Assessing Resilience of Water Infrastructure Projects in Urban Areas

(A Case Study of Colombo Metropolitan Region - CMR)

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"This dissertation was submitted to the Department of Civil Engineering of the University of Moratuwa in partial fulfilment of the requirement for the master of Science in Construction Project Management"

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November 2022

Declaration

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Abstract

In the Colombo Metropolitan Region (CMR), sustained productivity development is key to Sri Lanka's 2022 growth as a middle income economy. One of the most valuable growth engines in Sri Lanka is the increased productivity of the CMR or Western Province. However, the CMR must remain comparable with other Asian urban areas. Priority should also be given to reinforcing the most vibrant service industries such as Information Technology (IT), financial services and shifting from low to high value-added production opportunities. Urban sprawl is the consequence of legal and structural restrictions on land prices and insufficient resources for effective and productive land usage and property development.

Several underground water pipelines were built in the Colombo Metropolitan Region about fifty years ago. These pipes have reached the end of their useful life and require extensive repairs. Based on the literature review, it was identified that water and wastewater treatment systems require upgrades to meet contemporary environmental standards. However, as per the objectives of the research, it is to assess the resilience of water infrastructure projects in urban areas to examine the required level of policies for resilience of water infrastructure projects in urban areas and to examine the impact and externalities on the resilience of water infrastructure projects in urban areas.

The capacity utilization and requirements, policies, strategy, and capital accumulation to the resilience of water infrastructure projects in Colombo Metropolitan Region (CMR). Additionally, it implies that the impact and the corelation of the independent variables, capacity utilization and requirements, policies, strategy, capital accumulation to resilience of water infrastructure in Sri Lankan urban areas.

Key Words: Resilience, Water Infrastructure Projects**,** Urban areas, National Water Supply & Drainage Board

Acknowledgement

May this be a gratitude for those who offered me encouragement, valued cooperation, advices and assistance for achieving my objective.

It is my foremost duty to give special thanks to my supervisor Dr. C.S.A. Siriwardana for the valued, tireless guidance and support offered despite his busy schedules.

I pay my sincere thanks to the Construction Management unit of Department of Civil Engineering, University of Moratuwa for organizing Construction Project Management course which is very useful in the emerging infrastructure projects in Sri Lanka.

I would like to thank the Construction Project Management staff unit of the UOM, those who all motivate and help several ways to do my research.

I appreciate the all the staff of Greater Colombo & Wastewater Management Improvement Investment Program System Rehabilitation for NRW Reduction, NWSDB. Especially, I would like to thank Eng.V.U Alawatta who gave valuable support and encouragement to my research study.

Ultimately, I make this an opportunity to appreciate each and every person who gave their assistance in every mean to achieve successful completion of this research.

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Abbreviations

ADB - Asian Development Bank

CMR - Colombo Metropolitan Region

IUWM -Integrated Urban Water Management

KDI - Key Dimension Index

NWSDB - National Water Supply and Drainage Board

SDGG - Socially Disadvantaged Groups Grant

SDG - Sustainable Development Goal

UDA - Urban Development Authority

ULAs - Urban Local Authorities

UN - United Nations

WSS - Water Supply and Sanitation

CHAPTER ONE

INTRODUCTION

1.0. Background of the Study

Water is the basic necessity for the functioning of all life forms on earth. It is impossible for life to function without water. After all, it makes for almost 70% of the earth.

Water covers more than two-thirds (67%) of the world's surface. However, the five seas contain 97.2 percent of it. Fresh water makes up less than 2.7 percent of the world's total water. The majority of fresh water (2.05%) is trapped in ice caps and glaciers. Only about 0.7 percent of fresh water is available for human consumption in the form of groundwater, lakes, and rivers. (Bureau of Reclamation, 2020)

Despite the importance of water for development, most countries' funding has recently been inadequate to meet the required level of national drinking water goals. Instability in the political and economic status, as well as climate change, aggravate the issues already exist in the sector. This has made the Water to be one of the most critical issues globally, which is no doubt. (Policy Perspectives, 2016)

Sri Lanka lies in the Indian Ocean. Sri Lanka, an island nation with a very long history of around 3,000 years, with at least 125,000 years of prehistoric human settlements. (General information about Sri Lanka, n.d.)

According to Department of Census and Statistics data, only 40 percent of the people in Sri Lanka have organized access to water supply facilities, while 59.4 percent depend on various other sources such as wells, tube wells, streams, and rivers. And it is sad to note that around 10% of the population depend on unprotected water sources. The Government of Sri Lanka, with the support of National Water Supply and Drainage Board, the country's national drinking water authority, gears to provide accessibility and availability of safe drinking water to all by 2025, with piped born water supply coverage to 65 percent by 2020. (Gamini)

The first level Administrative capital of the country is situated in the Western Province, one of the nine provinces of Sri Lanka. It is contributed 39.1% of the country’s GDP

(Central Bank of Sri Lanka, 2020) Density of population per square km in Sri Lanka is 348, it was 1711 in the western province (Department of Census and Statistics, 2020). Further, the urban population has risen from 14.6 per cent of the national population in 2001 to 18.3 per cent in 2012, the most recent census year, indicating a slightly faster rate of urbanization. However, between 2013 and 2015, Colombo's population increased by only 0.75 percent each year, from 2.3 million to 2.4 million. (Asian Development Bank, 2017)

Colombo is one of Sri Lanka's oldest districts. Colombo's history dates back over 2,000 years, with Arab traders first arriving in the city in the 8th century AD. The city has traditionally been a desirable trading center due to its enormous natural harbour and tropical plant and spice plantations.

Figure 1 : Colombo Municipal Area -Water Supply, CMC, (2021)

The CMR must remain comparable with other Asian urban areas. Priority should also be given to reinforcing the most vibrant service industries such as Information

Technology (IT), financial services and shifting from low to high value-added production opportunities. Collaboration with national and international private sector stakeholders is critical to improving the CMR's infrastructure, citizens' quality of life, and human capital are some of the key areas where government have to empathises. Western provinces have 99% safe water access however, new water supply projects are implemented because of high Non- Revenue Water (NRW) value and demand increase due to internal migration of population (ADB, 2016)

Urban sprawl is the consequence of legal and structural restrictions on land prices and insufficient resources for effective and productive land usage and property development. Private developers strive to mobilise land in city centres for development and restrict development in vast areas. However, efficient land usage – backed by high-density urban transit – will yield significant economic gain by minimising vulnerabilities in natural hazards, reducing infrastructure expense, reducing adverse environmental effects, boosting private investment in land and housing and enhancing local own-source generation as per the present context of the country (Jayasinghe, Raghavan, & Yonezawa, 2021).

1.1. The Problem Statement

Fifty or so years earlier, several underground water pipelines were constructed in the Colombo Metropolitan Region (CMR). These pipes have reached the end of their lifetime and need significant renovations. And if these facilities already operate well, modernised water and wastewater treatment systems will need updates that will meet current environmental requirements.

The current urban water management case in the Colombo Metropolitan Region (CMR) is an example of how decisions can also be adopted in so-called developing countries without proper analyses of the potential impacts. After two decades of transition, the Colombo Metropolitan Region (CMR)’s water supply was polluted by plumage in the city’s water delivery scheme.

However, this has led to a substantial risk to public health. This leads to several major health issues. Further, delay in completion of water supply project is one of the most important problems faced by National Water Supply & Drainage Board, as per auditor general statement some projects are delay 180 days to 1000 days. (Audit general department, 2018).

Therefore, implementation of water infrastructure projects is timely needed while proper assessment of resilience of those projects.

1.2. The Enablers and Barriers

National long-term development programmes and related strategies are the government's main instruments for achieving the national economic development targets and guiding the sector's development objectives. A conceptual approach to developing water supply and sanitation (WSS) throughout the time is outlined under the existing framework of development policy for 2030 and offers a framework for government and development partners to discuss and develop investment strategies and suggestions. The goals and the projected financial needs to complete this initiative for the water supply and sanitation (WSS) delivery are mentioned. It offers a valuable framework in which government cooperation with development partners can be coordinated, and development partners may establish unique investment projects but is now approaching the end of the planning cycle. The next development plan is likely to be prepared by 2022, which could be a valuable framework for collaboration and preparation for development. The relevant government departments responsible for various industries prepare detailed national business development strategies. The National Water Supply and Drainage Board (NWSDB) is primarily responsible for the water supply and sanitation (WSS) field and prepares development proposals for ten years, most recently for 2016–25. Also, for 2016–2020, medium-term business proposals are currently being drawn up. These plans together create a solid foundation for medium-and long-term development. They frequently overlook details, such as the priorities to be provided to Waianae Wastewater Treatment Plants (WWTPs). Relevant sector master plans must also be developed to lead sectoral initiatives and goals.

Similar proposals may be developed for urban and rural water supplies to provide the foundation for government, development partners, and other donors to cooperate on geographical or technical assistance areas, thus fostering improved sector cooperation (Hewawasam, & Matsui, 2020).

1.3. Research Questions

i. What are the factors affecting the implementation of water infrastructure projects in Colombo Metropolitan Region (CMR)?
ii. Does the economic environment have any significance on the implementation of resilience of water infrastructure projects in urban areas?

1.4. Objectives of The Research

i. To understand the factors defining for resilience of water infrastructure projects.
ii. To examine the impact and externalities on the resilience of water infrastructure projects.

1.5. The Significance

The partnership between water, electricity and land use and the diversification of water resources must prioritise sustainable urban development to ensure a stable supply.

Internationally, there have been several studies have been done in the global perspective to risk analysis in water supply projects. But in Sri Lanka’s perspective, not much studies have been done in water supply projects. Hence, this research aims to bridge the existing literature gap in assessing resilience of Water infrastructure projects in urban areas

1.6. Structure of the report

The report is organized in following order.

Chapter 01 - Introduction, objectives and the significance of the study

Chapter 02 - Literature review

Chapter 03 - The methodology

Chapter 04 - Results and Discussion

Chapter 05 - Conclusion and recommendation of assessing resilience of water infrastructure projects in Colombo Metropolitan Region (CMR).

1.7. Limitations

The case study is primarily based on the Colombo Metropolitan Region (CMR), in order to generalize the resilience of water infrastructure projects in urban areas in Sri Lanka.

