ASSESSMENT OF FLOOD RESILIENCE OF BLANTYRE CITY USING FLOOD RESILIENCE INDEX

MASTER OF SCIENCE IN ENVIRONMENTAL PROTECTION AND MANAGEMENT

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ASSESSMENT OF FLOOD RESILIENCE OF BLANTYRE CITY USING FLOOD RESILIENCE INDEX

Master of Science in Environmental Protection and Management Thesis

By

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The Polytechnic

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DECLARATION

I, the undersigned, hereby declare that this thesis entitled '*Assessment of Flood Resilience of Blantyre City using Flood Resilience Index*' is my own original work and has not been submitted to any other institution for similar purposes. It has not been submitted for any degree or examination to any university or college.

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Date **:** 24 May 2022

CERTIFICATE OF APPROVAL

We, the undersigned certify that we have read and hereby recommend for acceptance by the University of Malawi, a thesis entitled '*Assessment of Flood Resilience of Blantyre City using Flood Resilience Index*'.

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Head of Department **:** Dr. H.W.T. Mapoma

Signature **:** ______________________________

Date **:** ______________________________

DEDICATION

I dedicate this work to my wife, Masozi, and our two sons, Hilary, and William Jr. and two daughters, Lillian and Taonga Tembo Chimzinga.

ACKNOWLEDGEMENTS

I greatly appreciate efforts by all those that supported me financially, technically, and morally up to the extent of accomplishing this research work, hence my graduate level qualification. Particularly, I am grateful to the Organisation I currently work with, Blantyre City Council, my Supervisors, Dr. I.B.M. Kosamu and Dr. H.W.T. Mapoma at The Polytechnic.

ABSTRACT

Floods rank the highest in frequency and impact of all natural hazards worldwide. They have to-date affected more than 2 billion people, the worst in cities owing to their high infrastructural economic values. Efforts to prevent and mitigate this challenge exist with the aim of building resilience to floods through flood risk management (FRM). The building of resilience to floods requires benchmarks in form of flood resilience metrics, which are phenomenal for efforts' accountability and decision-making. This study was performed to assess resilience of Blantyre City in Southern Malawi to floods using flood resilience index (FRI), which employed a questionnaire and quantitative analyses. Prior to the assessment, the City's urban dimensions were analysed using key informant interviews. In furtherance, flood resilience strategies were explored from a body of literature to highlight strategies suitable for the City's flood risk management. Consequently, city dimensions were very low, where only 5/33-dimensional variables achieved at least 50% of best performance. The City's FRI was at 1.97 (39.4%) representing very low flood resilience, according to FRI ratings. This showed that authorities and stakeholders such as Blantyre City Council needed to upscale their efforts to improve the City's flood resilience. Flood resilience strategies explored from thirty-nine (39) sources turned out forty-nine (49) strategies suitable for Blantyre City, which we recommend its stakeholders to practise thereby enhancing the City's resilience to floods.

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LIST OF ABBREVIATIONS AND ACRONYMS

AWMI	Average Weighted Mean Index
BCC	Blantyre City Council
CORFU	Collaborative Research on Flood resilience in Urban areas
CPC	Civil Protection Committee
DoDMA	Department of Disaster Management Affairs
EAD	Environmental Affairs Department
FRe	Flood Resistance
FRI	Flood Resilience Index
FRM	Flood Risk Management
GoM	Government of Malawi/Malawi Government
HINARI	Hinari Access to Research for Health Programme
HVAC	Heating, Ventilation and Air Conditioning
ICLEI	Local Governments for Sustainability
IFRM	Integrated Flood Risk Management
LID	Low Impact Design
MHC	Malawi Housing Corporation
MoLHUD	Ministry of Lands, Housing and Urban Development
NNBI	Natural and Nature-Based Infrastructure
PDNA	Post Disaster Needs Assessment
PFR	Property Flood Resilience
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
SFDRR	Sendai Framework for Disaster Risk Reduction
SUDS	Sustainable Urban Drainage Systems
UNDESA	United Nations Department of Economic and Social Affairs
UNISDR/UNDR	United Nations Office for Disaster Risk Reduction
WMI	Weighted Mean Index
WSUD	Water Sensitive Urban Design

CHAPTER ONE: INTRODUCTION

1.1 Background

Floods are natural phenomena (Jha et al., 2012) and occur as hydrological hazards and one form of disasters (Centre for Research on the Epidemiology of Disasters/CRED, 2020; Takeuchi et al., 2018). Government of Malawi (GoM, 2013) defined flood as natural process that occurs when the quantity of water in a watershed exceeds the capacity of stream, river and lake. More to that, United Nations (2016) defined a disaster as a serious disruption of the functioning of a community or a society at any scale due to hazardous events interacting with conditions of exposure, vulnerability and capacity, leading to one or more of the following: human, material, economic and environmental losses and impacts.

