



Risk Mitigation in the Dubai Water Canal Construction: A Comprehensive Study

CASE STUDIES

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ABSTRACT

This study examines the lifecycle of the Dubai Water Canal construction, focusing on risk mitigation strategies implemented across its four distinct phases. By incrementally addressing potential risks, the project minimized exposure to uncertainties and ensured the quality and safety of the end product. Key findings highlight the minimal impact on urban growth and emphasize the importance of comprehensive feasibility studies, geological assessments, and environmental impact assessments in identifying and managing risks. The study uniquely contributes to the discourse on urban development by highlighting the effectiveness of a phased approach in large-scale projects. The research methodology involved detailed environmental and technical assessments, stakeholder engagement, and continuous monitoring throughout the project. Our conclusions underscore the need for proactive risk management, thorough planning, and sustainability to ensure the resilience and success of similar infrastructure initiatives globally.

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1. INTRODUCTION

In recent decades, the world's population has increased, and global urban growth and economic growth trickle into the major cities and pose growing threats in urban areas. Most people migrate to major cities intending to have better lives. The rapid growth of urban populations can affect social, economic, and environmental sustainability.

In low-income regions, growth can overwhelm the local planning capacities. According to the United Nations, all these changes in the world population in urban areas have increased from 11.8% in 1950 to an estimated 80% by 2050 (Fleck, 2014), as shown in Figure 1. Today, more than half of the world's population lives in urban areas (Shaddick, et al., 2020).

According to Joshi et al. (2022), urban growth can affect cities and lead to risks such as environmental degradation, pollution, and overstretching of the few available resources. In addition, sustainability, resilience, and economic development threaten urban infrastructure. That makes countries look for solutions to balance economic, technological, and social development.

The trend has been the same in the UAE, with massive growth in the major cities since their inception. According to World Bank data, the population of the UAE reached 9,991,083 in 2021 (The official portal of the UAE Government, 2022). Riadh (2022) noted that 85% of the UAE population lived in urban centers. Research by the United Nations pointed out that the number would increase to 91% by 2050. As it is, the urban population growth in the UAE is more rapid compared to the rest of the world. Specifically, Dubai's population averaged 3.3 million in 2020 from 40000 in 1960 (The United Arab Emirates' Government portal, 2022). In addition, Sharjah's population increased from over 0.6 million in 2005 to over 1.5 million in 2020 (Statista, 2020). At the same time, Dubai and Sharjah have experienced quick economic growth and expansion over the last two decades, as have the other emirates. Over the years, Dubai has implemented an explicit transformation to become modern compared to New York. In addition, to accommodate the high population, Dubai has

implemented a quantitative expansion of the city and built a new city near the old city (Awad & Jung, 2022).

The local authority showed the need for new plans and policies to prevent the risks and provide a conducive environment for the growing masses. Urban planning and policies help urban centers move forward despite rapid growth. Therefore, urban planning is a strategy that focuses on land use development and design. It designs the built environment, including water, air, and the infrastructure passing through and out of the city (IEREK, 2022). Urban planning is considered one of the most relevant decision-making processes. It is a large-scale concept concerned with planning and development at all levels (architectural, infrastructural, ecological, economical, and even political). The higher the level of strategy, the more complex the decisions and capability requirements (Fuertes, et al., 2020). Strategic urban planning is broader than traditional master planning, focusing on land use regulation and infrastructure requirements (Conway & Vincent, 2021). However, urban planning faces some risks that may hinder its success.

Along with rapid population growth are various risks, depending on the city's location, government policies, and the size of its occupied land. According to several scholarly references, several key risks associated with urban planning include small parcels of land, urban sprawl, physical features, housing affordability, climate change, accessibility to public transportation, urban policies, and enough revenue for infrastructure.

Besides structural changes, urban management must be flexible. New development trends need to be adopted for the economic and social sectors, and land use impacts public health, insufficient data, poor display of information, and building criteria that do not meet population needs, among other risks. The role of the local authority and strategic leaders becomes more critical. They need to transfer from a short-term versus long-term perspective and make investment decisions for the city to face global and regional risks and changes. Indeed, many authors highlighted that urban planners and designers must take a proactive role and focus on urgent urban planning risks to handle emerging issues.

Urban planning is an essential strategy for any city that wants to develop and, at the same time, protect public health. Several billions of dollars are invested every year by the United Arab Emirates in developing the country's infrastructure (Cherian, 2020). This includes housing, schools, hospitals, shopping malls, telecommunications, electricity, water, hotels, and recreational facilities. Without proper planning, many urban centers deteriorate and degrade economically with time. Therefore, most urban planning initiatives only remain as sustainable as expected with appropriate risk assessment and management. Many cities fail to plan sustainably because they need to understand the importance of risk management frameworks.

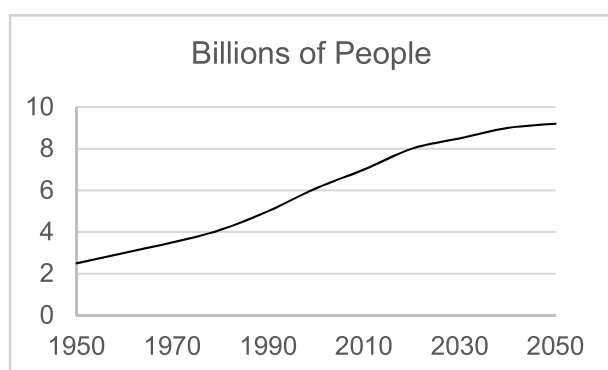


Figure 1 Histogram of population growth perspective (1950–2050).

In the UAE's rapid urbanization, the nature of migration and spatial fragmentation has significantly affected social and economic systems in both urban and rural areas. The risk management framework is essential in the UAE's urban planning strategies for a green, sustainable environment. The framework aids in the identification, measuring, monitoring, and evaluation of various risks, crises, and disasters before implementing a strategy (Ullah, et al., 2021; Alter, 2021). Additionally, it involves cost-effective and organized usage of resources to have a practical impact. Therefore, a risk management framework is vital because it will increase the chance of preventing any associated risks. However, initiatives in UAE cities without a proper risk management framework will stagnate and deteriorate over time. This research study proposed a management framework outlining the risks in urban planning and proposing a solution. The proposed framework is new to planners and beneficiaries within the UAE.