CHAPTER TWO

LITERATURE REVIEW

2.1. Introduction

Today, tap water is a valuable resource. Engineering developments in management of this resource with water treatment, supply and delivery systems. In the 21st century, urban existence was transformed profoundly, waterborne illnesses in the developing countries were practically eliminated, and cities, farmers and industry had safe and ample water. For instance, the International Water Management Institute, is among the engineering achievements of the 21st century in innovative water solutions for sustainable development. However, it remains to be done even in developing countries to provide everybody with clean tap water, particularly in urban areas. The world's population is increasing by about 80 million citizens annually, and by 2050, 10 billion is expected to come. Presently more than half of the world's population lives in urban areas today, and it is increasing more and more. When populations constantly migrate to towns for better economic opportunities and higher living standards and cities converge into megacities, water development and management become an essential part of urban infrastructure's integrated planning and management (Jayasooriya, Ng, Muthukumaran, & Perera, 2020).

Resilience of water infrastructure and resilient cities are the areas for living safe. However, required water and sanitation services are based on sound ecosystems. High water efficiency and improved urban resilience against catastrophes as Water-Resilient Cities in the world. Water -resilient cities and the integrated urban water management framework follows integrated water resources management principles and adopts eco-city, compact town and rational urban planning development concepts and methodologies. However, this is based on a long-term, sustainable strategic vision strengthened by innovative measures and suitable action measures at the country level, community, and city level. It is interactive approaches for regional policymakers and practitioners to use the lenses of water resilient cities to promote SDG-ready policies, giving an environment with a sense of greater social well-being and good fortune. (Water Resilience Profile, 2021)

2.2. Resilience

The term "resilience" refers to the ability to quickly adapt to and recover from any disruptions. (Merriam-Webster, 2022)

This concept was initially used by Holling (1973) in his paper "Resilience and Stability of Ecological Systems," which defined it as an ability of system to accept changes in state variables, driving variables, and criteria while remaining firm and solid. Since then, the idea has been used in a variety of fields, including the socio-ecological system (SES), which is concerned with the study of the interconnections between social (human) and ecological (biophysical) subsystems in the resilience-building process. (Panchali Saikia, 2022),

2.2.1. Resilience Assessment

Resilience assessment incorporates a collection of important principles and draws on researchinsights from complex adaptive systems to present an alternate method of thi nking about and conducting natural resource management.
Building a model of the system of interest is part of the resilience assessment framew ork (i.e., the place, issues, and people involved). Although some activities and questi ons focus on specific system components, these insights are aimed to aid our compre hension of the overall system dynamics. A final synthesis of the assessment data, as well as the conceptual model, aidsin the identification of elements that may be degra ding or boosting system resilience.
This knowledge serves as the foundation for exploring possibilities for ensuring a lon g-term future trajectory. (Resilience Alliance, 2010)

2.2.2. Assessing Resilience of Water System

This review raised awareness of the value of strengthening cooperation by drawing sector-specific lessons that can help Sri Lankan development partners work more efficiently together to support the government's development plans in the water supply

and sanitation (WSS) sector. Most of research provide value for both the country and its development partners by analysing the existing scenario and how developing partners should work together to enhance the result and impact mechanism of a field in which the challenges are complicated and challenging to address without strong cooperation between all stakeholders. The focus areas of development are water supplies and sanitation. It is also vital to other development goals, such as wellness, safety, human empowerment, and learning. It provides access for people to sufficient, secure, accessible and clean water and sanitary services central to human development (Tan, 2021).

Table 1: The KDI Index and Regional Piped Water Access %

Country	Piped Water Access %	KDI Index
Bangladesh	12	1
Bhutan	58	1
India	28	1
Maldives	45	3
Nepal	23	1
Pakistan	38	1
Sri Lanka	34	3

Source- Edirisinghe, & Pathirana, (2021).

KDI = key dimension index-Piped water, Sanitation access, Diarrhea daily (dehydration due to fluid loss).

2.2.3. Resilience Dynamics of Urban Water Supply Strategy

Cities are drivers of socioeconomic innovation and are obliged to face the increased risks of existing and future failure of vital services, such as water supply. Here, the resilience of urban water supply security assessed by the services provided for residents is explored. However, the availability of the main components of the system and the strength of the 'capitals' which include available water resources,

infrastructure, finances, management efficacy, and community adaptation (Abeysinghe, 2007). Therefore, it is required to convert quantitative information from different cities on deferent locations or regions to understand the boundaries for the capital portfolio, as per the combined dynamic system model which is a systematic review of resilience dynamics of urban water supply security (Cardoso, Brito, & Almeida, 2021).

Whether natural or captured or focusing on regions of urban society that live in water poverty, the average water availability is evaluated by a joint assessment of the safety of urban water. Some experts say that urban water security is a mix of local water and management organisations responsible for building regional water infrastructure. However, 7% of the 108 cities studied are still uncertain, possibly due to a lack of access to local resources as per the South Asian context. However, 482 of the world's largest towns and cities develop water security scenarios by integrating multiple businesses with conflicting consumption impacts. Their findings suggest that by 2050, 46% of agricultural cities face water security difficulties, either due to surface water shortages or competitive differences concerning water. A broader water scarcity analysis finds that water scarcity estimates for 2050 are between €3 billion and $4.5 billion (Zivdar, 2021). In addition to urban water insecurity, a far more significant (unquantified) proportion in global urban regions is affected by the insufficient water resources available in urban settings. Water insecurity should affect at least 23% of the world's informal urban population with no sufficient access to urban public services for 883 million people as per the United Nations. Integrated approaches to water insecurity mainly were qualitative, theoretical, and case-based assessments (Hanna-Attisha, 2016). Therefore, the methodology is principally based on qualitative, theoretical, with case-based assessments of the case study area, where the National Water Supply and Drainage Board (NWSDB) is the state entity who responsible for the providing of quality and safe drinking water to the nation.

The review has been showing the necessity for systems, methods and metrics to allow cross-site comparisons and integrate quantitative measures with contextual and qualitative information while it addressed the connection between water security and adaptability, including the "capital" notion which also known as assets, resources and

desirable factors, essential for adaptive capacity (Wutich, & Ragsdale, 2008). Further, it describes a quantitative, empirical and comparative technique that consistently integrates specific 'capital' for adaptive abilities and sets a framework for identifying locational differences in these investigations. However, the technology is required to apply to test the safety of urban water supply against genuine services given to people, including access, access security and water quality, reliability, continuity and costs (UN, 2018).

In the current framework, the Capital Portfolio Approach -CPA, that require not just the availability of city-level water resources but intra-urban water storage, processing and distributing infrastructures; financial and administrative institutions; and community adaptation when public services fail to deal with and adapt to resources insufficiency. The literature showed that adaptation to communities remain passive in high-quality cities while service performance is essential. Cities with high water insecurity depend on adaptation to community support. Therefore, the variability of safety in urban water depends significantly on the community's adaptability where this applies to water security concept in response to and evaluate its resilience against recurring shocks and disruptions (Jeffrey, 1997).

In this respect, it required to solve these weaknesses by merging system status, risk, and dynamic reaction with the empirical data where it regards urban water security as a system state, shook by pressures that might threaten the system's status as provided in the portfolio approach that has followed water services concerning safety, access, security and safety of water and access (Srinivasan, 2008). The resilience of the system refers to its dynamic, energetic performance in shock response. The dynamic response integrates several types of 'capital', and human activity consists of adaptive management by making the capital accessible through solid capital. Thus, the concept of urban water resilience is consistent with urban water resilience which based on the capital accumulation (Keath, Brown, 2009).

2.3. Country Context-Sri Lanka

The aftermath of COVID-19 pandemic left a devastating effect in Sri Lanka profoundly, like in many other countries. The first few domestic cases of COVID-19 were reported in March 2020, and it was contained successfully by the end of October 2020, as the government rapidly scaled up efficient and effective quarantine measures. Restricting tourist arrivals and imposing nationwide curfew from mid-March through June 2020were the key measures in the successful control of first wave. In addition to these measures, the active case finding, rigorous contact tracing, and efficient quarantine and isolation ensured that the first wave was controlled in an effective manner. With the tireless support of Health staff and other related sectors, there were only 3,380 cases and 13 deaths reported by September 30, 2020. But, with the sudden influx of patients rapidly in an uncontrolled manner, the country had to struggle with the second wave of infections during the last quarter of 2020. Instead going for the complete close down of the country, this time, the government resorted to go for targeted lockdowns to minimize economic activity, including water infrastructure projects in the Colombo metropolitan region (Gallage, Devapriya, & Perera, 2021).

2.3.1. The Case Study Area-Colombo Metropolitan Region (CMR)

The decline of urban vegetation, mostly substituted by quality water, impervious land surfaces such as homes, parking areas, roads and flooring, is one of the main consequences of unplanned rapid development in cities. As a result, at the cost of vegetation, as the percentage of impenetrable surfaces continues to grow, the urban heat island which is forming and being increasingly intensified. Sri Lanka is one of South Asia's fast-urbanizing metropolitan areas, the Colombo Metropolitan Area (CMA).

Colombo Municipal Council is in charge of the city of Colombo. It is the capital city of Sri Lanka, located on the island's west coast, and is the center of commercial activity due to its vast harbor. With a land area of roughly 37.3 km2 and a metro population of almost 700,000 people, it is a heavily inhabited and urbanized city. The majority of the roadways are asphalt concrete, with pedestrian walkways on both sides.

