It is also

linked to project management factors such as coordination, review, and monitoring. So, enhancement of collaboration among the stakeholders and different organizations engaged in infrastructure project delivery should help in resolving both project management and organization management challenges that plague efficient project delivery. As seen from Table 6, this strategic measure is the fourth most important strategy ($B = 2.109$), which could help improving water infrastructure project delivery in South Africa.

SM 5: Enabling accountability and transparency

Accountability and transparency remain the two most important attributes related to project management, organization and management, and sociopolitical aspects in infrastructure project delivery. Moreover, these aspects are linked to the ethical behavior of stakeholders and organizations engaged in infrastructure project delivery. A remedial strategic measure to enhance accountability and transparency was found to be the second most important strategy ($B = 2.499$) that could enhance the efficiency of the delivery of water infrastructure projects in South Africa (Table 6). This strategy in combination with a structured review and compliance system would likely enable the development of a system, which could assist in reducing unethical behavior and corruption and take responsibility and ownership of the activities.

SM 6: Adopting Participative leadership

Leadership is one of the major factors for the success of any organization and in this context the infrastructure project delivery system. Although different leadership styles have different implications, participative leadership has a unique advantage of decision-making through a collaborative approach, creation of belongingness, and taking responsibility for the actions. It is aligned with organization and management and sociopolitical aspects of the project delivery system. According to the results obtained from the model, this strategy was statistically significant with successful and efficient project delivery, although ranked relatively lower ($B = 1.399$) to the above five strategic measures discussed. However, as found in Table 6, this strategic measure would assist more in the efficient project delivery compared to the current form of leadership observed in the organizations engaged in water infrastructure delivery.

Strategic measures: SM 7, SM 8, and SM 9

The strategic measures SM 7, SM 8, and SM 9 were the adoption of the total quality management (TQM) system, adoption of the material and equipment management system, and reinforcing contract and documentation management respectively. These three strategies are related to both project management and construction and construction management aspects of the project delivery system. It was also found that contract management and documentation, equipment and material, poor quality control, and defects had a significant influence on project delivery. However, as found from the model results, the strategies linked to these aspects (SM 7, SM 8, and SM 9) were found to be statistically not significant ($p\text{-value} > 0.05$) with efficient project delivery of water infrastructure projects (Table 6). Thus, it cannot be conclusively inferred that these three strategies would likely improve the water infrastructure project delivery. The reason could be that the organizations might be following appropriate strategic interventions or undertaking proper activities to ensure the management of these constructions and construction management and project management aspects related to contract management and documentation, equipment and material, and quality control.

4. Discussion

Infrastructure development is vital for the sustainable economic development of a country. Sustainable development of infrastructure and efficient infrastructure delivery remain paramount for a well-functioning economic ecosystem and society at large, specifically, in a developing country such as South Africa. The South African national government and the provincial governments and the municipalities are making efforts to build and reinforce various infrastructures to meet the increasing demands and to overcome the challenges of inefficient project delivery. Water infrastructure is found to be one of the vital

infrastructures that are faced with the challenges of delay and poor project delivery and requires significant attention to improve the scenarios.

At the macro level, inflexible fiscal policies, and a high budget deficit that leads to a lack of adequate funding, is argued to be the major reasons for poor infrastructure development and project delivery [13,20]. Similarly, various challenges also emanate from poor infrastructure development and project delivery. In this context, the study explored what challenges plagued the water infrastructure project delivery system and what factors contribute to the creation of such challenges.