Floods are a global threat to life and property whose prevalence and impacts are second to none of all disasters (PreventionWeb, 2020), with prevalence of 3,148 flood events, seconded by 2,049 cases of storms from 1998 to 2017 (UNISDR & CRED, 2018). Figure 1 shows list of disasters and their global trends. Within 20-year period, floods alone affected 2 billion people thereby killing 11% of the affected, followed by drought which affected 1.5 billion where in terms of global economy, floods contributed to loss of $23 billion.

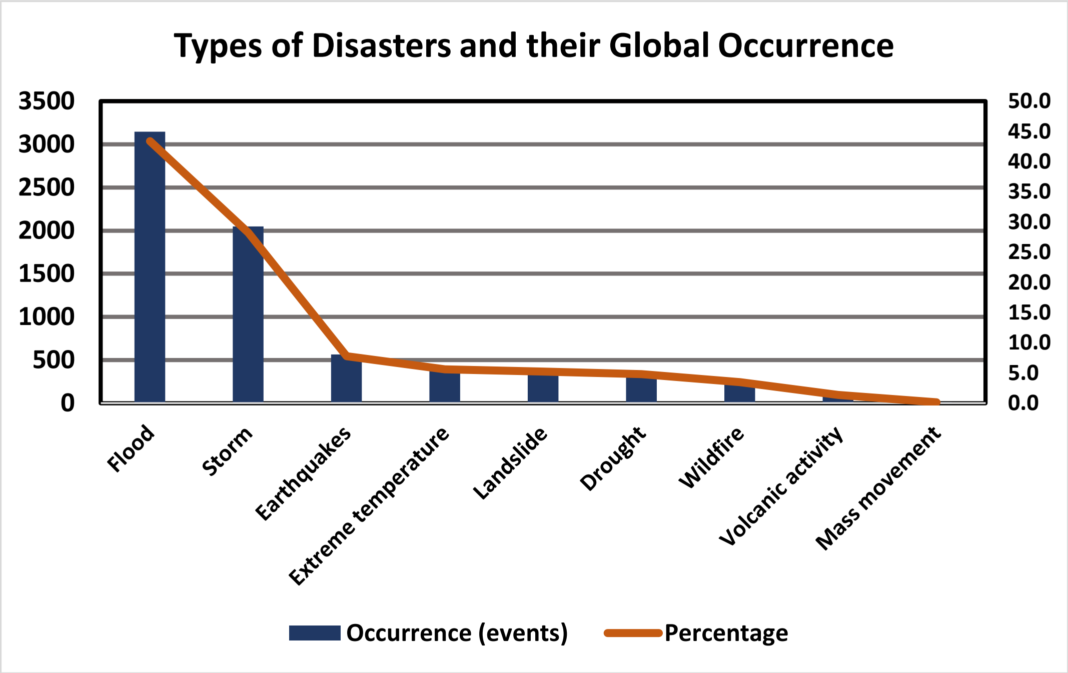

Figure 1. Global numbers of disasters per type (1998 – 2017). Source (UNISDR & CRED, 2018)

In Malawi high impacting extreme weather events do occur and is as a result of factors such as its location along the great African Rift Valley, rapid population growth, unsustainable urbanization, climate change, and environmental degradation (GoM, 2019). The most common weather-related threats in Malawi include floods, drought, stormy rains and hailstorms of which over the past five decades, Malawi has been hit by more than 19 major floods and seven droughts which are increasing in frequency, magnitude and scope over the years (Malawi Hazards & Vulnerability Atlas, 2015) which impairs its socio-economic development.

Frequently, almost every rainy season, floods occur along the Shire Valley in the Districts of Chikhwawa and Nsanje as a result of overflowing Shire River, the only river that drains the Lake Malawi to Zambezi River and as of 2015 Malawi was ranked a third country worldwide to be frequently hit by climate caused hazards (Kita, 2017). Figure 2 shows trends of the disasters in two decades from the year 1992 in Malawi.