Telecommunication cables, electricity cables, fiber optic lines, water supply lines, drainage and sewer mains are all examples of underground utilities. (Colombo Municipal Council, 2015)

The existing Colombo City water supply system, which is controlled by the National Water Supply and Drainage Board, delivers pipe-borne water to about 127,000 service connections. The existing pipe network is made up of a combination of CI, DI, GI, and PVC pipes, with most of the CI and GI pipes installed more than 50 years ago deteriorating or narrowing in diameter. (National Water Supply and Drainage Board, 2022)

2.3.2. The Water Infrastructure in Colombo Metropolitan Region

Colombo city faces access and municipal infrastructure limitations that needs to be trained to deal with natural hazard risks and impacts. The development of a well-linked city grid and the improvement of "time-measured distance" is vital in order to improve market access. Municipal solid waste collection is insufficient for urban development, and drainage spending has decreased, leaving urban areas vulnerable to flood conditions. There are risks to urban water supply schemes and changes in water quality, especially in the Colombo Metropolitan Region (CMR) since last few decades due to weaker town plan and internal migration in the country. As per the Sri Lankan context, Colombo Metropolitan Region (CMR), particularly commercial, requires an integrated environmental protection strategy, including sewage treatment, wastewater management, drainage and waste management and resilience of water infrastructure are some of the areas where it is strongly required to enhance as per the demand, today. However, the urban water infrastructure is a vital factor in community competitiveness. Still, there is a lot to do to enhance water infrastructure in major cities of the Colombo Metropolitan Region (CMR) and make more quality and efficient supply to meet development objectives of the country. In the face of global climate change, Sri Lanka's urban areas have become more vulnerable to natural disasters, and adaptation strategies must be integrated into urban risk management policies. Urban water sources are threatened, and changes in water quality are needed, particularly in

the Colombo Metropolitan Region (CMR). The major cities, and in particular tourism and commercial attractions, require an integrated approach to environmental protection, including the wastewater treatment, drainage and management of solid waste. Urban transport is another major contributor to city competitiveness, which is parallel to the resilience of water infrastructure today (Sivakumar, 2021).

Nevertheless, more remains to be done to enhance water infrastructure in major cities and make urban areas healthier. In the context of global climate change, urban areas in Sri Lanka are increasingly susceptible to natural catastrophes, and adaptation strategies need to be integrated into urban risk management plans. In the social viability of the vision, the connectivity and quality distance between CMR and the principal cities beyond the Western Province must be reduced. Sri Lanka must preserve its well-served urban infrastructure globally, recognising that the CMR will remain an effective attraction for economic migration, at least for years to come. Reduced connectivity and quality gaps between Colombo and the major urban centres outside of the Western Province could lessen the pressure for better services for migrants to Colombo. Differences in access to water and energy, particularly for the less educated people, influenced migration decisions in the 1990s due to job opportunities and better income. However, evidence suggests that improving education quality in urban areas outside the Western Province is increasing rather than decreasing the draw of skilled work to Colombo, as professional work progresses to pursue improved economic opportunities with a significant economic impact on the economy through expanded infrastructure including water (Rathnayake, Jones, & Soto-Berelov, 2020).

2.3.3. The Policy of SDG

Considering the global context, it is also crucial to other development policies, such as health, nutrition, equality of sex and education, and access to enough, dependable, inexpensive and safe water and sanitation, essential to human development. Overall, it is estimated that 873 million people have no access to better water sources and that 4.4 billion people have no access to better sanitation. Most of them are in South Asia and sub-Saharan Africa. The 2030 Agenda for Sustainable Development focuses on

overcoming the gap in access to better water and sanitation. Sustainable Development Goal (SDG) is "to guarantee the available water management and sanitation for all sustainably.

Sri Lanka provides a unique chance to learn in challenging situations from positive experiences in water supply and sanitation (WSS). Despite the comparatively low per capita income, the country has achieved remarkable accomplishments in this area, a backdrop of civil warfare between 1983 and 2009 and a catastrophic tsunami in 2004. In 1990, it was estimated that over 68% of the population had access to safe drinking water and better sanitation. From 1990 to 2015, poverty dropped from 26% to less than 7%. Simultaneously, access to safe drinking water rose to 90%, and access to better sanitation reached 87% (Panos, Wolfand, & Hogue, 2021).

By 2030, Sri Lanka was considered to have met most of its Millennium Development Goals (MDGs), including those relating to the WSS subject to the good governance (Pathirana. et.al, 2020).

2.3.3.1. Recent Developments - Water Infrastructure Projects

With the COVID-19 pandemic, Sri Lanka's GDP was slashed by 3.6% in 2020, the most inadequate record of growth, as is the case in many pandemic countries. Swift government actions in the second quarter contributed in a successful way to the containment of the first COVID-19 wave. Still, these measures struck challenging industries such as water infrastructure projects, tourism, manufacturing and transport, while worldwide demand collapsed. Employment and lack of income have interrupted private spending and inhibited investment by uncertainty. The third quarter saw the economy rebound as the initial wave was controlled and containment measures loosened. During the fourth quarter, the trend continued, as the economy was primarily open despite the second wave of infections of COVID-19 (Pathirana. et.al, 2020).

The government has not taken proactive steps to reduce the pandemic. Although the fiscal area is restricted, health measures, cash transfers, and postponed tax payments have been allotted resources (around 0.7% of GDP). As public spending grew due to high state recurrent expenditure, income decreased, and the fiscal deficit widened in 2021. Due to the economic recession and high fiscal deficit in the COVID–19, and the

high level of recurrent state expenditure, it is predicted that public and publicly insured debt has risen to 109.7% of GDP. Debt financing is becoming more and more dependent on domestic sources, in line with the government's aim of reduction in external debt over the medium term while minimising all infrastructure projects, including urban water supply and sanitary, due to the exorbitant level of recurrent state expenditure (ADB, 2021).

2.4. Theoretical Approach

As per the theoretical approach, general equilibrium theory has dominated economics of infrastructure for the sustainable development. However, this area mainly relies on the structure of the infrastructural arena for both the deterministic and stochastic available equilibrium model balances. In short, competitive balance cannot be reached with incorrect institutions, inadequate communication and transportation networks or insufficient public information. Including infrastructure—material networks, general knowledge and institutions is a precondition for theory, whether capital growth, competitive market balances, or linkages between information flows and market processes. The lack of institutions, notably the absence of mechanisms for ownership rights, is a fundamental error in dominant theory. Initial distribution of wealth and income and establishing tools to ensure stability and uniqueness of price determination procedures are required for these organisations. To resolve these issues, we provide a general theory of the implications for short-term market and information flows and the build-up of private capital stocks of material and non-material facilities. This theory also makes it possible to fork into new economic systems through development of infrastructure. Standard stochastic shocks disrupt water services as explain by new Keynesian model with uncertainty, and that describe cycles of dynamics and recovery. Resilience should be reflected with various constraints within the terms of the capital portfolio of any city. The systematic spatial assessment gives the urban water resilience landscape and identifies the placement of every city along a steady gradient of insecure and unstable waters. Stochastic disturbance systems in different cities face steady conditions, and the driving system collapsed. Water-stressed and unsettled communities are more likely to become poor pits, towns with high capital risk become

rigid, and a schism between high and low-capacity services stiffens and collapses. Where insufficient public services are provided, community adaptation will strengthen the security and resilience of water (Dasgupta, & Heal, 1979).

2.5. The Capacity Utilization and Requirements

The Western Province is Sri Lanka's most developed province and focuses on its administrative and economic tasks. Simultaneously, forestry and agriculture exist, particularly in the eastern and agricultural sections of the area. Other urban centres rely less on Colombo. Consequently, the centre of Colombo has fewer links between these locations (Gunawardena, 2011).

However, the urban environment of Sri Lanka is characterised by small, coastal urban settlements. 1 km from the seashore, more than 47-48% per cent of the people, an area of just 10%. There are only six towns with over 200,000, 34 municipalities of the Small-to-medium size of 350,000 – 130,000, and 94 municipalities with a population of less than 40,000. Large urban centres in this area are dominated. Only 15% of the population lives in urban areas, according to the 2020 state census definition of urban areas, indicating extremely low urbanisation of Sri Lanka relative to its per capita income. But many regions not described in the 2020, the state census in urban terms, such as large population and construction density, rapidly show urban features.

In addition, the significant floating populations in the main cities in the country cannot be considered urban. An estimated 500,000-700,000 people come to Colombo every working day. The priorities for development are water supply and sanitation are one of the significant tasks to the central government, today (Kumar, Deka, & Kumari, 2020).

2.6. Capital Accumulation and Portfolio Approach

In the context of a mix of public services and community adaptation is one of the significance areas where the public services offered via the municipality and the general services were created and implemented to respond to deficient services (further

water purchased from the private market, water stored and treated from household levels, etc. (World Bank, 2015).

Four kinds of 'capital' are required for public services: natural 'water resources' including natural resources and water resources collected, infrastructure, 'physical capital' needed for the storage, handling and supply of water system capital and financial assets for the operational and maintenance of water, management capital and effective operations and services of political capital. "Social capital." is a community adaptation that adds to or substitutes for insufficient public services. These capitals are calculated on the basis of outcomes instead of capabilities, which means they evaluate results including losses resulting from inefficiency. Three dimensions of the capital availability, robustness and risks are other areas of the portfolio approach. However, the service can be consumed or accumulated to grow the capital stock in this scenario (Nemec,2014). Capital accumulation is a reversible process where the capital can be converted back into a consumption service at no cost. Furthermore, there is no physical depreciation of capital, or, to put it another way, the service process is described in net terms that construct a minimally differentiated production model which allows us to separate fundamental interactions that are muddled in a single production sector model. As a result, that believe, there are two types of production sectors: good consumer production and good capital production, both of which rely on labour, capital, and non-renewable resources such as deep aquifers (water). Furthermore, capital is an intangible asset that cannot be consumed and depreciates over time. Because each good's production process is described in net terms, capital depreciation is made clear when applied to manufacture consumer goods and services as per the Dasgupta and Heal (D. H model) (Dixit, Hammond and Hoel, 1979).

2.7. The Challenges and Regulatory Matters

The Government of Sri Lanka has commenced projects on Urban Renewal, connectivity and Green City in the CMR and urban centres in other than the Western Province. Still, issues persist in planning, finance, urban management and land and housing development. The limits on Urban Local Authorities (ULAs)' roles, capacity,

and resources delay urban planning and cause inefficiencies in the provision of services. The achievement of the Urban Vision depends on ULAs being repositioned as competent and responsible service providers. Nowadays, ULAs have restricted functions for planning and services and insufficient financial and required resources. The Urban Development Authority (UDA), provincial councils and ULAs have shattered their planning tasks, and sectoral plans are not integrated into the urban projects. And urban delivery systems are sandwiched between central government agencies and two parallel government systems and there by overlapping mandates and the public resources being wasted unnecessarily.

The urban expansion of low-density drivers and ribbon development are defining features of Sri Lanka's urban development. They are economical for service. Urban development results from regulatory and institutional limitations on land markets and insufficient motivations to promote effective, efficient, sustainable use of land and the development of real estate. Private property developers are interested in mobilising development of land in large metropolitan centres, which limits big-scale growth. Sustainable and efficient land use, supported by high-density urban transport , could deliver considerable benefits in economy through reducing vulnerability to natural and manmade disasters, diminishing infrastructure costs, reducing negative environmental impacts, enhancing private land and housing investments, and increasing municipal own source production.