The study revealed that five challenges were found to be pertinent regarding efficient water infrastructure project delivery. These challenges are cost overruns, poor quality of work, poor fund utilization, and delay in project completion. Additionally, poor service delivery to society is a major consequence of these challenges. Each of these challenges is also intertwined and become both a cause and an effect. Furthermore, factors related to the four aspects of the infrastructure project delivery such as project management, organization and management, construction and construction management, and sociopolitical engender the above-mentioned challenges that create hindrances in the project delivery. As observed from this study, organization and management factors such as human resource and skills availability, funding, strikes, and disputes within the organization, external and internal communication, institutional environment, and leadership are the major factors that influence project delivery significantly. These findings are in alignment with the findings from previous studies [13,22,43]. In conjunction with organization and management factors, project management factors such as planning and scheduling, monitoring and review, and coordination exacerbate the challenges of project delivery. The project management factors are mostly related to organizational factors such as competency of human resources engaged in the organizations and lack of funding. Similarly, contract management and documentation, equipment and material, poor quality control, and defects are the construction and construction management factors that influence project delivery. However, these factors are also linked to project management aspects, such as planning and scheduling, equipment and material management, and quality management. Thus, organization and management, project management, and construction and construction management related factors in combination create an inappropriate water infrastructure project delivery ecosystem. Furthermore, sociopolitical factors, which are external to the project or organization such as priorities set by politicians (political rush), and political interference aggravate the situation and impair the project delivery system. More importantly, unethical behavior such as corruption was found to be one of the major barriers, which is in alignment with the arguments presented in previous studies [11,13].

Premised upon these findings, nine important strategic measures were evaluated and six of them such as capacity building, the appointment of competent and skilled professionals, structuring of the review processes and compliance, enhancing collaboration and communication among stakeholders, enabling accountability and transparency, and adopting participative leadership were found to be more suitable to meet the challenges of project delivery. These strategies are linked to and expected to improve the project management, organization and management, and sociopolitical aspects of the project delivery system. However, it was concurrently found that strategies to reinforce construction and construction management might not contribute significantly.

5. Conclusions

The availability of water is a crucial element for the sustainable development of society and communities; therefore, efficient delivery of water infrastructure projects becomes vital. However, many developing countries including South Africa are experiencing infrastructure delivery challenges, despite the efforts from national and provincial governments. It was argued that water utility agencies in South Africa, despite their efforts, are facing serious challenges of delivering water infrastructure projects efficiently and need strategic intervention to improve the situation. This study, therefore, examined what challenges

emanate from the poor water infrastructure delivery, what factors influence poor water infrastructure delivery, and what strategies are needed by the water utility agencies for efficient water infrastructure delivery projects.

The findings of the study suggested that the major consequences of poor project delivery were delays in project completion, cost overruns, poor quality of work, poor fund utilization, and poor socioeconomic benefits to society. These challenges of poor project delivery occurred because of the various factors under the four important aspects of the projects such as project management, organization and management, construction and construction management, and sociopolitical. Lack of competent and adequate human resource and skill availability, funding, the occurrence of strikes and disputes within the organization, poor communication, institutional environment, and leadership are the major organization and management linked factors that are obstacles against effective project delivery. Poor planning and scheduling, monitoring and review, and coordination among the stakeholders are the project management related factors, which exacerbate the challenges of project delivery. Poor contract management and documentation, equipment and material, poor quality control, and defects are the major construction and construction management factors that adversely affect project delivery. Moreover, sociopolitical factors such as political rush, political interference, and corruption play vital roles in hindering efficient project delivery.

The study revealed that six important strategies could address the various challenges caused by the influential factors under the four project related aspects (project management, organization and management, construction and construction management, and sociopolitical). These strategies are capacity building, the appointment of competent and skilled professionals, structuring review processes and compliance, enhancing collaboration and communication among stakeholders, enabling accountability and transparency, and adopting participative leadership.

However, it is essential to evaluate the challenges that emerge from the four previously important aspects related to project management, organization and management, construction and construction management, and sociopolitical faced in each project and different organizations. Then, it is needed to align the strategic measures with respect to the challenges as relevant and take appropriate actions, which could improve the infrastructure project delivery system.

The limitation of the study is that in the absence of structured statistical data the study was conducted based on the perceptions of the stakeholders. Additionally, the scope of the study was confined to the evaluation of endogenous factors of the water utility agencies and the exogenous factors at the national and international level such as the use of advanced technology, availability of FDI or grants, and change in infrastructure development policies, amongst others, were not considered. However, despite the limitations, this study contributes in terms of identifying the factors and plausible strategic measures that could enable water utility agencies in developing countries including South Africa to take remedial courses to improve the infrastructure project delivery system.

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