2. URBAN PLANNING

Urban planning is a concept that is interested in designing and developing all sectors within an urban center to meet the diverse needs of its population (IEREK, 2022). As the planning theorist, Beauregard (2001) argued, planning is an interaction between different disciplines. The disciplines include the infrastructural, economic, architectural, ecological, and political. For the plan to be effective, it must incorporate an initiative to ensure that the correct urban development is carried out to promote a sustainable environment for the future. Urban planning influences various aspects of city life, like communal spaces, lands, roads, transport, economic development, and the environment. In the past, planners would not involve the communities in the implementation process. However, Somers (2021) notes that since the 21st century, the concept has included everyone in every step. Inclusive participation improves the effectiveness and efficiency of the strategy, as residents will have a sense of belonging to the project (Elrahman & Asaad, 2021).

There are different types of urban planning that any planner or manager can implement in their strategy. Somers (2021) states they include strategic urban planning, economic development, land-use planning, master planning, infrastructure planning, environmental planning, and urban reawakening. To begin, strategic planning involves developing quality goals and specifying the best sectors for the growth of an urban center. It is at the top of any planning process; other concepts happen alongside its creation. Strategic planning must be part of the implementation process for any plan in the UAE. This ensures the creation of achievable goals that are suitable for each city. Secondly, land-use planning includes creating laws and policies that regulate land usage in

a city. Governmental regulations, statutes, and zoning codes are some policies that can be utilized to ensure that the city is organized correctly. In the UAE, land-use planning ensures land for any specified function within its cities.

Additionally, infrastructure planning creates essential facilities and systems for the city and its residents. According to the author, this plan's success makes the residents' lives easy and smooth. Generally, it concerns civic facilities, roads, water, electricity, telecommunication, waste and sewage systems, parks, and services buildings. The smart city initiative in the UAE cities utilizes this plan to ensure they are modernized and digitalized. On the other hand, urban reawakening involves improving a city's degraded areas. Different forms of urban planning can be used during revitalization to ensure effectiveness. The UAE uses this planning method to avoid the degradation of its cities; however, it has yet to be common.

Further, master planning concentrates on the development of land that has not yet been developed. According to Somers (2021), it identifies what can be built on the land and the goals needed to ensure success. The scale of the planning covered area can range from a whole country to a city of a country, a sector, or a sub-sector. At the same time, economic development looks at the possible areas for growth within an urban center, and its correct utilization will ensure the city's financial growth. For example, the UAE is known for its oil production and export, which has been a major catalyst for economic growth in the region. Accordingly, urban planners envisage a sustainable plan for economic zones. Lastly, environmental planning focuses on sustainability and is a category of strategic development. Executing this plan requires considering ecological factors, making it the most complex plan to implement. The UAE is currently concentrating on this planning form with sustainable city strategies.

2.1 RISKS IN URBAN PLANNING

Risk management in urban planning can only occur with associated challenges. In the design and implementation of urban development strategy, the challenges experienced are the same worldwide. Several risks may hinder the effectiveness of a plan for any city, and they have causative agents. They may occur due to urbanization, which leads to population growth, environmental factors, governmental restrictions, and regulations. Below are some types of risks associated with urban planning.

2.1.1 Risks from Urbanization

Urbanization refers to "the process of expansion in urban population and urban scale, and the corresponding series of economic and social changes. Urbanization automatically leads to population growth in urban centers" (Wang, et al., 2015). High populations affect

urban planning because it may not cater to the growing mass when intended for fewer people. Residents may have to scramble for the few resources that need more for them. The situation may worsen and lead to the development of slums to give housing to many people (Almulhim & Cobbinah, 2023). High populations also lead to rising unemployment rates, leading to poverty and insecurity in the cities. This condition promotes poor economic growth in the city; therefore, the revenue required for development may be limited. In short, these negatively affect the individual quality of life (Kuddus, et al., 2020).

Moreover, increased population facilitates urban sprawl, which is the movement of people from crowded cities to cities with fewer people. It leads to high demand for housing and other essential infrastructures like roads and public amenities. According to Srivastava & Srivastava (2020), urban sprawl may increase road accidents and degrade the environment. Overcrowding in low-density regions facilitates environmental degradation and pollution through deforestation and haphazard construction of infrastructure to accommodate the growing mass. Until the conditions in rural areas improve, urban sprawl will continue to move to urban settings. Proper urban planning and risk management can prevent these challenges by controlling the urbanization rates and being ready for any eventuality, such as urban sprawl. That makes governments and real estate development companies concentrate on adapting to the challenges of urbanization while seeking to reduce unplanned urbanization (Kuddus, et al., 2020).

2.1.2 Environmental Risks

Environmental degradation is a result of population growth caused by urbanization. However, general environmental challenges affect urban planning in a city. Natural disasters such as floods and drought can influence the effectiveness of a plan (Pauleit, et al., 2020). Climate change, adaptation, and mitigation are critical challenges for cities worldwide (Lafortezza & Sanesi, 2019). The funds allocated for the development may be used to cater to the disaster and hence put a halt on the planning strategy.

Further, the physical features of a city may promote development or not. For example, the UAE's cities are covered mainly by water and desert. Therefore, with proper planning, the cities may grow to accommodate the growing number of people. Another challenge is the small parcels of land that may be available and cannot accommodate the development strategy (Gabriele, et al., 2023). This can lead to the utilization of the entire land, leaving no land for trees, which threatens public health. Furthermore, poor drainage system maintenance challenges the environment and people's health. However, this is more of a risk caused by government management than the environment.

2.1.3 Risks from Regulations

Urban planning is a government project designed, implemented, monitored, and evaluated by them. Therefore, any decision and policies created by the government affect the planning process a great deal. To begin with, housing affordability influences urban planning because it continues to bring parity between low-income and high-income areas. The government must initiate affordable housing for urban residents to foster human dignity. Additionally, transport system accessibility leads to effective urban planning. Accessible roads and railways make an urban center appealing to investors (Hrelja, et al., 2020).