2.8. Restriction of government authorities

Lack of coordination between government offices, particularly between water offices and other area offices including the Road Development Authority presents critical difficulties in completing the project on time. This frequently requires extensive time and assets. The absence of satisfactory quality is mostly an after effect of the acquisition systems needed by individual advancement accomplices, which are not lined up with worldwide accepted procedures. (Asian Development Bank, 2017)

Due to a lack of coordination and a variety of other factors, the procedures for obtaining clearance certificates from government agencies for trenching excavation are difficult and time-consuming. (Nguyen , Soo-YongKim, Stephen , & Van , 2009)

2.9. Traditional water management system of Sri Lanka

Sri Lanka's historic water management system has a long history. Rainfall in Sri Lanka is caused by monsoons, convectional storms, and depressions. The water that is brought by monsoon rainfall is mostly collected by ancient people. Sri Lanka's water management system isn't just for show; such art represents rituals and beliefs about water resources, and worshipful thinking about water resources is strongly linked to the agricultural life pattern of Sri Lanka's ancient civilians. Embuldeni (Embuldeni, 2018)

In dry zone of Sri Lanka, there are still around 10,000 operation tanks. from the old water-harvesting system are still operational. Tank-based irrigation in the arid zone has helped immensely in landscape management and social organization for about two millennia, due to the numerous uses of irrigation water for agriculture and home consumption. (Nuwan Abeywardana, 2018)

2.10. Research Overview

Sri Lanka's urban centres face connectivity and municipal facility constraints, and they must be prepared to address resilience of water infrastructure projects in urban areas other than the natural infrastructure risks and effects. Connectivity is important to establish a system of connected cities and enhance the "time-measured distance" to improve market access. The municipal solid waste collection does not go hand in hand with urban expansion and sluggish drainage investment and exposure to the floods of urban centres.

Urban water supply systems are in threat, requiring improvements in water quality, particularly in urban areas. The commercial cities, especially the tourist attractions, need an integrated management approach, encompassing sewage treatment,

wastewater treatment, drainage, and solid waste management. Urban mobility is a crucial factor to the competitiveness of cities.

It is very important to incorporate adaptation strategies in urban risk management plans as Sri Lanka is vulnerable to natural catastrophes due to global climate change. Unplanned human settlements result from fragmented housing policies, regulatory and road bottlenecks that restrict land development and inadequate financing for housing. A sustainable long-term approach does not define the participation of the government and sector agencies in the housing market. Consequently, agencies carry out several duties that often overlap.

The UDA is chiefly responsible for the preparation of urban development plans. ULAs have limited planning functions, and, due to personnel limitations, their capacity for planning is not up to the mark. Supervision is carried by the UDA on land use policy and regulations and is also involved in land development as the National Planning Agency, regulator, and land developer. However, despite its potential to overcome this situation, the UDA is sluggish in complying with its legal requirements to produce urban and municipal development plans. For instance, the current plan for Colombo, the Structural Plan for the Metropolitan Regions, was developed in 1998 and modified in 2004 and subsequently in 2020. Strategic cities like Colombo do not have an urban development plan established by statute.

Furthermore, in non-UDA regions claimed to be urban but nominally rural, there are no limits on land use. Further fragmented planning responsibilities were exacerbated by the inadequate cooperation between infrastructure development authorities at a national level ULAs and development agencies for resilience of water infrastructure projects in the case study area.

CHAPTER THREE

METHODOLOGY

3.1. Introduction

Considering research methods, all processes and procedures used to perform the investigation to answer the formulated questions of the case study area assess the resilience of water infrastructure projects in urban areas. Therefore, exam designs relate to the outlines of investigation to achieve the specific goals. The collecting primary and secondary data and analysing it to understand the case study area of assessing resilience of water infrastructure projects in urban areas which based on review of literature as per the positivism.

3.2. Research Approach

According to the case study, it is principally based on the deductive approach that involves a systemic process for answering the question, forming a hypothesis, gathering, analysing the data, and transferring the reliable conclusion to achieve the goals of the case study.

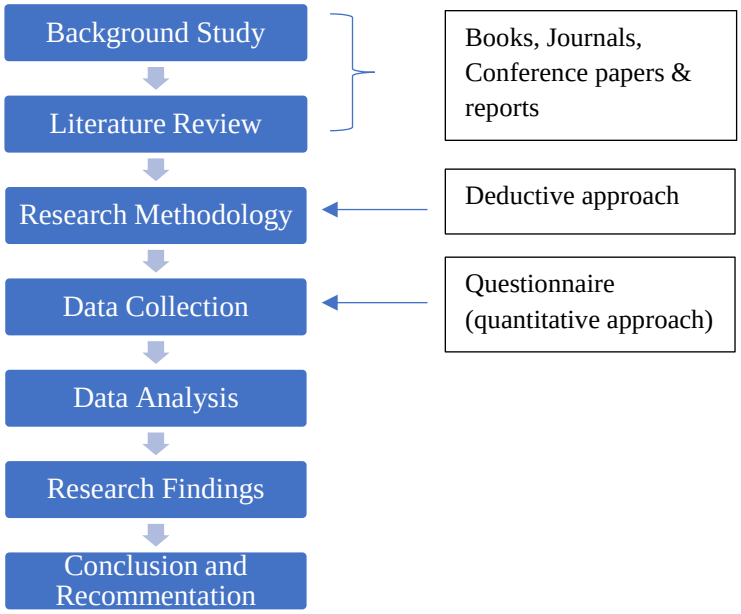

Figure 2: Research path diagram

However, a descriptive analysis mainly involves surveys and specific informative questions from various denominations considering the approach. The principal objective of the descriptive examination is to describe the present situation of the case study, which will help answer the formulated questions.

The factors affecting the implementation of assessing the resilience of water infrastructure projects in urban areas, the economic environment have any significance on the implementation of the resilience of water infrastructure projects in urban areas (Noor, 2008).

3.3. Research Strategy

The research strategy defines a research issue that assesses the resilience of water infrastructure projects in Colombo Metropolitan Region (CMR) with the most specific measures. Therefore, it is more important to formulate a query than its results, in which the strategy defines which technique to gather and analyse the data is used.

However, according to the quantitative approach, the process evaluates the questionnaire other than the secondary data (Kothari, 2004).

3.4. Conceptual Framework

According to the literature survey following variables were identified which are capacity utilization and requirements, policies, strategy, capital accumulation and resilience of water infrastructure in urban areas.

Independent Variables

Capacity utilization and requirements - The Western Province is Sri Lanka's most developed province, with administrative and economic responsibilities. Forestry and agriculture coexist throughout the area, particularly in the eastern and agricultural portions. 2011 (Gunawardena, Asoka, 2011).

Policies - Sri Lanka was judged to have met the majority of its Millennium Development Goals (MDGs) by 2030, including those related to the WSS if strong governance was maintained (Pathirana. et.al, 2020).

Strategy - Cities are engines of socioeconomic innovation, but they must also contend with the heightened risks of current and future failures of critical services such as water supply. The resilience of urban water supply security as measured by services given to inhabitants is investigated in this paper.

Capital accumulation - This is a reversible process in which the capital is turned into a free consumer service. Capital is a non-consumable intangible asset that depreciates over time. Because each good's manufacturing process is defined in net terms, capital depreciation is obvious when the Dasgupta and Heal (D. H) model is used to manufacture consumer goods and services (Dixit, Hammond and Hoel, 1979).

Dependent Variables

The concept of urban water resilience is congruent with the concept of capital accumulation in urban water resilience (Keath, Brown, 2009).

Table 2: Conceptual Framework

Independent Variables	Dependent Variable
Capacity Utilization and Requirements	Resilience of Water Infrastructure in Sri Lankan Urban Areas
Policies	
Strategy	
Capital Accumulation	

Source-Literature Review

3.5. Hypothesis

In deductive studies, the researcher formulates a set of hypotheses at the start of the investigation. The hypotheses are then put to the test using proper research procedures to see if they are true or not.

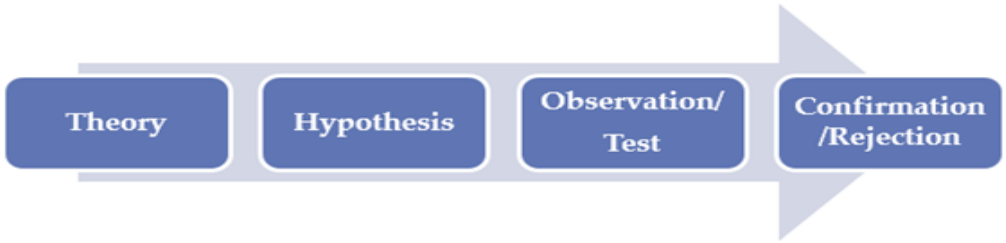

Figure 3: Deductive studies diagram

As mentioned in the conceptual framework in order to forming a hypothesis for deductive approach method null hypothesis (H_0) and alternative hypothesis (H_a) were developed.

H_a	There is a strong relationship between capacity utilization and requirements, policies, strategy, capital accumulation and resilience of water infrastructure in Sri Lankan urban areas.
H_0	There is no strong relationship between capacity utilization and requirements, policies, strategy, capital accumulation and resilience of water infrastructure in Sri Lankan urban areas.

Source- Conceptual Framework

3.6. Sampling Method

The nature of the research project determines the sample method used. It could encompass theoretical as well as practical considerations.
In a sample survey, people's opinions and attitudes are assessed using a standardized questionnaire. Structured surveys can be used to count a specific population or subset of people. highlighted how a smaller group of people could make assumptions about a larger number of people. This method of selection also helps to save time and mon ey by avoiding the need to investigate the entire target group. 2014 (Birks, Malhotra, & Wills)

According to the sampling method, it primarily relies on convenience sampling, a non-probability process in which people are chosen based on their approachability.

3.6.1 The Population and Sample Size

Based on the inferential method of inquiry, it is primarily from the area where it must infer features to conduct the specific survey, International Water Management Institute (IWMI) (www.iwmi.cgiar.org) and National Water Supply and Drainage Board (www.waterboard.lk). The validity of the district of Colombo was chosen.

Table 3: Population -Colombo Metropolitan Region-CMR

Year	Population	Growth Rate
2022	625,637	1.07%
2021	**619,001**	1.06%

Source-Colombo Municipal Council, (2021).