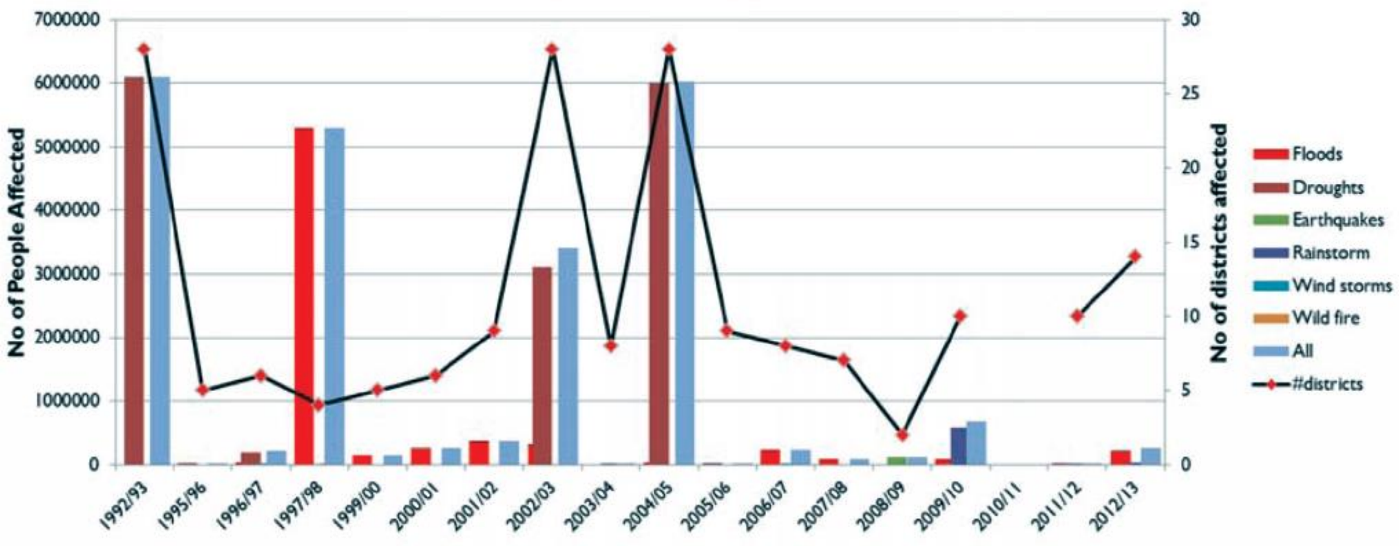

Figure 2. Disaster trends in Malawi over 20 years. Source: Malawi Hazards and Vulnerability Atlas (2015)

In early 2015 after heavy downpours, floods affected 1,101,364 people, displaced 230,000 people and killed at least 106 people as 117 were reportedly missing which also destroyed people's houses and household property including crops (GoM, 2015a). It was further reported in the Post Disaster Needs Assessment Report of 2015 by GoM (GoM, 2015a) that the damage and loss for the year was $335 million and that reconstruction required a sum of $494 million. This affected several sectors; water and sanitation, transport, social protection and infrastructure, nutrition, housing, health, environment, energy, education, commerce and trade and agriculture, of which the housing sector had the greatest impact and recovery needs followed by the transport and then agriculture sectors.

In March 2019 Tropical Cyclone Idai caused another set of flooding, which affected 15 districts and two cities. The districts affected were Balaka, Blantyre, Chikwawa, Chiradzulu, Machinga, Mangochi, Mulanje, Mwanza, Neno, Nsanje, Phalombe, Thyolo, Zomba districts in the Southern Region and Dedza and Ntcheu in the Central Region whereas the two cities were Zomba and Blantyre City (GoM, 2019). Reports from BCC indicated that floods were common in areas surrounding hilly terrain of Soche, Ndirande, Michiru, Sanjika, Nyambadwe, Bangwe, Mpingwe and Mzedi Hills where streams catch water to lower areas then to the River Shire (Blantyre City Council, 2015). Figure 3 is a hazard map showing areas where floods and other hazards are common in Blantyre City.

As classified in table 1, Malawi lost \$62 million to the floods and required \$370 million for reconstruction and recovery. The effect of the flood events heavily impinge the Malawi's socio-economic development efforts considering that its nominal Gross Domestic Product (GDP), \$7.436 billion and per capita of \$367 (Mundi Index, 2019) is one of the lowest worldwide. Drivers of national socio-economic growth underscore the need for efficient production, consumption and export of goods and services also recognising the existence and efforts from rural and largely urban societies (Manda, 2015).

Urban areas, cities in particular have a greater bearing on national growth and development, such that urbanisation levels, i.e. proportion of people's population living in cities and towns vary across the world's major regions which as of 2014 stood at 40.0 % in Africa, 47.5 % in Asia, 73.4 % in Europe, 79.5 % in Latin America and the Caribbean, 81.5 % in North America, and 70.8 % in Oceania (Polèse, 2005; Vinod-Kumar & Dahiya, 2017). Figure 4 shows population growth rise in cities and decline in the rural areas.

GoM and GSURR (2016) decried data constraints to clarify precisely how cities and towns contribute to national growth, however they acknowledged that Malawi's four cities (Blantyre, Lilongwe, Mzuzu and Zomba) form the economic hinge of the national economy, thus contributing to national GDP (33%) which is greater than their population share (13%). Further to that, GoM and GSURR (2016) reported that rural areas contain 85 percent of Malawi's population, but account for only 62 percent of national GDP, whereas secondary towns contain about 3 percent of the population, but contribute 6 percent to national GDP.