The local authority should strive for a smooth and accessible transport system to promote development. Furthermore, they can create favorable urban policies that drive the success of any city plan and not hinder it. Moreover, it provides sufficient revenue for implementing any development initiative within the cities. Moreover, frequent structural changes also influence urban planning, and if it needs to be more dynamic to keep up with the current development, sustainability may be low. Therefore, the management and planning of a city should be as flexible as possible to deal with unprecedented changes.

The next challenge is the plan's ability to adopt new development trends. New trends for development are often observed and may emerge before the strategy is fully implemented; therefore, the plan should have room to incorporate a new procedure at any level of implementation. Additionally, risks are associated with displaying suitable and sufficient information related to urban planning. The information may be available, but the government needs to display it appropriately, or there may be a lack of the correct data to be referred to during the implementation. Insufficient and misleading data may deter the efficiency of a planning strategy, while correct data availability propels its sustainability.

Further, a specific town's building criteria and urban patterns can influence urban planning. Every city has its unique building criteria and patterns. Challenges are the primary determinant of the success of any urban planning strategy.

To ensure the sustainability of the urban planning process, sustainable solutions should be put in place to handle the challenges. For instance, the government can ensure the availability of affordable and sustainable housing for every city. Secondly, there is a need to promote renewable energy that is friendly to the environment to avoid pollution. Further, according to Viecco et al. (2021), developing green roofing techniques to provide a green environment that gives fresh air to the residents by hindering dust and the emission of smoke should be a priority. Additionally, the government must develop accessible transportation to enable smooth movement in and out of the cities. The solutions for the

challenges are available; therefore, the local authority should ensure they deal with them as efficiently as possible.

To summarize, the challenges in urban planning are universal, and it does not matter which city is involved. They include population growth, urban sprawl, environmental pollution, insecurity, slum development, and poverty. In addition, small parcels of land, the physical features of a town, climate change, land-use effects on public health, natural disasters like floods, poor drainage maintenance, flexibility in urban planning and management, and building criteria also affect urban planning. More challenges include housing affordability, accessible public transport, urban policies, sufficient revenue for infrastructural development, structural changes, lack of enough data, adoption rate of new development trends, display of correct information, and

random urban patterns. Table 1 summarizes all the above-mentioned global risks in urban planning all over the world, as follows.

3. METHODOLOGY

The purpose of this section is to develop a thorough understanding of the current knowledge relevant to this research. The goal is to draw conclusions from various perspectives, limitations, and boundaries to identify gaps in the research area. This will be accomplished through a systematic review that aligns with the research objectives. Thus, the research methodology for this study involved a multi-phase approach to systematically investigate the risk mitigation strategies employed in the Dubai Water Canal project (Figure 2). The methodology

RISK CATEGORY	DESCRIPTION	REFERENCES	MODES OF REPETITION
Risks from Urbanization	High populations	(Humbal, et al., 2023)	Frequently cited
	Few available resources	(Almulhim & Cobbinah, 2023)	Common in developing cities
	Rising unemployment rates, leading to poverty and insecurity in the cities	(Adojo & Eugene, 2020)	Urban areas with economic downturns
	Poor economic growth	(Awasthi, 2021)	Developing countries
	Urban sprawl	(Srivastava & Srivastava, 2020)	Suburban expansion
	Environmental pollution	(Humbal, et al., 2023)	Industrial cities
Environmental Challenges	Natural disasters	(Pauleit, et al., 2020)	High-risk zones
	Climate change	(Laforteza & Sanesi, 2019)	Coastal cities
	Physical features of a city	(Haughton, 2021)	Cities with varied topography
	The small parcels of land	(Gabriele, et al., 2023)	Densely populated areas
	Poor drainage system maintenance	(Pauleit, et al., 2020)	Aging infrastructure
Risks from Regulations	Decisions and policies created by the government	(Wang, et al., 2021)	Varies by governance
	The ability to plan to adopt new development trends	(Wang, et al., 2021)	Varies by region
	Lack of the correct data	(Haque, et al., 2022)	Common in underdeveloped areas
	Building criteria and urban patterns	(Abubakar & Dano, 2020)	Historical urban centers
	Accessible public transport	(Hrelja, et al., 2020)	Developing cities
	Lack of revenues for infrastructural development	(Pauleit, et al., 2020)	Low-income regions
	Random urban patterns	(Awasthi, 2021)	Cities with rapid growth

Table 1 Risks in Urban Planning.

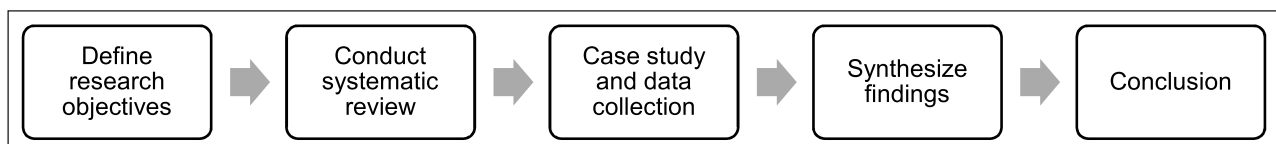


Figure 2 The flowchart of the methodology.

was designed to achieve research objectives and provide recommendations for future projects.

The research objectives are as follows:

1. Identify potential risks in the Dubai Water Canal project.
2. Evaluate the effectiveness of the risk mitigation strategies employed.
3. Based on the findings, Provide recommendations for future large-scale urban infrastructure projects.

3.1 THE RESEARCH DESIGN AND DATA COLLECTION

The research design incorporates qualitative and quantitative methods, thoroughly examining the project's risk management framework. The methodology includes the following key components:

Literature Review: A comprehensive review of existing literature on risk management in urban planning and large-scale infrastructure projects was conducted. This involved analyzing previous case studies, theoretical frameworks, and existing research to establish a foundation for the study. Review existing literature on risk management in urban planning and large-scale infrastructure projects. Analysis of previous case studies and theoretical frameworks. Identification of key findings from the data analysis. Comparative analysis with similar international projects. Reviewed detailed project reports, feasibility studies, environmental impact assessments, and risk management plans. Secondary Data: Analyzed data from government publications, academic journals, and industry reports.