Table 4: Demand for Water-Colombo Metropolitan Region-CMR

Year	Population	Liters (per person per capita per day)
2022	625,637	74726083.28
2021	**619,001**	79209648.28

Source-Colombo Municipal Council, (2021).

The sample of this research study has been selected as Engineering provisional those who are involved in the water supply projects in the western province of Sri Lanka.

Table 5: Data Collection Sample

Category	No of sample
Deputy General Managers of Provinces -NWSDB	11
Deputy General Managers and Project Directors – NWSDB	6
Assistant General Managers – NWSDB	26
Country Manager-IWMI	1
Director General-IWMI	1
Senior Fellow-IWMI	3
Researchers –IWMI	8
Project Managers-IWMI	5
Total	61

Source- NWSDB & IWMI, (2021).

Table 6: Standard Deviation of the sample

Standard Deviation σ:	7.64
Count, N:	8
Sum, Σx:	61
Mean, μ:	7.62
Variance, σ^2:	58.48

Source- SPSS, (2021).

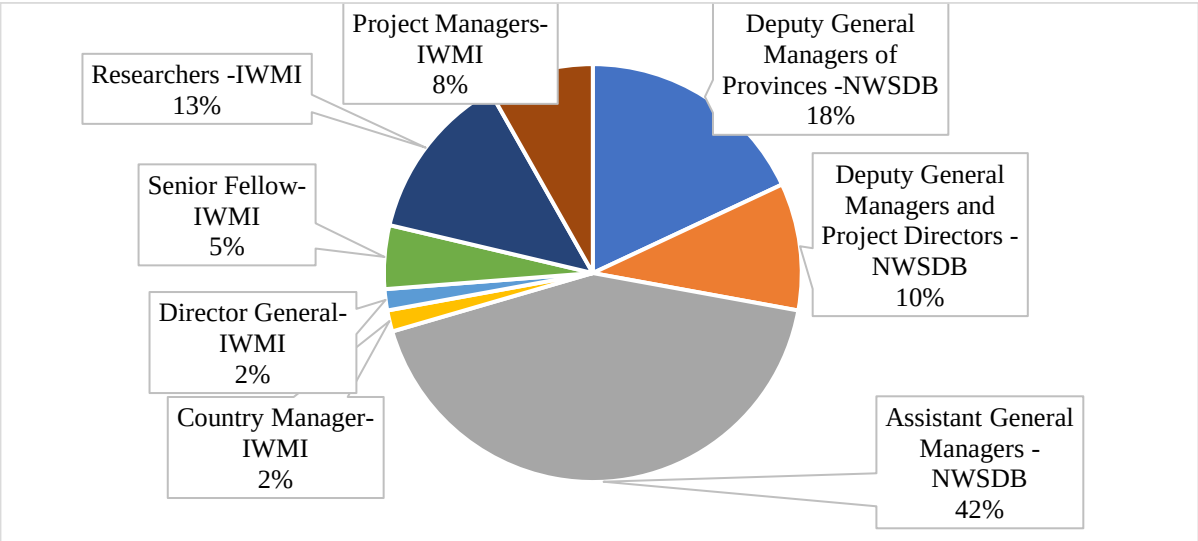

Figure 4: The Ratio of the sample, (2021)

Table 7: Sample Size

Confidence Level:	95%
Margin of Error:	5
Population Proportion:	86.88%
Population Size:	61
Sample size:	**53**

Source-IBM-SPSS

3.7. Data Collection Procedures and Analysis

Considering the research methodology, there are various data collection methods, and the case study carefully selects both the primary and secondary data for multiple factors, including availability in Sri Lanka, time, cost, while it primarily emphasizes survey questionnaires following the research issue.

Primary data collection

Books, journals, conference papers, reports, and websites were used to gather primary material for the study, which was used to identify risk features in water supply projects around the world and in Sri Lanka. In addition, primary data was collected to gather knowledge about existing risk analysis approaches. In order to gather trustworthy data from the participants, secondary data was used into the construction of the questionnaire survey guideline.

Secondary data collection

In terms of secondary data, it was gathered through a questionnaire survey with the help of industry specialists. The questionnaire study revealed the primary risks that water delivery projects face, as well as offered solutions to mitigate those risks. Additionally, the questionnaire survey was used to validate the secondary data gathered in the literature review and introduction chapter.

However, in the case study area, descriptive statistics, reliability tests, correlations using ANOVA and non-probability test which based Chi-squared tests will aid in accepting or rejecting different hypotheses and log leaner analysis for additional to fulfil the examination's objectives as per the Likert scale -secondary data approaches (Goddard, & Melville, 2004).

$$\hat{y} = b_0 + b_{1x}$$

3.8. Ethical Considerations

The seven principles of public life outlined by the Nolan Committee in 1995 are also an eye opener for research ethics. These attributes include selflessness, uprightness, impartiality, responsibility, openness, honesty, and leadership. 2011 (Nilamadhab)

Other key research values include caution, intellectual property protection, confidentiality, responsible publication, responsible mentorship, respect for colleagues, social responsibility, non-discrimination, competency, legitimacy, animal care, and human subject protections. (Shamoo & Resnik, 2009)

As a result, the ethical standards of professional organisations in the construction sector will be evaluated in the main data collecting process when gathering relevant data. This research has benefited the community far more than it has harmed it. Throughout the study process, honesty, integrity, corporation, accountability, and data security are all assured.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1. Introduction

The results and discussion contain a detailed description of the study's key findings and discusses the results in more depth while the discussion section goes into detail about the findings and explains the results in both socio-economic data and the Likert scale as per the case study of assessing resilience of water infrastructure projects in urban areas.

4.2. Socio-Economic Data

Accordingly, there were 53 participants consisting of 42 males and 11 females participated in the respective survey. Out of them, 38 were married and 13 were unmarried. 8 of them were between the ages of 24 and 29, 21 of them between 30 and 35 years and 15 of them between 36 and 41 years of age. Their educational background varied as 12 of them were graduates, 39 were postgraduates and 2 had other qualifications. Amongst them, 9 had 1 to 5 years of experience, 8 had 6 to 10 years, 20 had 11 to 15 years, 17 had 16 to 20 years and 9 had more than 21 years of experience.

Out of the 53 participants, 47 had some form of experience or recognised qualifications in water infrastructure projects. Amongst the 47 participants, 4 had 1 to 5 years' experience 11 had 6 to 10 years, 20 had 11 to 15 years 9 had 16 to 20 years and 3 gad more than 21 years of experience.

Respective pie charts are attached at Appendix 01

4.3. Reliability

Reliability analysis enables the examination of the measuring scale properties and the composition of the scales. The Reliability Analysis method assesses a variety of commonly used scale reliability measurements to provide information on connections between specific items in the scale. Intra-class coefficients can be used to enumerate reliability estimates for inter-ratters. Cronbach's alpha is an internal consistency

metric, the most prevalent being "reliability." It is often used when many Likert questions are in a scale survey/questionnaire (Likert, 1932) and want to find out whether the scale is trustworthy. Moreover, that also offer guidance on the usage of Cohen's kappa if they are concerned about inter-rotator reliability (Cronbach, 1951). (table 18 & table 19 at appendix 02)

The Cronbach's alpha is a measure of internal consistency, the way tightly linked a collection of items is. It is a measure of reliability in scale. An alpha "high" value does not indicate a one-unidimensional measure. If further analysis is carried out and evaluating internal consistency, it will demonstrate that the scale at issue is unidimensional. One technique to validate dimensionality is the exploratory factor analysis. Cronbach's alpha is not a statistical test but a reliability coefficient or consistency test in order to recognize the correlation between independent variables. (Cronbach, 1951).

As per table 20 in appendix 02, it implies mean and the Std. Deviation of the ordinal data the average mean is 80.08 and the average Std. Deviation is 16.952 among 53 responded in the survey.

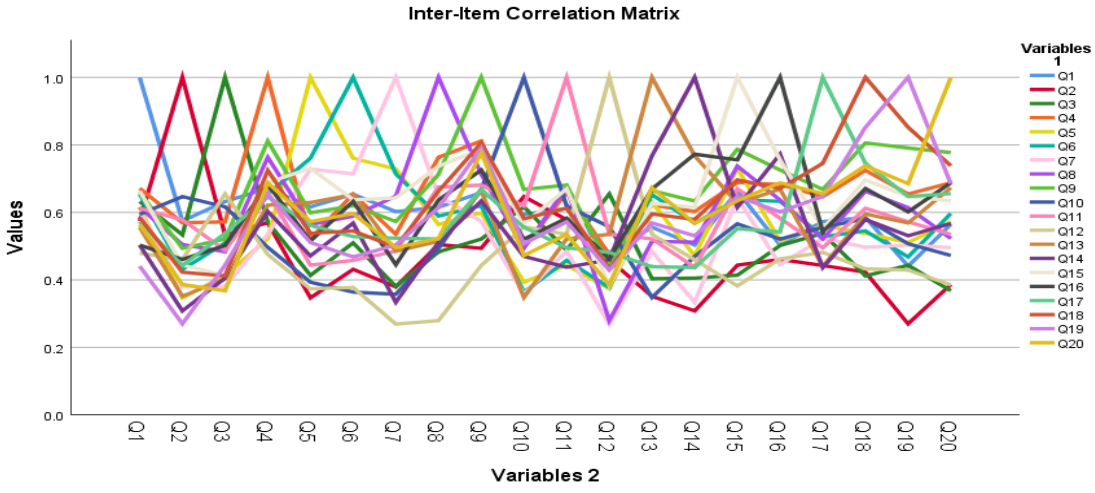

Figure 5: Inter-Item Correlations Analyse, (SPSS, 2021)

As per the above graph, inter-item correlations analyse the extent to which results on one item are related to each item on a scale. However, most of the items follow similar

paths, except for a few while showing general opinion. Moreover, the following chart will give the relationship in detail in order to understand the level of significance among the answers given by each.