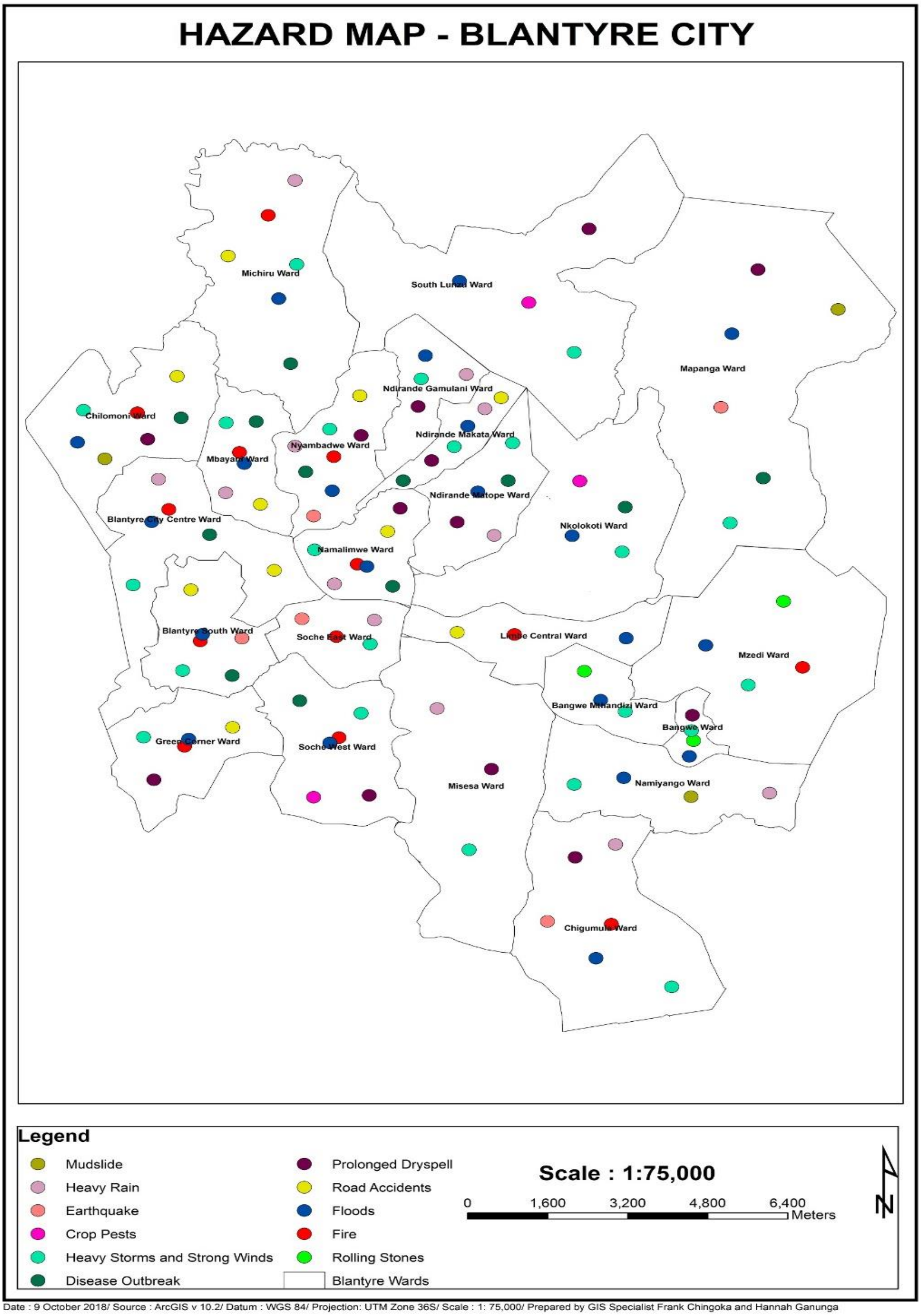

Figure 3 Hazard map showing areas with common hazards. Source: Blantyre City Council (2018).

Table 1. Damage, losses and needs for recovery by sector and cross cutting issues (in million US$)

Sector	Sub Sector	Damage	Losses	Effects (US$ m)	Needs (US$ m)
Social	Housing	82.7	23.9	106.6	106.1
	Health & Nutrition	0.2	2.4	2.6	30.9
	Education	20.3	0.8	21.0	62.3
Productive	Crops	-	11.1	11.1	19.6
	Livestock	0.5	7.7	8.2	2.4
	Irrigation	4.2	9.6	13.8	17.9
	Fisheries	1.8	1.4	3.2	1.4
	Commerce and Industry	0.3	1.7	2.1	3.1
Infrastructure	Transport	36.1	0.9	37.0	42.6
	Energy	2.8	0.3	3.1	4.3
	Water and Sanitation	3.7	2.7	6.4	12.3
	Water Resources	5.1	-	5.1	17.0
Cross Cutting	DRR & EWS				10.9
	Environment				1.0
	Governance				1.3
	Persons with Disabilities				0.3
	Social Protection				29.0
	Gender Equality and Social Inclusion				4.0
	Older Persons				0.3
	Child Protection				3.7
Total		**157.7**	**62.5**	**220.2**	**370.5**