Secondary Data Analysis: The study relied heavily on secondary data sources, including government publications, academic journals, industry reports, and detailed project documentation such as feasibility studies, environmental impact assessments, and risk management plans. This data provided insight into the project's lifecycle and the strategies' effectiveness.

Stakeholder Engagement: Stakeholder engagement was a critical component of the research methodology. The project team engaged with various stakeholders, including public and government agencies and private sector entities, to identify potential risks and concerns. This engagement was conducted through interviews, surveys, and focus group discussions, providing a comprehensive understanding of stakeholder perspectives.

Comparative Analysis: A comparative analysis was performed by reviewing similar international projects, such as the Thames Tideway Tunnel in

London, UK. This comparison helped contextualize the findings and provided additional insights into the effectiveness of the risk mitigation strategies employed in the Dubai Water Canal project.

Data Analysis Tools: The data collected was analyzed using both qualitative and quantitative analysis tools. Qualitative data from interviews and focus groups were analyzed using thematic analysis to identify recurring themes and patterns. Quantitative data from reports and assessments were analyzed using statistical tools to quantify the impact of various risk factors and the effectiveness of mitigation strategies.

Conclusions and Recommendations: Draw conclusions based on the research findings and provide actionable recommendations for future projects.

4. STUDY AREA – DUBAI WATER CANAL

Population growth in all the cities in the world, especially in the UAE, has seen significant cities plan and develop over the past decade. For instance, there has been a significant overhaul of cities' infrastructure in the UAE to transform some cities into smart cities. Due to this, risk management is an integral part of developing significant projects like bridges connecting water and land or waterfronts in the middle of cities to attract tourists and reduce traffic. For instance, building bridges that connect water to land in major cities is an objective. This calls for significant urban planning with a strategic risk management framework. For example, a bridge can be built to link land and water on the islands of the UAE.

The UAE's economic, cultural, and historical center is Dubai (35 km²). Its geographical location and cultural, historical, social, and economic potential have made Dubai an attractive global center for many years. Dubai is now one of the world's most populous urban centers. It is connected to ancient business locations. In the second half of the twentieth century, Dubai's population increased rapidly after a long period of population increases and declines, as shown in Figure 3. As the population grows, transportation problems have become more complex.

Dubai's water canal, a \$2.7 billion project that would build a 3.2-kilometer waterway, was planned by the Road and Transport Authority (RTA), whose mission is to promote safe and efficient transportation for all. As it winds around downtown Dubai, which has the world's tallest building and largest mall, Dubai Mall, the project was expected to take over a decade to complete (dipmf.ae, 2016). The canal was originally constructed to link the historic parts of Dubai, Shindagah, and Al-Bastakiya of Deira, and the contemporary urban context of Dubai, Business Bay, Downtown, and Jumeirah (Figures 4 & 5) to mitigate the rapid development of Dubai (Chuloh, et al., 2021).

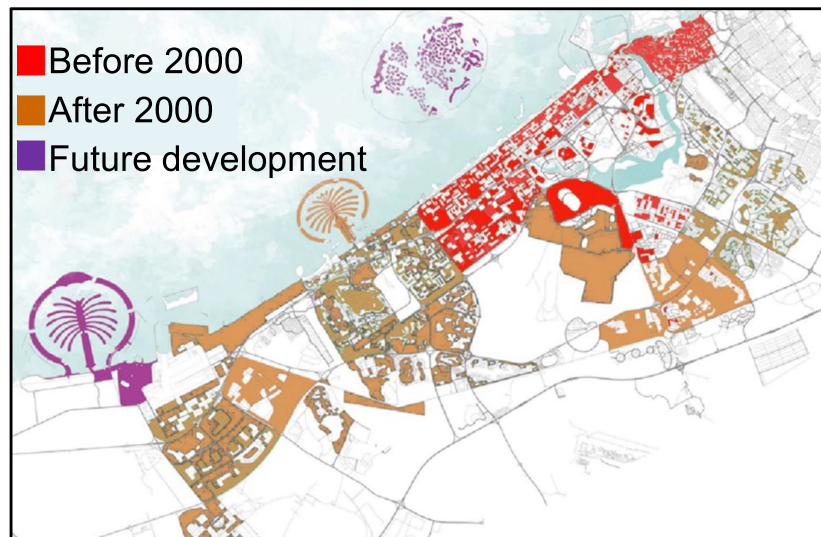


Figure 3 Map showing different phases of urban development in Dubai (Malhotra & Dobriyal, 2021).



Figure 4 Satellite image of the Dubai Water Canal.



Figure 5 The Dubai Water Canal and districts' images.

This bridge turned a good part of the emirate into an island, with its beauty and magnificent positioning acting as a tourist attraction site. The mission of the RTA is to develop an urban area characterized by excellent roads and transport systems. The building of Dubai's water canal bridge was founded under the objectives of urban development that can be summarized into six significant points as below:

- **Smart Dubai:** To Foster connectivity and enhance efficient and smart solutions for transportation and government services.
- **Integrated Dubai:** Enhance integration between transportation and urban planning, ensure transport systems are friendly for all, and preserve national identity.
- **People Happiness:** Pioneering happiness, ensuring customer harmony, and fostering workplace positivity.
- **Smooth Transport for All:** Encourage public transport, develop sustainable transport networks, manage travel demand, and improve transport policies and legislation.
- **Safety and Environmental Sustainability:** Enhance transport safety, foster environmental sustainability, ensure health and safety sustainability, and promote security sustainability.
- **Financial Sustainability:** Maximize and diversify revenues, foster partnerships with the private sector, and enhance financial efficiency.

In the quest to integrate urban planning and risk management, there has also been building up of other bridges in the UAE with similar objectives in mind; some of the bridges built that connect water with the land include:

Sheikh Zayed Bridge: This iconic bridge spans the Abu Dhabi Channel, connecting Abu Dhabi City with the island of Abu Dhabi. The bridge is a cable-stayed structure with a total length of 842 meters and a height of 64 meters at its highest point (Hadid, n.d.). The design of this bridge is one of its kind, featuring cantilevered road decks that are symmetrically suspended from the steel arch. According to the Zaha Hadid Architects (2023), these bridges form sinusoidal waveforms that give them a unique fluid silhouette.