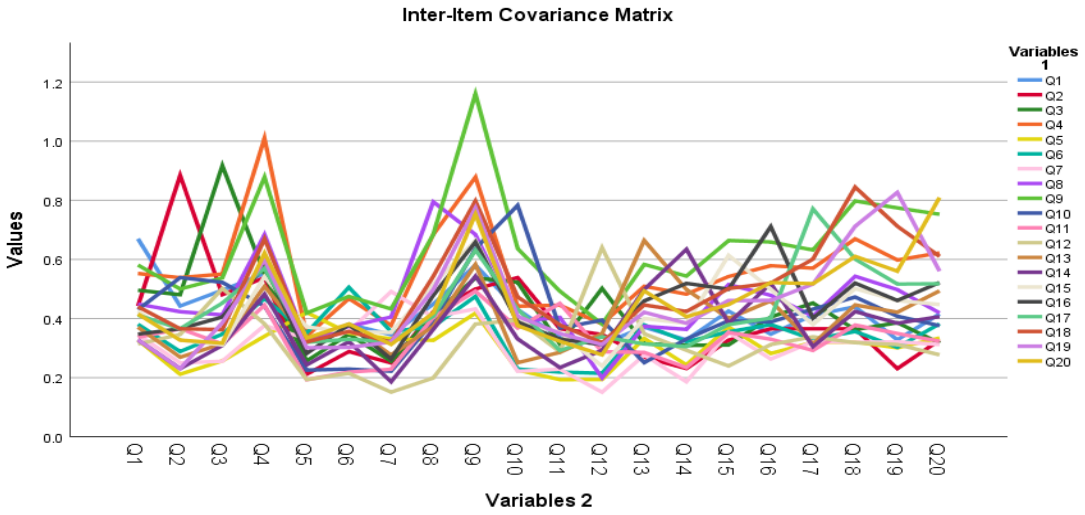

Figure 6: Inter-Item covariance matrix, (SPSS, 2021)

The above figure shows the inter-item-covariance matrix, which is the relationship between items and the level of relationship as per the homogeneity test.

Table 08: Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance	N of Items
Item Means	4.005	3.736	4.340	.604	1.162	.029	20
Item Variances	.730	.421	1.160	.739	2.755	.036	20
Inter-Item Covariances	.404	.151	.878	.728	5.820	.016	20

Inter-Item Correlations	.558	.269	.852	.583	3.167	.014	20

Source-SPSS, (2021).

The above table provides mean, minimum, maximum, range, maximum/minimum and the variance among inter-item covariances and the inter-item correlations in various scales. Nevertheless, that will help to understand the behaviour of the data through the measurements (Never, Bent, & Hull, 1975).

As per the values of Cronbach's alpha, it is primarily used for determining reliability coefficients for specific surveys, as per the Likert-scale, with more excellent rates indicating improved reliability of the data, where most of the coefficients are closer to 1 (table 21 in appendix 02), and therefore, the more excellent reliability of the data (Levesque, 2007).

Table 098: Scale Statistics

Mean	Variance	Std. Deviation	N of Items
80.09	168.087	12.965	20

Source-SPSS, (2021).

As per the scale statistics, it shows mean, variance, Std. deviation and number of items in order to understand the behaviour of variables, such as capacity utilization and requirements, policies, strategy, capital accumulation that how impact on resilience of water infrastructure projects in Colombo Metropolitan Region (CMR).

Table 90: ANOVA

	Sum of Squares	df	Mean Square	F	Sig
Between People	437.026	52	8.404		

Within People	Between Items	29.618	19	1.559	4.778	.000
	Residual	322.332	988	.326		
	Total	351.950	1007	.350		
Total		788.976	1059	.745		

Grand Mean = 4.00

Source-SPSS, (2021).

An analysis of variance (ANOVA) is a statistical technique that is used to investigate overall variability within a data set of the case study of assessing the resilience of water infrastructure projects in urban areas -Colombo Metropolitan Region (CMR).

However, it breaks down the total observed variability into all components: systematic variance and random variance to identify the relationship in order to understand the significance level. Even though the systematic factors influence the data set, the random factors do not. An ANOVA test is used to evaluate how independent variables influence the dependent variable in regression research. The capacity utilization and requirements, policies, strategy, and capital accumulation to the resilience of water infrastructure projects in urban areas -Colombo Metropolitan Region (CMR). However, since the p-value of 0.000 can be described as less than the significance level of 0.05, (typically $p < 0.05$), can reject the null hypothesis, no strong relationship between capacity utilization and requirements, policies, strategy, capital accumulation and resilience of water infrastructure in Sri Lankan urban areas. Hence, it except the alternative hypothesis where there is a strong correlation between capacity utilization and needs, policies, strategy, capital accumulation and resilience of water infrastructure in the urban areas of Sri Lanka. Moreover, it implies the impact and the correlation of the independent variables, capacity utilization and requirements, policies, strategy, capital accumulation to resilience of water infrastructure in Sri Lankan urban areas (Noor, 2008).

4.4. Nonparametric Test

The nonparametric test assumes the distribution based on the normal distribution and makes assumptions about a population's parameters to test the null hypothesis of the case study area through the One-Sample Chi-Square Test (Hinton, McMurray, & Brownlow, 2014).

Refer table 22 for hypothesis test summary attached in appendix 02

4.5. Summary

According to above analysis, it rejected the null hypothesis of the case study where there is no strong relationship between capacity utilization and requirements, policies, strategy, capital accumulation and resilience of water infrastructure in Sri Lankan urban areas. Therefore, again it accepts the alternative hypothesis, where there is a strong relationship between capacity utilization and requirements, policies, strategy, capital accumulation and resilience of water infrastructure in Sri Lankan urban areas.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1. Introduction

In the Colombo Metropolitan Region (CMR), sustained productivity growth is crucial for Sri Lanka to be a high middle-income economic country in 2022. During the period, the improved productivity of the CMR, or Western Province which has 34 % of the population in the region but generates 49 % of GDP, was one of the most valuable economic mechanisms in Sri Lanka. The CMR, on the other hand, must stay similar to other Asian metropolises. Prioritize strengthening the most vibrant service industries, such as IT and services related to finance, and changing from low to high value-added manufacturing opportunities. Collaboration with national and international private sector stakeholders is essential for strengthening the CMR's infrastructure (Jayasinghe, Raghavan, & Yonezawa, 2021), citizens' quality of life, and human capital. Low-density urban spread and industry development and mounting environmental issues and constraints on city economic drivers such as clean water are some of the features of urban development in Sri Lanka that are unreasonable to service. The result of legal and structural limits on land pricing and a lack of resources for insufficient and productive land use and property development is urban sprawl. Private developers are attempting to mobilize land for development in city centres while restricting development in large areas. However, in the current context of the country, efficient land use – supported by high-density urban transit – will yield significant economic gains by reducing natural disaster vulnerabilities, lowering infrastructure costs, mitigating adverse environmental effects, increasing private investment in land and housing, and boosting local own-source generation

Access and municipal infrastructure are limited in Sri Lanka's urban areas, and residents must be trained to deal with natural hazard risks and repercussions. In order to improve market access, the development of a well-connected metropolitan grid and the improvement of "time-measured distance" is critical. Municipal solid waste collection is insufficient for urban development, and drainage spending has been reduced, leaving urban areas prone to flooding. Due to a weaker town plan and internal

migration in the country, there are risks to urban water supply schemes and changes in water quality, particularly in the Colombo Metropolitan Region (CMR).

In the Sri Lankan context, the Colombo Metropolitan Region (CMR), particularly the commercial sector, requires an integrated environmental protection strategy, including sewage treatment, wastewater management, drainage and waste management, and water infrastructure resilience few areas.

On the other hand, the urban water infrastructure is a critical component of a community's competitiveness. Still, much quality has to be done to improve water infrastructure in key cities within the Colombo Metropolitan Region (CMR) and provide a more reliable and efficient supply to satisfy the country's development goals. Sri Lanka's urban areas have become more vulnerable to natural disasters due to global climate change, and adaptation strategies must be integrated into urban risk management plans. Changes in water quality are required, particularly in the Colombo Metropolitan Region, because urban water sources are under threat (CMR). The environmental protection of big cities, particularly tourism and commercial attractions, necessitates an integrated approach that includes wastewater treatment, drainage, and solid waste management. Another key contributor to city competitiveness is urban transport, which is similar to today's water infrastructure (Sivakumar, 2021).

However, more areas are to be done to improve water infrastructure in large cities and make them healthier. Urban areas in Sri Lanka are becoming increasingly vulnerable to natural disasters due to global climate change, and adaptation strategies must be integrated into urban risk management plans. The connectivity and quality distance between CMR and the major cities outside of the Western Province must be minimized for the ambition to be socially viable. Sri Lanka must protect its well-served urban infrastructure worldwide, acknowledging that the CMR will continue to be a powerful economic migration magnet for years to come. Limited connectivity and the disparities in the qualities between Colombo and other urban centres outside the Western Province could relieve the demand for migration to Colombo for better quality of life. In the 1990s, differences in access to water and energy (Rathnayake, Jones, & Soto-Berelov, 2020), particularly among the less educated, influenced migration

decisions driven by employment opportunities and higher wages. Evidence suggests, however, that as professional work progresses to pursue improved economic opportunities with a significant economic impact on the economy through expanded infrastructure, including water, the draw of skilled work to Colombo is increasing rather than decreasing, as professional work progresses to pursue improved economic opportunities with a significant economic impact on the economy through expanded infrastructure including water

5.2. Conclusion

Many issues surround urban water supplies, including possible risks and the need to deliver more sustainable and resilient services. The transition away from entirely centralized water supplies is a crucial answer to the difficulties and pressures facing cities today. Several underground water pipelines were built in the Colombo Metropolitan Region about fifty years ago (CMR). These pipes have gone beyond their useful life and require major repairs. The modernized water and wastewater treatment systems will require upgrades to meet contemporary environmental standards, even if the old structures are in working order. It is a pity to note that the cost of those adjustments outweighed the service profits. Moreover, it is expected that many individuals in the case study area will lack access and availability to safe drinking water and improved sanitation. Many of them live in the Colombo Metropolitan Region (CMR), and the Sustainable Development Agenda 2030 focusses on bridging the gap between access to better water and sanitation; particularly, the goal is "to ensure the availability of sustainable water and sanitation management for all." in Sustainable Development Goals (SDG).