Source: Government of Malawi (2019)

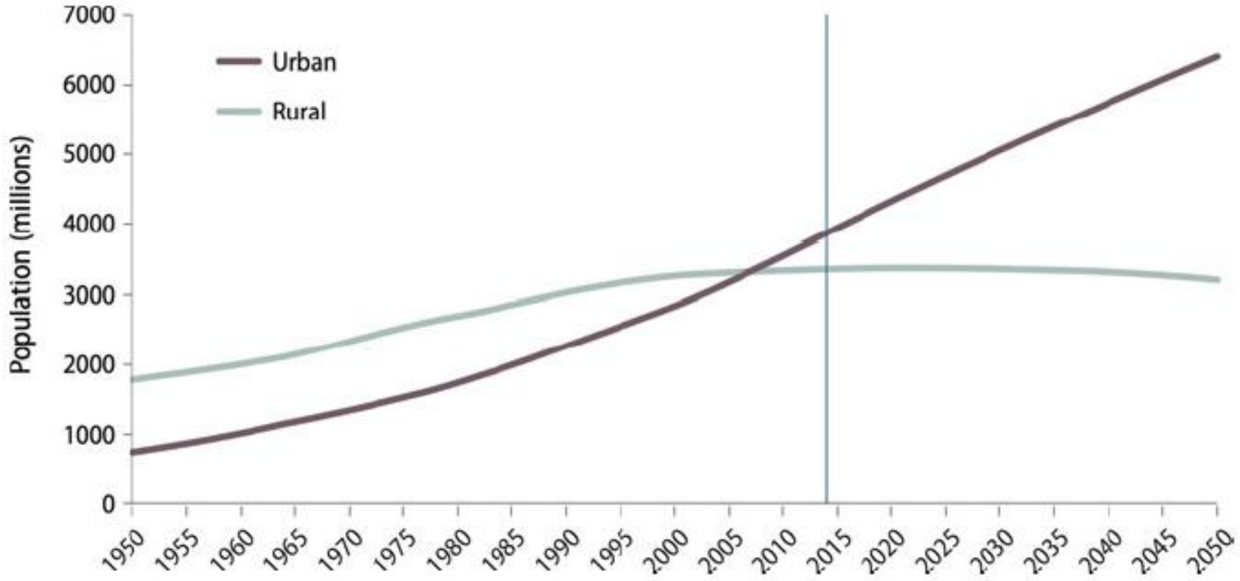

Figure 4. Rural to urban population shift projection for 1 century. Source: Vinod-Kumar and Dahiya (2017)

Vinod-Kumar and Dahiya (2017) found a direct correlation between urban population growth and economic development leverage by an application of a comparative analysis of the USA and Europe. Vinod-Kumar and Dahiya (2017) found that in the USA 164 million people lived in 50 major metropolitan areas, whereas in Europe there were only 102 million inhabitants in metropolitan areas; but GDPs of European metropolitan areas was of smaller size in comparison with those of the USA. Further to that, the European metropolitan areas produced 72 % of the GDP of 50 largest cities of the USA, and that in 31 American states, one or two metropolitan areas account for most of the a state's economic production, and in 15 other states, a large metropolitan area alone produces most of the GDP.

When cities are therefore hit by disasters such as floods it turns catastrophic especially when their preparedness and response systems including their critical infrastructure are seldom strong. In a world of flood hazards, cities are exposed to threats of highest economic impact since they capture a greater proportion of people's population per unit area and consist of improved infrastructure compared to rural areas (McClymont et al., 2020a). This phenomenon where greater economic losses are experienced in cities stricken by floods emphasises the need for institutionalisation of efforts in urban flood risk management (FRM) whose goal is to build urban flood resilience (McClymont et al., 2020a; Wals, 2015).

In relation and as a remedy to the losses, international and local development agenda enlist building of disaster resilience as one of their focus areas; the World Bank, United Nations Office for Disaster Risk Reduction (UNDRR), United Nations Department of Economic and Social Affairs (UNDESA), Sendai Framework for Disaster Risk Reduction (SFDRR), African Union Commission and Malawi Government through the Department of Disaster Management Affairs (DoDMA) and indeed the Malawi Growth and Development Strategy III (MGDSIII) are determined to enhancing flood resilience, which according to Restemeyer et al. (2014) has three key characteristics namely: robustness, adaptability and transformability.

In order to build flood resilience of a city, it is important to understand its present level of flood resilience in form of indicators (Oladokun et al., 2017). Presently, flood resilience level of Blantyre City has not been defined by research and this study was performed to contribute knowledge in addressing this research gap. Before the determination of flood resilience level of the city, Blantyre City's physical, natural, social, economic, and institutional dimensions were evaluated. In addition to those, flood resilience strategies suitable for Blantyre City were explored and classified.