Besides there is also the Al Maqtaa Bridge, which connects mainland Abu Dhabi with the island of Al Maqtaa. This bridge is a cable-stayed structure with a total length of 600 meters and a height of 60 meters at its highest point. This is one of the oldest bridges ever built in the United Arab Emirates. Currently, the bridge is undergoing renovation, bringing the hope of traffic ease when it is

finished. It is worth noting that some other bridges, like Ras Al Khaimah Bridge, also link the mainland Ras Al Khaimah with the Al Marjan Island. This is a suspension bridge with a total length of 1.6 kilometers and a height of 23 meters at its highest point.

Rapid urbanization has been part of the UAE's development in the last few decades. According to Ferreira and Magalhaes (2018), development has led to significant economic growth, infrastructural development, and integration of smart urban planning. However, with rapid development comes several challenges that result in the exposure of the local population and the natural resources and/or amenities to various risks. Effective risk management strategies are necessary to ensure the sustainable development of cities.

UAE urban planning has been at the forefront of these risk management efforts. One essential step the government took was establishing the National Emergency Crisis and Disaster Management Authority (NCEMA) in 2007 (Alkheder & Liyanage, 2018). NCEMA is responsible for developing and implementing emergency and disaster management plans across the UAE. It guides local authorities on risk management strategies and coordinates emergency response efforts. Furthermore, the UAE government has implemented several initiatives to mitigate risks in urban planning (Ghazali & Che-Ani, 2018). For example, the Abu Dhabi Urban Planning Council (UPC) has introduced several guidelines to promote sustainable urban development (Council, 2018). The guidelines focus on infrastructure, energy efficiency, and waste management. The UPC also ensures that new developments comply with the Building Code, which contains building safety and emergency preparedness provisions.

Overall, developing risk management in urban planning in the UAE is a continuous process. The government continues introducing new regulations and guidelines to manage risks and ensure sustainable development (Boudiaf & Hammad, 2018). As the UAE continues to urbanize, it is important to recognize the potential associated risks and develop effective mitigation strategies. In the development of the Dubai Water Canal and other bridges, implementation occurs in phases:

With the segmentation of the whole project into phases, risk control and mitigation are easy as the project is implemented. As per Figure 6, some of the phases include the feasibility study: During this phase, the economic, environmental, and technical viability of the given project was assessed. During this phase, potential environmental impact is highlighted, thus making the constructors and other stakeholders aware of the possible risks. The feasibility phase included the following: Project brief, scope definition, site visitation, and project cost estimation. The

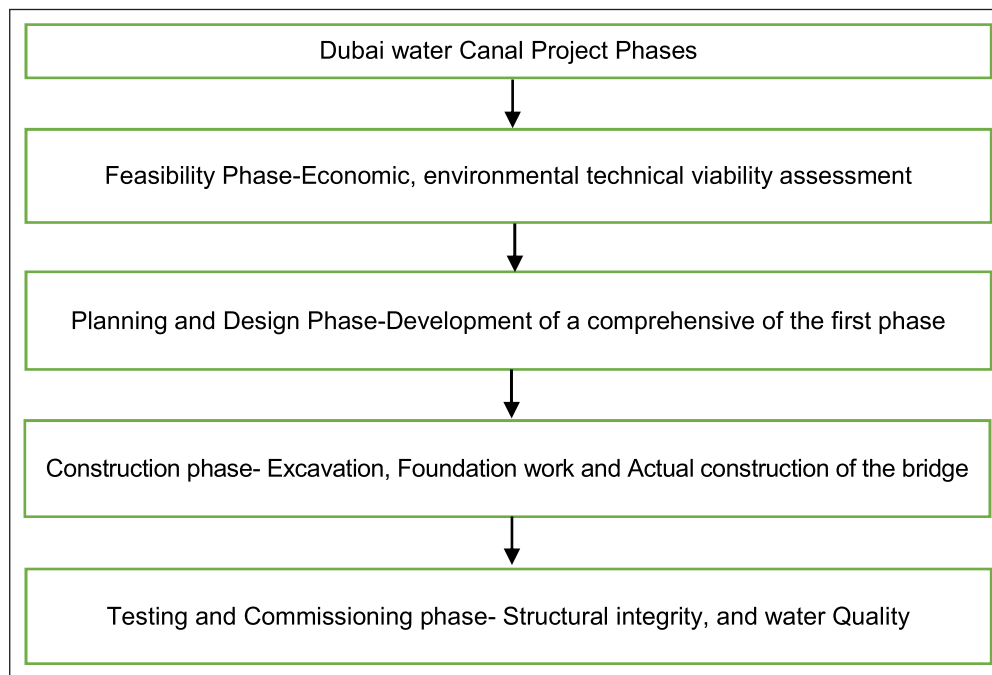


Figure 6 Development Phase in the Dubai Water Canal Project.

project's second phase was the planning and design phase, dependent on the first phase. In the case of the Canal Bridge, a comprehensive result was developed considering factors like the impact on traffic, environment, and urban development.

The third phase, construction: the construction of the Canal and Bridge occurred in various sub-stages, including excavation, foundation work, and construction of the bridge itself. Finally, the testing and commissioning phase: Once the construction was completed, the bridge and canal were thoroughly tested to ensure they were safe and operational before citizens were allowed to use them. This included testing the structural integrity of the bridge, as well as the flow and water quality of the canal. This was to avoid any risk neglected during the process and ensure the final product was safe. The UAE always complies with construction and urban city plan risk management frameworks. This ensures that the vision and missions of such frameworks are maintained and in line with Dubai's past and future. If anything, constructing bridges connecting land to water is part of their sustainable urban development. For instance, the Dubai 2040 urban master plan (2023) mentions that Dubai's ruler launched a master plan that maps sustainable urban development. It is important to note that sustainability and infrastructure improvement are at the core of this master plan.