The current urban water management situation in the Colombo Metropolitan Region (CMR) is an example of how decisions can be made in so-called developing nations without considering potential health repercussions and the consequences of poor government follow-up. Faults contaminated the Colombo Metropolitan Region (CMR) in the city's water distribution infrastructure after two decades of transition. However, this has resulted in significant public health dangers. However, this causes a slew of

serious health problems; thousands of people have dangerously high lead levels in their blood. It appeared to be a national issue unless Flint people supported individuals who conducted water quality assessments and collected public health data from local clinics; local government, central officials, and political figures appeared to be appropriately engaged. Inorganic and organic chemical cancer products (for example, compounds containing arsenic, chloride, copper, leather, and mercury) and hazardous components in the supply of natural aquatic goods (cryptosporidium and giardia lamblia are examples of contaminants such as radium and uranium). Pumping and distribution piping systems are included in water delivery services. The performance of the other components determines the hydraulic efficiency of each component in the distribution network. Designers are concerned about network flows and stressors, which are essential areas to be answered nowadays.

The objectives of the research aim to assess the resilience of water infrastructure projects in urban areas, to go through the required level of policies and facts for the resilience of water infrastructure projects in urban areas and to scrutinize the impact and externalities on the resilience of water infrastructure projects in urban areas - Colombo Metropolitan Region (CMR). Based on the research questions, the elements affecting the execution of assessing resilience of water infrastructure projects in urban areas, does the economic environment have any importance on the execution of resilience of water infrastructure projects in urban areas and any disparity in the level of the implementation of resilience of water infrastructure projects in urban areas - Colombo Metropolitan Region (CMR).

However, based on the random factors do not influence the data set, but the systematic factors do. In regression research, an ANOVA test is used to evaluate how independent variables influence the dependent variable. The capacity utilization and requirements, policies, strategy, and capital accumulation to the resilience of water infrastructure projects in urban areas -Colombo Metropolitan Region (CMR). Additionally, it implies the impact and the correlation of the independent variables, capacity utilization and requirements, policies, strategy, capital accumulation to resilience of water infrastructure in Sri Lankan urban areas.

Nevertheless, it rejected the null hypothesis of the case study where there is no strong relationship between capacity utilization and requirements, policies, strategy, capital accumulation and resilience of water infrastructure in Sri Lankan urban areas. Subsequently, once again it accepts the alternative hypothesis, where there is a strong relationship between capacity utilization and requirements, policies, strategy, capital accumulation and resilience of water infrastructure in Sri Lankan urban areas as per the study findings.

5.3. Recommendations

Sri Lanka's ambitious goals for economic growth and membership in the community of upper-middle-income countries necessitate establishing high standards in the water supply and sanitation sector. To help the country achieve its growth goals, the water supply and sanitation (WSS) sector should look beyond the Sustainable Development Goals and move toward physically, fiscally, and environmentally sustainable service delivery that meets rising customer expectations and the needs of a developing economy. Therefore, it is required to enhance the capacity utilization and requirements, policies, strategy, capital accumulation and resilience of water infrastructure in Sri Lankan urban areas as per the survey results.

5.4. Suggestion for Further Research

In order to battle the increasing water problems faced by all parts of the country, Sri Lanka needs to make commitment for more comprehensive research on water resilience. A new mechanism is needed to coordinate water research currently fragmented among several agencies like CMC, RDA, etc.

Regular funding should go annually to water research projects, specially to the areas of water demand and use.

The scope of the future projects should cover both the rural and urban areas to capture the comprehensive information of the entire country.

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APPENDIXES

Appendix 01

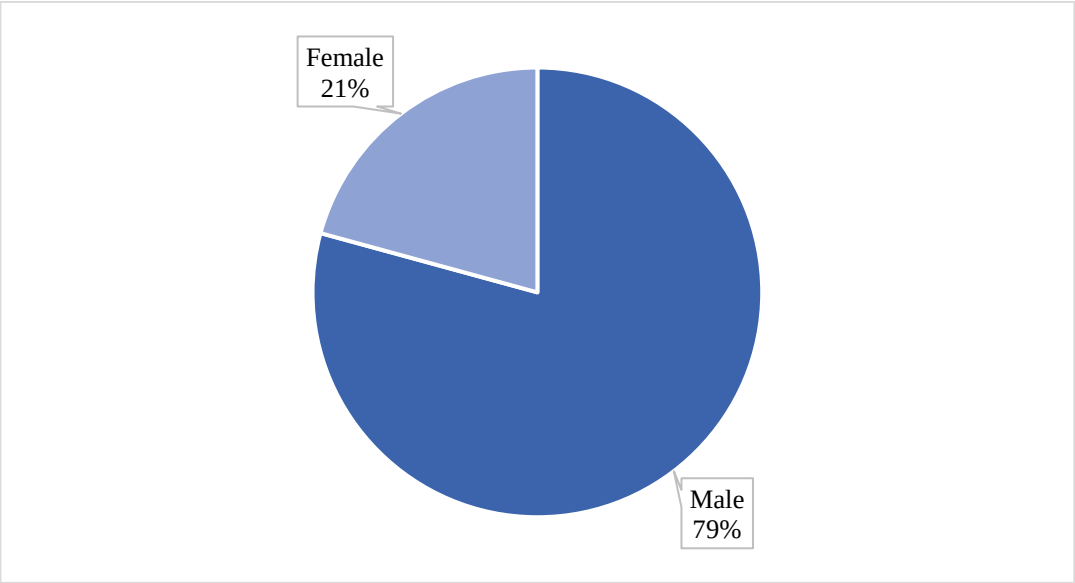

Figure 7: The Ratio- Gender of The Participants (Survey, 2021)

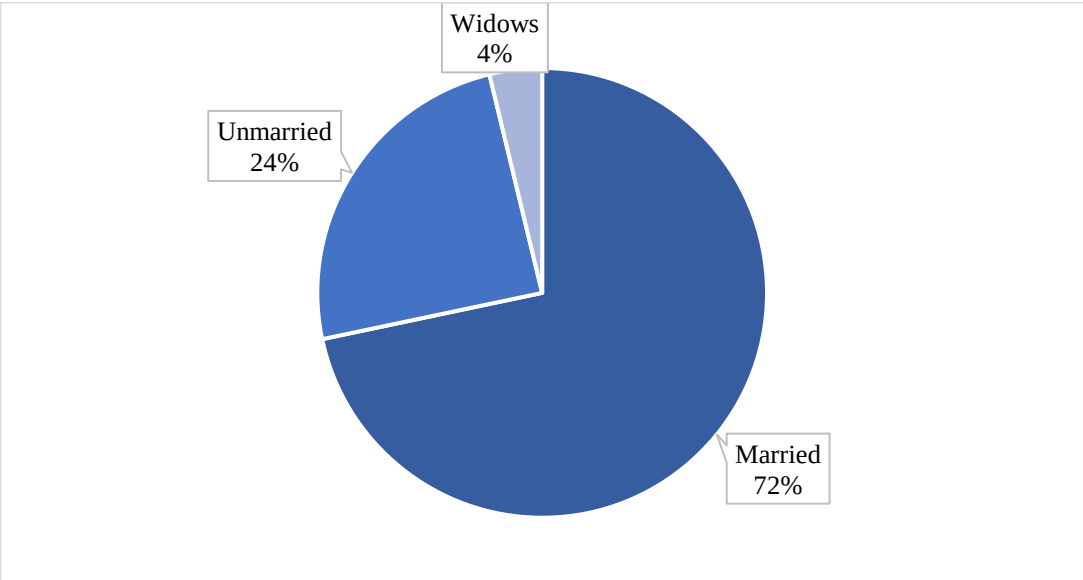

Figure 8: The Ratio- Marital Status (Survey, 2021)

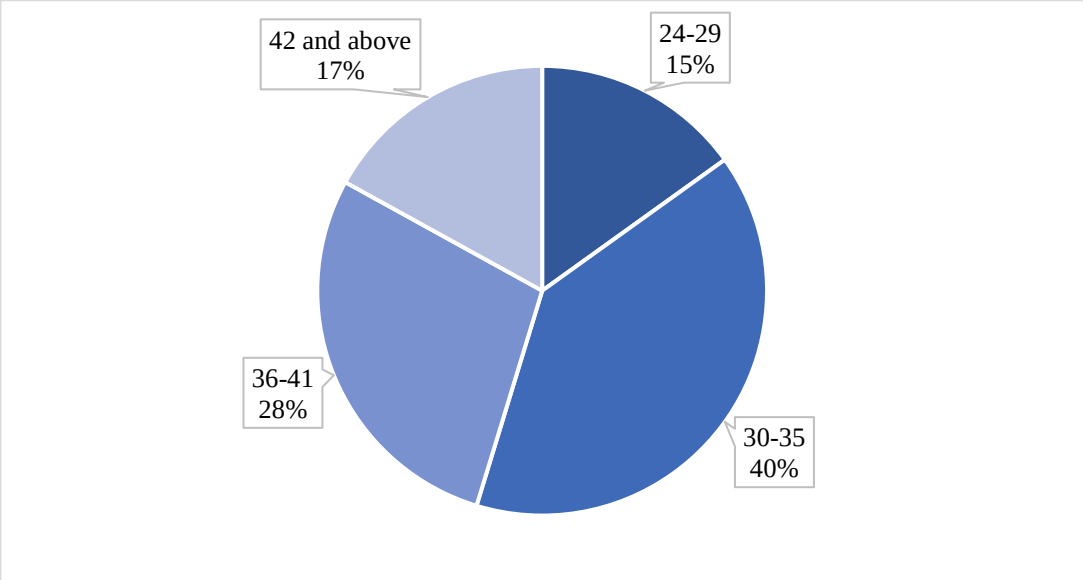

Figure 9: The Ratio- Participant Age (Years) (Survey, 2021)