Similar work has been widely carried out to determine indicators of resilience using different methods (Table 2) and addressing different hazards, natural and anthropogenic. This study borrows the method from research series that were carried out in different cities, mostly in Europe under the European Commission's Project in 2010-2014 by Jelena Batica and Phillipe Gourbesville. The Project called CORFU Project used the Flood Resilience Index (FRI) method which was applied to nine (9) cities in Europe and Asia with various levels of economic progresses, social systems, infrastructure, age and decision making processes (Batica & Gourbesville, 2012).

1.2 Problem statement

Of all natural hazards, floods lead in causing fatalities and infrastructural destruction across the globe. Malawi, one of the poorest countries with gross domestic product (GDP) per capita of $411.552 in 2019 (World Bank, 2020) and GDP based on purchasing-power-parity (GDP-PPP) per capita of $1,240 in 2020 (Global Finance, 2020), suffers climatic shocks including floods and the Country's development progress is therefore marred (International Monetary Fund, 2017).

The floods of 2015, drought of 2016 and floods of 2019 alone crippled the economy by creating a demand for recovery and reconstruction of $494 million, $500.2 million, $370.5 million, in that order (GoM, 2015, 2019; International Monetary Fund, 2017;), a situation that requires coordinated flood risk management efforts.

Worsening further is that Malawi's Cities which play a vital role in driving its economy having robust infrastructures and systems, fall vulnerable to floods too (Malawi Hazards & Vulnerability Atlas, 2015). Between 2014 and 2019 all Cities in Malawi were heavily hit by floods (GoM, 2019). In Blantyre City, the 2015 floods affected over 16,000 households while in 2019 floods affected about 15,000 people in all its administrative wards (Blantyre City Council, 2019a).

In devising efforts to manage flood risks, scholars emphasised the need to building resilience of communities including urban areas to floods, a process that require quantification and benchmarking using resilience indicators (McClymont et al., 2020; Summers et al., 2017; Batica, 2015). Oladokun et al. (2017) reported that understanding the level of flood resilience of an area is a key element for flood risk management agencies to consider in decision-making and performance review of their efforts.

Of the four Cities in Malawi, Blantyre City is the oldest and the economic and industrial capital (United Nations & Mpoola, 2011), unfortunately their level of resilience to floods is not known (not informed by research) despite various stakeholders aiming at raising resilience. Due to limited data availability which as stressed by Adeloye et al. (2015), most flood risk studies in Malawi and most of Sub-Saharan Africa (SSA) dwelt much on cause, impacts, perceptions and coping, among others.

Thus, failure to tangibly define levels of flood resilience of the city would render development efforts by the GoM and its agencies such as the Department of Disaster Management Affairs (DoDMA) and Blantyre City Council (BCC) and other stakeholders ad hoc and to the whole extent, ineffective. Therefore, this research was conducted to contribute to the knowledge of city dimensional performance, flood resilience levels and flood resilience strategies suitable for the flood-vulnerable Blantyre City which could help in planning and accountability of efforts by the relevant stakeholders.

1.3 Research objectives and questions

1.3.1 General objective

The general objective of this study was to assess flood resilience of Blantyre City.

1.3.2 Specific objectives

To achieve the overall objective, the following were the specific objectives of the study:

i. To find levels of 5 city dimensions for resilience assessment
ii. To determine the flood resilience index for Blantyre City
iii. To identify suitable flood resilience practices for Blantyre City

1.4 Research questions

i. What are the levels of urban dimensions for Blantyre City: physical, social, natural, economic, and institutional?
ii. What is the flood resilience index for Blantyre City considering the city dimensions?
iii. Which are the suitable flood resilience strategies for Blantyre City?

1.5 Significance of the study

With increasing temperature, rainfall intensity and variability in the recent years, flood disasters are envisaged to be on the increase also, in frequency and magnitude. This calls for improved FRM efforts to build flood resilience of communities. Malawi Governments' priority area 4 of the National DRM Policy emphasises a *culture of safety,* a one easy representation of resilience and adoption of resilience-enhancing interventions, (GoM, 2015b) which is also a mainstay in other global and Malawi's strategic frameworks. The Sendai Framework for Disaster Risk Reduction's (SFDRR) four priorities for action (Understanding disaster risk, Strengthening disaster risk governance to manage disaster risk, Investing in disaster risk reduction for resilience and Enhancing disaster preparedness for effective response and to "Build Back Better" in recovery, rehabilitation and reconstruction), circle on resilience building (UNISDR, 2017).

To realise the planned efforts, there is a critical need to scientifically define levels of resilience of the target community. This body of knowledge is very important for local and international development actors that work in the field of DRM, the Malawi Government as well as researchers and students undertaking research in disasters, FRM and resilience-building.