According to the Dubai 2040 urban master plan (2023), it looks to enhance Dubai's competitiveness as a global

destination by offering diverse lifestyle and investment opportunities to citizens, residents, and visitors in the next two decades. This plan aims to achieve the vision of making Dubai the city with the highest quality of life by providing top-notch urban infrastructure and facilities. Sheikh Mohammed bin Rashid Al Maktoum, who aims to continue the creative development journey initiated by Sheikh Rashid bin Saeed Al Maktoum in the 1960s, believes that Dubai's evolution into a city that promotes the best human values and possibilities will provide an environment for people worldwide to thrive (Dubai, 2023). This vision also aligns with the objectives used to enhance the building of the Dubai Water Canal, which include a smart, integrated Dubai with happy people who experience a smooth transport system, financial sustainability, and a safe and sustainable environment (Canal, 2018). It is noteworthy to say that such frameworks are in line to keep urban cities well-planned and in line with their future development while ensuring that risks are minimized and benefits are maximized.

In the case of the Dubai Water Canal, the project involved the excavation and reclamation of land and water. Three million cubic meters of sand needed to be excavated to create the canal waterway. These materials were later used to create the peninsula. This innovation reduced the project's cost by using the excavated sand. The peninsula is a 408000 square meters seafront situated at the point where they see and the canal meets. With this on-site and during the construction, the urban planning and risk development framework was well in place. The reclamation of the land ensured that the risks of abandoned land would not befall the city even after the completion of the project. Besides, this aligned with the city's vision under the Dubai Plan 2021.

This plan mentions that the urban planning involved here is to build a smart city where all the resources are used sustainably. The theme under the smart and sustainable city involves building a fully connected city with easy access to economic centers and social places that would align with other best cities in the world. Besides, the reclamation of the used land and the use of the resources of sand excavated from the sea to build a peninsula is in line with the framework of the importance of sustainability for the future of Dubai and the UAE. This act of reclamation ensures that natural resources like soil, water, and even air are taken care of, and no risk can be experienced due to their misuse or management. Besides, according to the theme of a smart and integrated city, this project step ensured that the safety standards were adhered to protect all the city's users and ensure that the city was as beautiful and well-planned as it must be.

According to Dubai Plan 2021, one major point in building an innovative and sustainable city is ensuring that the environmental elements are clean, healthy, and sustainable. In this case, during the building of the Dubai Water Canal, the process involved using other contractors to conduct specialist ground improvement works as part of the construction package. In the improvement works, the objective included the improvement of soils on the reclaimed land in an area of about 185000 square meters. Besides, the improvement involved pre and post-verification testing of these grounds, where a combination of soil treatment methods was used. The methods ranged from vibro compaction to high-energy roller techniques. Before the soil improvement process, Cone penetration testing was used to conduct a pre-survey of the soil conditions. This process is crucial as it provides the information for the design of vibro compaction that is viable for the specific project. After that, vibro compaction was deemed the best method since water was involved.

This project reported that vibro compaction was used to improve the ground's condition before construction. The technique is unique in increasing the soil's bearing capacity, thereby mitigating the potential of seismic liquefaction and settlement reduction. Similarly, a post-CPT was also done to assess how effective the ground treatment was. Besides, the high-energy impact roller technique achieved a 95 percent in situ maximum dry density of the top layer of about 1.5m. All these were ways to ensure the city remained smart but sustainable for future use without exposing environmental risks.

In the United Arab Emirates, building bridges that connect water to land and form the uniqueness of their cities is one of the major urban projects in which the government participates. Most often, the projects take a proactive approach to adhere to the urban plan development and mitigate risks that might come about due to the developments being early enough. For instance, it involves assessing potential risks in the

initial stages of the project and putting measures in place to mitigate such risks. During the building of the Water Canal Bridge, the process involved conducting a thorough impact assessment before the project. The Impact assessment report details the project's risks, benefits, mitigation measures, and viability.

Stakeholder engagement is always a key point during the project lifecycle. For instance, the Road Transport Authority's involvement in constructing the Dubai Canal Water Bridge took all the stakeholders into account. The project team engaged with various stakeholders, including public and government agencies and private sector entities, to identify potential risks and concerns and develop strategies to address them. This helped to ensure that the project was aligned with the interests and needs of all stakeholders, which helped mitigate risks and enhance the success of the project mitigate risks and enhance the project.

Additionally, the project team employed a robust monitoring and evaluation process to ensure that risks were managed effectively and that the project met its objectives. For example, using the vibro and high-energy roller techniques ensured that the solution was in situ and the conditions were good enough after the project's completion. Regular progress reports and risk assessments were conducted to track the project's progress and to identify any emerging risks that needed to be addressed.

5. COMPARISON OF THE DUBAI WATER CANAL WITH THE THAMES TIDEWAY TUNNEL, LONDON, UK

The Thames Tideway Tunnel is a major infrastructure project to upgrade London's aging sewer system. It involves constructing a 25 km tunnel under the River Thames to capture and store overflow sewage and rainwater that would otherwise discharge into the river. The estimated cost is £4.2 billion, and completion is expected by 2024.

Risk Mitigation Strategies implemented are:

- **Environmental Impact Assessments:** Extensive studies were conducted to minimize the ecological impact on the River Thames and surrounding areas. This included measures to protect marine life and water quality.
- **Stakeholder Engagement:** Regular consultations with local communities, government agencies, and environmental groups ensured that the project addressed public concerns and received broad support.
- **Phased Implementation:** Like the Dubai Water Canal, the project was divided into multiple phases to manage risks incrementally and allow for adjustments based on ongoing assessments.

- **Community Involvement:** Engaging local communities early in the process can lead to better acceptance and smoother project implementation.
- **Robust Environmental Planning:** Comprehensive environmental assessments are crucial for large-scale urban projects, ensuring minimal negative impact on the natural surroundings.

DISCUSSION

The comparative analysis of the Dubai Water Canal project and similar large-scale urban infrastructure projects globally reveals several key insights that align with and diverge from the existing literature on risk management in urban planning. By connecting this study's findings with the theoretical frameworks and case studies reviewed earlier, we can strengthen our understanding of risk management strategies and their application in modern infrastructure projects.