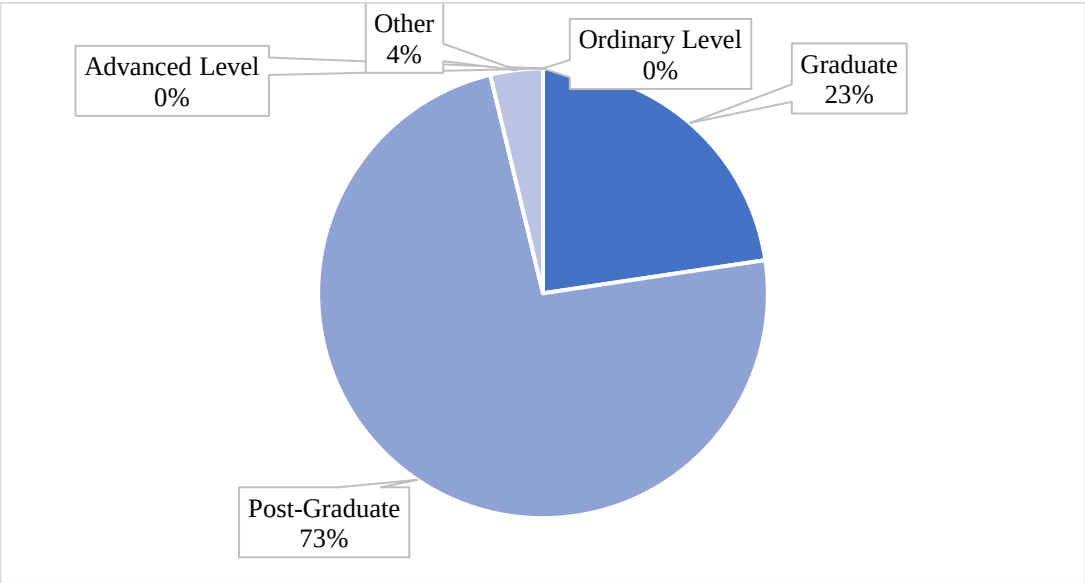

Figure 10: The Ratio- The Education Background of The Participants (Survey, 2021)

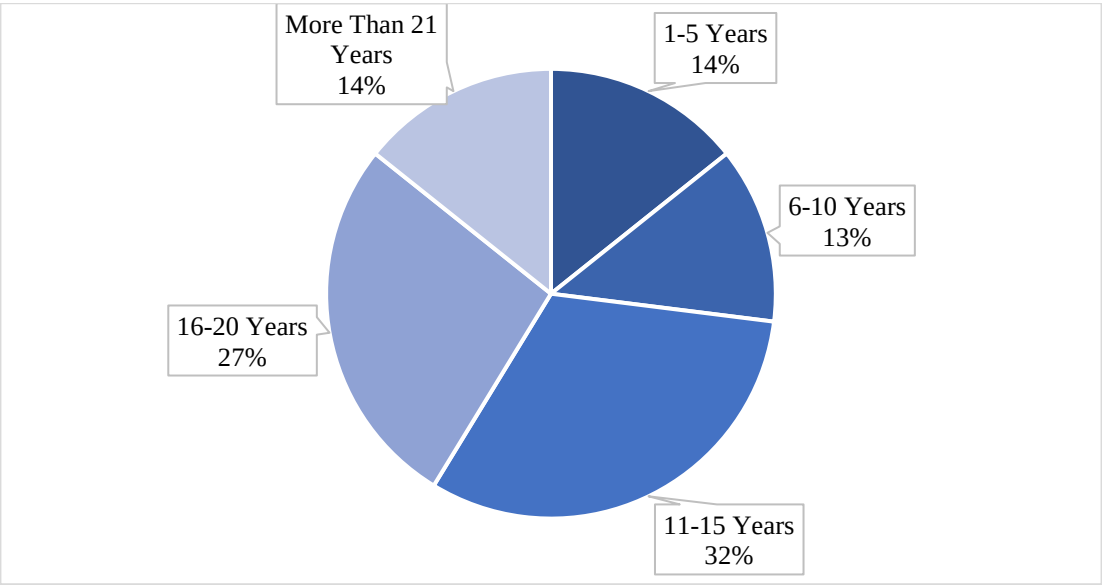

Figure 11: The Ratio- The Experience (Survey, 2021)

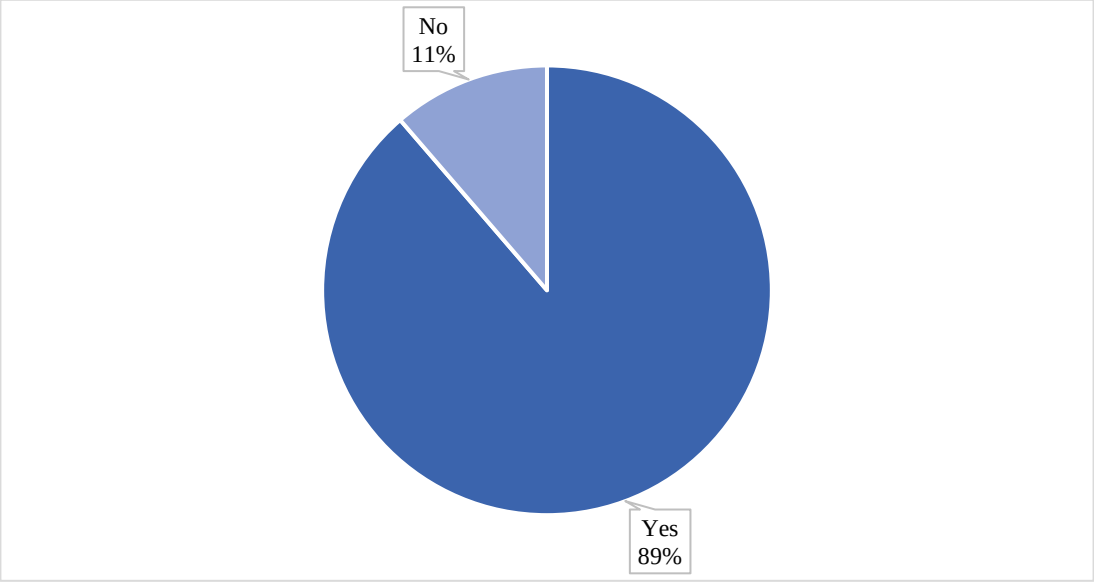

Figure 12: The Ratio- Any experience or recognized qualification (Survey, 2021)

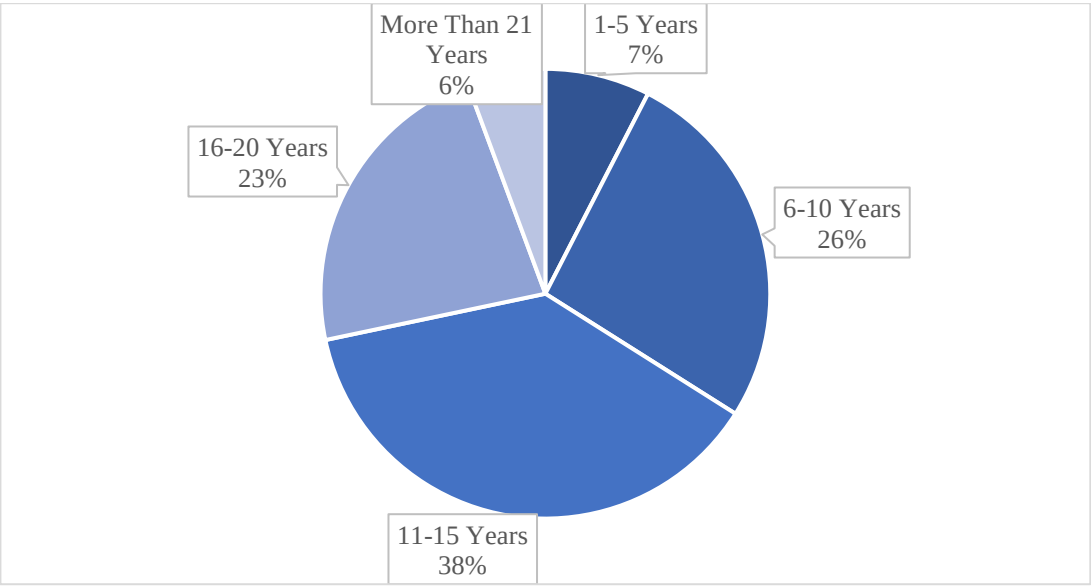

Figure 13: The Ratio- If yes, how long (Survey, 2021)

Appendix 02

Table 10: Case Processing Summary

		N	%
Cases	Valid	53	100.0
	Excluded[a]	0	.0
	Total	53	100.0

a. Listwise deletion based on all variables in the procedure.

Source-SPSS, (2021).

Table 112: Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.961	.962	20

Source-SPSS, (2021).

Table 1312: Item Statistics

	Mean	Std. Deviation	N
Q1	3.94	.818	53
Q2	4.00	.941	53
Q3	3.92	.958	53
Q4	3.91	1.005	53
Q5	4.34	.649	53

Q6	4.26	.711	53
Q7	4.32	.701	53
Q8	4.11	.891	53
Q9	3.74	1.077	53
Q10	3.79	.885	53
Q11	3.83	.672	53
Q12	3.77	.800	53
Q13	4.09	.815	53
Q14	4.02	.796	53
Q15	4.04	.784	53
Q16	4.02	.843	53
Q17	4.13	.878	53
Q18	3.96	.919	53
Q19	4.02	.909	53
Q20	3.87	.900	53

Source-SPSS, (2021).

Table 1413: Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Q1	76.15	151.977	.765	.	.959
Q2	76.09	153.472	.589	.	.961

Q3	76.17	152.105	.638	.	.961
Q4	76.19	146.618	.841	.	.958
Q5	75.75	156.304	.700	.	.960
Q6	75.83	154.567	.736	.	.959
Q7	75.77	156.179	.652	.	.960
Q8	75.98	150.596	.763	.	.959
Q9	76.36	144.081	.884	.	.957
Q10	76.30	152.407	.682	.	.960
Q11	76.26	155.237	.741	.	.959
Q12	76.32	155.837	.581	.	.961
Q13	76.00	152.769	.727	.	.959
Q14	76.08	153.879	.687	.	.960
Q15	76.06	151.631	.821	.	.958
Q16	76.08	151.033	.788	.	.958
Q17	75.96	151.499	.732	.	.959
Q18	76.13	148.925	.817	.	.958
Q19	76.08	150.610	.746	.	.959
Q20	76.23	150.448	.763	.	.959

Source-SPSS, (2021)

Table 1514: Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
Q1	The categories of Q1 to Q20 occur with equal probabilities.	One-Sample Chi-Square Test	.000	Reject the null hypothesis (H_o)
Q2			.008	
Q3			.000	
Q4			.000	
Q5			.001	
Q6			.019	
Q7			.008	
Q8			.001	
Q9			.001	
Q10			.006	
Q11			.000	
Q12			.000	
Q13			.000	
Q14			.000	
Q15			.000	
Q16			.000	
Q17			.000	
Q18			.000	
Q19			.000	
Q20			.000	

Asymptotic significances are displayed. The significance level is .050.

Source-SPSS, (2021)