For different developmental actors such as urban planners, access to research-supported information is important as it ensures that their efforts are based on authentic and accurate information, and are therefore genuine and effective. When such information is readily available, individuals, institutions and organisations involved in flood risk reduction and resilience-building will utilise it for planning, resource mobilisation and prioritisation and even for monitoring and evaluation of their efforts.

On the other hand, academicians, researchers, and students will use the information for knowledge advancement. Acknowledging limited availability of research-backed literature in the field of disaster resilience, especially on urban flood resilience, in Malawi this study therefore contributes to providing a foundation for research in the field of urban disaster and flood resilience.

1.6 Thesis organisation

The thesis is organized as follows: every new chapter begins with an introductory section to that chapter, followed by its details; chapter 1 is *introduction* which gives the background to the study and initial highlights into the research inquiry, such as study objectives, the research problem and its rationale. Chapter 2, *literature review*, follows, which describes previous studies and existing knowledge on the topic, including the study area (Blantyre City). This is followed by chapter 3, *materials and methods* which explains in detail how the data was collected and analysed to arrive at the findings (results), which are presented and discussed under chapter 4, *results and discussion*. Thereafter, the findings are summarised under chapter 5, *conclusion and recommendations*, which also presents authors' recommendations according to the study results, as a message to the readers/users and decision making stakeholders. References and then appendices follow at the end of this research report.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

In this chapter, research insights from previous studies have been highlighted. Conceptual frameworks of disasters, floods, resilience, and flood resilience have been explained from literature and their analytical aspects such as resilience measurement and disaster risk management in Malawi have been underscored. More to that, disaster occurrence across the globe and Malawi have been outlined.

2.2 Disasters

The world is exposed to numerous forms of disasters, some artificial, others natural. A disaster is a serious disruption of the functioning of a community or a society at any scale due to hazardous events interacting with conditions of exposure, vulnerability and capacity, leading to one or more of the following: human, material, economic and environmental losses and impacts (United Nations, 2016). From the societal point of view, Palanivel et al. (2015) contributed further that an extreme event within the Earth's system that results in death, injury to humans and damage or loss of valuable goods is called is a 'Disaster'.

There are many types of disasters, from natural cause such as earthquakes, tsunamis, hurricanes, and floods (Cavallo et al., 2010) to artificial or man-made disasters, such as military actions and terrorism, accidents such as water dams collapsing, food shortages, epidemics and pandemics (Mörner, 2010). A disaster at risk stages is a function of interplaying factors of nature and society, where the disaster is a phenomenal result of the factors' interaction, hazard, vulnerability, exposure and resilience or coping capacities (ISDR, 2012).

Disasters have unimaginable negative impacts on society and the environment. From 2005 to 2015 over 700 thousand people died, over 1.4 million got injured and approximately 23 million had been made homeless as a result of disasters and overall, more than 1.5 billion people were affected by disasters in various ways, with women, children and people in vulnerable situations disproportionately affected (UNISDR, 2018). The total economic loss was more than $1.3 trillion. These disasters, many of which are exacerbated by climate change and which are increasing in frequency and intensity, remarkably derail progress towards sustainable development (UNISDR, 2018).

Across Africa, 2017 which was a worst year since 2007 in terms of disaster prevalence and impact, forty-two disasters occurred, leading to 20% deaths of the total global disaster deaths (Below & Wallemacq, 2018). This is five-times higher a number compared to the decade 2007-2016's 4.4% death-toll, according to ibid. In Malawi, floods, drought, stormy rains, strong winds, hailstorms, landslides, earthquakes, pest infestations, diseases outbreaks, fire and accidents are some of the major disasters affecting the country (GoM, 2019). To emphasise the prevalence and impact, GoM (2015a) further reported of 2015 as the worst year that Malawi was hit by floods in fifteen districts, killing 106 people, displacing 230,000 and affecting 1,101,364 people. However, the impact of floods in 2019 which included Blantyre City showed higher economic losses than that of 2015 (GoM, 2019). Flood disasters are the highest impacting and most frequent disasters in the world, according to PreventionWeb (2020).

2.3 Floods and flooding

Flooding occurs when water overflows a river or a lake and covers land that is not normally submerged in water (WHO, 2020; Tarlock, 2012). Tarlock (2012) further stated that floods are inevitably connected in causal form, to the hydrological cycle and that in ancient times and recent past floods were considered blessings because they sustained riverine ecosystems and that floodplain economies had to depend on them. In this case, a certain level of flooding is acceptable and of socio-economic benefit, such as in agriculture and agribusiness, water transport and ecosystem health, but when they cause community disruption, they turn to be undesirable – thus becoming a disaster.

Classification of floods is based on their source and nature of occurrence. Buxton (2015) classified floods as river or fluvial flooding, coastal flooding, pluvial (also termed overland and sewer flooding), groundwater flooding and failure of artificial systems. Vojinović and Huang (2014) added flash flooding as another type, described as sudden, often destructive rush of water from a high or over sloping area, caused by heavy rainfall. Vojinović and Huang (2014) added that pluvial floods are caused by heavy rains directly over urban areas whose volume exceeds the capacity of drainage systems.