1. Environmental Impact Assessments (EIAs)

Alignment with Existing Literature: The importance of comprehensive environmental impact assessments (EIAs) in large-scale urban projects is well-documented in the literature. For example, Gencer (2013) emphasizes the critical role of EIAs in mitigating environmental risks in urban development. The Dubai Water Canal project's extensive use of EIAs, as seen in the careful water quality management and land reclamation, aligns with these established best practices. However, the Dubai Water Canal project takes this a step further by integrating EIAs with smart urban planning elements, such as developing green spaces and using advanced monitoring technologies. This approach aligns more with the modern concept of "smart sustainability," which goes beyond traditional environmental assessments by incorporating technological solutions to enhance urban resilience (Tzioutziou & Xenidis, 2021). This forward-looking strategy is less emphasized in older literature, suggesting that the Dubai Water Canal project may represent an evolution in risk management practices.

2. Phased Implementation

Alignment with Existing Literature: The phased implementation strategy used in the Dubai Water Canal project is consistent with the recommendations found in the literature. According to Ullah et al. (2021), phased approaches in urban planning allow for continuous monitoring and adjustment, which are crucial in managing the complexities of large-scale projects (Ullah, et al., 2021). The use of distinct phases—feasibility, planning, construction, and testing—mirrors the best practices outlined in the literature, ensuring that risks are managed incrementally rather than all at once. While the phased approach is well-supported by existing

studies, the Dubai Water Canal project's integration of sustainability and smart technologies within each phase is a notable divergence. Traditional literature treats phases such as environmental assessments, stakeholder engagement, and sustainability as separate components. In contrast, the Dubai Water Canal project exemplifies a more integrated approach, where these elements are woven throughout the project lifecycle. This integration reflects modern urban planning theories that advocate for holistic and adaptive planning processes, as discussed by Conway and Vincent (2021) (Conway & Vincent, 2021).

3. Stakeholder Engagement

Alignment with Existing Literature: The role of stakeholder engagement in mitigating risks in urban infrastructure projects is well supported by existing research. For instance, Somers (2021) discusses the importance of inclusive participation in urban planning, noting that it enhances the effectiveness and efficiency of strategies by fostering a sense of ownership among stakeholders (Somers, 2021). The Dubai Water Canal project's extensive stakeholder engagement, which involved regular consultations and public forums, aligns closely with these principles. What sets the Dubai Water Canal project apart is its use of advanced communication technologies to facilitate real-time feedback and engagement. This approach aligns with recent studies that advocate using digital platforms to enhance stakeholder participation. This trend is becoming increasingly important in the context of smart city development (Chuloh, et al., 2021). Traditional literature, which often emphasizes face-to-face consultations and meetings, may not fully leverage the potential of these technological advancements in enhancing stakeholder engagement.

4. Sustainability Focus

Alignment with Existing Literature: The emphasis on sustainability in the Dubai Water Canal project aligns with the broader literature on urban planning, which increasingly recognizes the need for sustainable development practices. For example, Laforzezza and Sanesi (2019) highlight the importance of integrating sustainability into urban infrastructure projects to ensure long-term environmental and social benefits (Laforzezza & Sanesi, 2019). The Dubai Water Canal's focus on green spaces, resource reclamation, and smart urban integration echoes these findings. However, the Dubai Water Canal project's approach to sustainability is more comprehensive and technologically integrated than what is typically discussed in earlier studies. Traditional literature often focuses on environmental sustainability in terms of resource conservation and pollution control. In contrast, the Dubai Water Canal project integrates these elements with smart city initiatives, such as using advanced monitoring systems and creating

connected urban spaces. This broader interpretation of sustainability, which includes technological innovation and smart urban planning, reflects the evolving nature of urban infrastructure projects in the 21st century (Ferreira & Magalhaes, 2018).

The research study provides information about two significant bridge projects in the United Arab Emirates (UAE): Dubai's water canal bridge and Sheikh Zayed Bridge, along with a mention of Al Maqtaa Bridge and Ras Al Khaimah Bridge. Additionally, it highlights the challenges of rapid urbanization in the UAE and the government's efforts to manage risks through organizations like the National Emergency Crisis and Disaster Management Authority (NCEMA) and initiatives such as those by the Abu Dhabi Urban Planning Council (UPC).

Here are some reasons for the data trends presented in the study and how these results make this study different from other similar studies:

- **Rapid Urbanization in the UAE:** In recent decades, the UAE has undergone rapid urbanization, leading to significant economic growth and infrastructural development. This trend responds to the increasing population and the desire for modern and efficient urban environments.
- **Infrastructure Projects:** Focusing on large-scale infrastructure projects, such as Dubai's water canal and Sheikh Zayed Bridge, reflects the UAE's commitment to creating modern and iconic landmarks. These projects improve transportation and serve as tourist attractions, contributing to the overall urban development strategy.
- **Integration of Smart Solutions:** This study's emphasis on smart solutions sets it apart, as outlined in the Road and Transport Authority (RTA) objectives. Incorporating technology and connectivity in transportation and government services aligns with the global trend of smart cities and urban planning.
- **Risk Management in Urban Planning:** The study highlights the challenges of rapid urbanization, including potential risks to the local population and natural resources. Establishing organizations like NCEMA and initiatives by the UPC demonstrates the UAE's commitment to effective risk management in urban planning, setting it apart from other studies that may not delve into the specific strategies governments employ to address these challenges.
- **Focus on Sustainability:** The six significant points outlined by the RTA, including safety, environmental, and financial sustainability, indicate a comprehensive approach to urban development. This sustainability focus distinguishes the study and highlights the UAE's commitment to sustainable urban growth.
- **Use of Iconic Designs in Infrastructure:** The description of the Sheikh Zayed Bridge's unique design by Zaha Hadid Architects and the mention

of the ongoing renovation of Al Maqtaa Bridge demonstrate a commitment to functionality and aesthetics in urban infrastructure. This design-oriented approach sets the UAE's urban planning apart from studies that may solely focus on utilitarian aspects.

- In summary, the combination of rapid urbanization, large-scale infrastructure projects, emphasis on smart solutions, risk management strategies, sustainability goals, and attention to iconic design elements collectively differentiate this urban planning study in the UAE from other similar studies worldwide. The focus on the UAE's unique initiatives and challenges contributes to a comprehensive understanding of the country's urban development landscape.

7. CONCLUSION

The Dubai Water Canal project is a notable example of successful urban development, demonstrating the critical role of comprehensive planning, risk management, and phased implementation in large-scale infrastructure projects. Key conclusions from the study include:

Effective Phased Implementation: The project's division into distinct phases allowed for incremental risk assessment and mitigation, ensuring that potential challenges were addressed systematically.

Thorough Environmental and Feasibility Assessments: Comprehensive feasibility studies, geological assessments, and environmental impact assessments were crucial in identifying potential risks early and developing effective mitigation strategies.

Proactive Risk Management: A proactive approach to risk management, including regular monitoring and evaluation, was essential in minimizing risk exposure and ensuring the project's success.

Stakeholder Engagement: Involving stakeholders, including local communities and government agencies, throughout the project lifecycle enhanced public support and ensured alignment with broader urban development goals.

Sustainability Focus: Emphasizing sustainability in planning and execution, including resource reclamation and environmental protection, contributed to the project's long-term resilience and environmental health.

Based on the findings of this study, the following recommendations are proposed to enhance the planning

and execution of future large-scale urban infrastructure projects:

Adopt Phased Implementation for Large Projects: Future projects should consider a phased approach to implementation, allowing for continuous risk assessment and mitigation. This method provides flexibility and enables project teams to respond more effectively to unforeseen challenges.

Conduct Comprehensive Pre-Project Assessments: Ensure thorough feasibility studies, geological assessments, and environmental impact assessments are conducted before project initiation. These assessments should be detailed and cover all potential risk areas, providing a solid foundation for effective risk management strategies.

Enhance Stakeholder Engagement: Engage stakeholders early and maintain open communication throughout the project. Regular consultations with local communities, government agencies, and other relevant parties can help identify potential concerns and build broad support for the project.

Integrate Sustainability into Urban Planning: Sustainability should be a core component of all urban planning efforts. Incorporate practices such as resource reclamation, green infrastructure, and sustainable design principles to ensure long-term environmental and economic benefits.

Implement Advanced Risk Management Frameworks: Develop and implement robust risk management frameworks that include continuous monitoring, regular risk assessments, and adaptive management strategies. These frameworks should be integrated into the project's overall management plan to ensure they are applied consistently and effectively.

Leverage Innovative Technologies and Techniques: To address complex urban challenges, utilize advanced engineering techniques and innovative construction methods. Technologies such as smart sensors, real-time data analytics, and advanced construction materials can enhance project efficiency and effectiveness.

Focus on Capacity Building: Invest in capacity building for project teams and local authorities. Training in advanced project management, risk assessment, and sustainable urban planning can

enhance the ability to manage large-scale projects successfully.

Document and Share Lessons Learned: Create a comprehensive repository of lessons learned from each project phase. Sharing these insights with other cities and project teams can contribute to the broader knowledge of best practices in urban infrastructure development.

Implementing these recommendations will allow future urban infrastructure projects to benefit from the insights from the Dubai Water Canal project, leading to more resilient, sustainable, and successful urban development initiatives.

In conclusion, the study provides a comprehensive overview of the United Arab Emirates (UAE) urban development landscape, focusing on critical infrastructure projects and the challenges associated with rapid urbanization. Notably, Dubai's Water Canal Bridge and Sheikh Zayed Bridge stand out as iconic landmarks, reflecting the UAE's commitment to cutting-edge technology, connectivity, and aesthetic design in urban planning. The study distinguishes itself by highlighting the multifaceted objectives of the Road and Transport Authority (RTA), emphasizing the integration of smart solutions, sustainability goals, and risk management strategies. The UAE's dedication to addressing challenges through organizations like the National Emergency Crisis and Disaster Management Authority (NCEMA) and the Abu Dhabi Urban Planning Council (UPC) underscores its commitment to ensuring the well-being of its population and the sustainable development of its cities. As the UAE continues to urbanize, the passage suggests its proactive and holistic approach sets it apart from similar studies, showcasing a model prioritizing innovation, sustainability, and effective risk management in the evolving urban landscape.

Furthermore, the Dubai Water Canal construction was a thoroughly planned and executed project that unfolded in four well-structured phases. Each phase of the project implementation was accompanied by rigorous risk mitigation and monitoring measures, reflecting a proactive approach to ensure the safety and success of the overall initiative.

The emphasis on comprehensive monitoring during the project's completion further highlights a commitment to delivering a high-quality end product, explicitly focusing on minimizing risk exposure to the population. By rolling out the project in phases, the strategy of identifying and mitigating risks incrementally was employed, preventing the entire project from being overly exposed to potential challenges.

The success of the Dubai Water Canal project underscores the importance of thorough feasibility studies, geological assessments, and environmental

impact assessments in the initial stages of planning. These practices not only contribute to the identification of potential risks but also enable the development of appropriate mitigation strategies. This research study's proactive approach emphasizes the significance of adequate preparation for any eventuality during large-scale infrastructure programs.

Overall, the Dubai Water Canal project serves as a model for urban development initiatives, highlighting the value of careful planning, risk management, and comprehensive assessments in ensuring the success and sustainability of such ventures.

In summary, the findings of this study both align with and extend the existing literature on risk management in large-scale urban projects. The Dubai Water Canal project exemplifies best practices in environmental impact assessments, phased implementation, stakeholder engagement, and sustainability, as supported by established research. However, the project also demonstrates an evolution in these practices, mainly by integrating smart technologies and holistic urban planning approaches beyond traditional frameworks. This suggests that while foundational principles remain relevant, modern urban infrastructure projects are increasingly characterized by adaptability, technological integration, and forward-looking sustainability strategies. These insights contribute to the ongoing discourse on urban development and risk management, highlighting the importance of continuously evolving practices to meet the challenges of contemporary urbanization.

COMPETING INTERESTS

The authors have no competing interests to declare.

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