This combination of pluvial and flash floods seem to define the situation of Blantyre City with hilly topography and narrower drainage channels (Blantyre City Council, 2015). Buxton (2015) further defined the types of flooding: river (fluvial) flooding occurs when excess water bursts the riverbanks, especially after a heavy storm accompanied by strong runoff into the river system thereby overcoming its capacity; coastal flooding as when sea-water is driven on to the land by storms, tsunamis and high tides which normally occurs when seismic activity causes tidal waves or when meteorological events, such as hurricanes or storms, combine with strong winds and low pressure to cause sea levels to rise above expected peak levels; groundwater flooding occurs when the below ground water rises above the surface of the ground; failure of artificial systems such as a dam failure, a burst water main or an embankment collapsing resulting in fast flowing water, in unexpected locations, catching people unawares. All in all, as presented previously, floods are the worst type of disasters globally.

2.4 Flood risk management

Floods being one of the important challenges the world faces today as disasters, strategies have been over time put in place to manage them in a framework described, *flood risk management* (FRM), a sub-set of disaster risk management framework (Schanze, 2016). FRM came into existence and progressed with a culture of resistance (Tagg et al., 2016) other than resilience where defence mechanisms such as levees, dykes, diversion channels, dams and related structures were embraced (Aldaba, 2013). It is a fact today that floods cannot be stopped and that the defence mechanisms are put only to mitigate their impact on vulnerable communities; which is where Gourbesville and Batica (2013) reported and recommended integrated risk management as an adaptive approach of "living with" floods which captures the flood hazard with concepts of sustainability, resilience, vulnerability and uncertainty (Morrison, 2019).

"Living with floods" is not a recent practice as it dates back to the ancient Egyptian Civilisation (Aldaba, 2013) where critical infrastructure were placed on elevated land (similar today in the churches and cathedrals of England), setting of flood warnings to people and elements at risk and flood-sensitive land use planning (as practised by the Romans). The use of defence mechanisms alone as a way of dealing with floods gradually diminished until late 20th Century when risk planning was in perspective (Murdock et al., 2018).

FRM in the world has been implemented with common strategic goals of reducing risk to people and communities, reducing risk to and promote economies, promoting ecosystem goods and services and promoting the social well-being, all that while safeguarding the use of limited resources (Aldaba, 2013). All in all, the huge investments in pre-flood, during and post flood phases force countries at risk to embrace risk-thinking and integrate flood risk management (Oladokun & Montz, 2019) with the principal determination to achieve flood resilience (Adeloye et al., 2015).

2.5 Flood risk management in Malawi

Frameworks for disaster risk management (DRM) – including FRM in Malawi, both policy and institutional are currently in force with a recognition of local and international requirements (Botha et al., 2018; GoM, 2013), dating back to 1991 when deadly flash floods called *Napolo* affected Phalombe and surrounding Districts. The GoM had in the same year instituted the Disaster Preparedness and Relief Act, which led to the instatement of administrative and technical offices and instruments for DRM, such as Office of the Commissioner, Department of Disaster Management Affairs (DODMA), the National Disaster Preparedness and Relief Committee (NDPRC), and the National Disaster Preparedness and Relief Fund (Botha et al., 2018).

Following the legal and institutional frameworks including focused action on DRM, the lead Department (DoDMA) with other partners realized shortfalls in the 1991 Act and embarked on updating it which had focused more on disaster management than comprehensive DRM. With increasing frequencies and impacts of hazards (floods leading) and climate change, new frameworks were a must-have for Malawi.

In 2015 the GoM developed the National DRM Policy (GoM, 2015b) to incorporate changes in economic, social, physical and political environments and also ensure that DRM is tailored to national policies and international frameworks such as the SADC Disaster Risk Reduction Strategy and the then Hyogo Framework of Action 2005-2015 (GoM, 2010; GoM, 2015b). In the process the current national platform for DRM recognized the importance of involving various decision levels at central, local government and typical beneficiaries (GoM, 2013) which can be regarded a top-bottom blended with a bottom-top approach to DRM. Figure 5 displays the institutional structure for DRM in Malawi at present.

From the central government level, local level action starts at district level where an office for DRM is formed, led by the DRM Officer who reports to the controlling officer (Botha et al., 2018; GoM, 2013; GoM, 2015b) who is a coordinator for DRM committees at district level called district/town/municipal/city civil protection committees (CPC) and lower civil protection committees. Lower level committees just like at district level are termed differently based on district structure, where in cities are known as ward civil protection committees (WCPCs) while in rural districts are two-tiered, area CPC (ACPC) and village CPC (Blantyre City Council, 2019b) whose major role is to lead local level action in planning and implementation including reporting of DRM programmes for risk reduction, emergency management, recovery and rehabilitation.

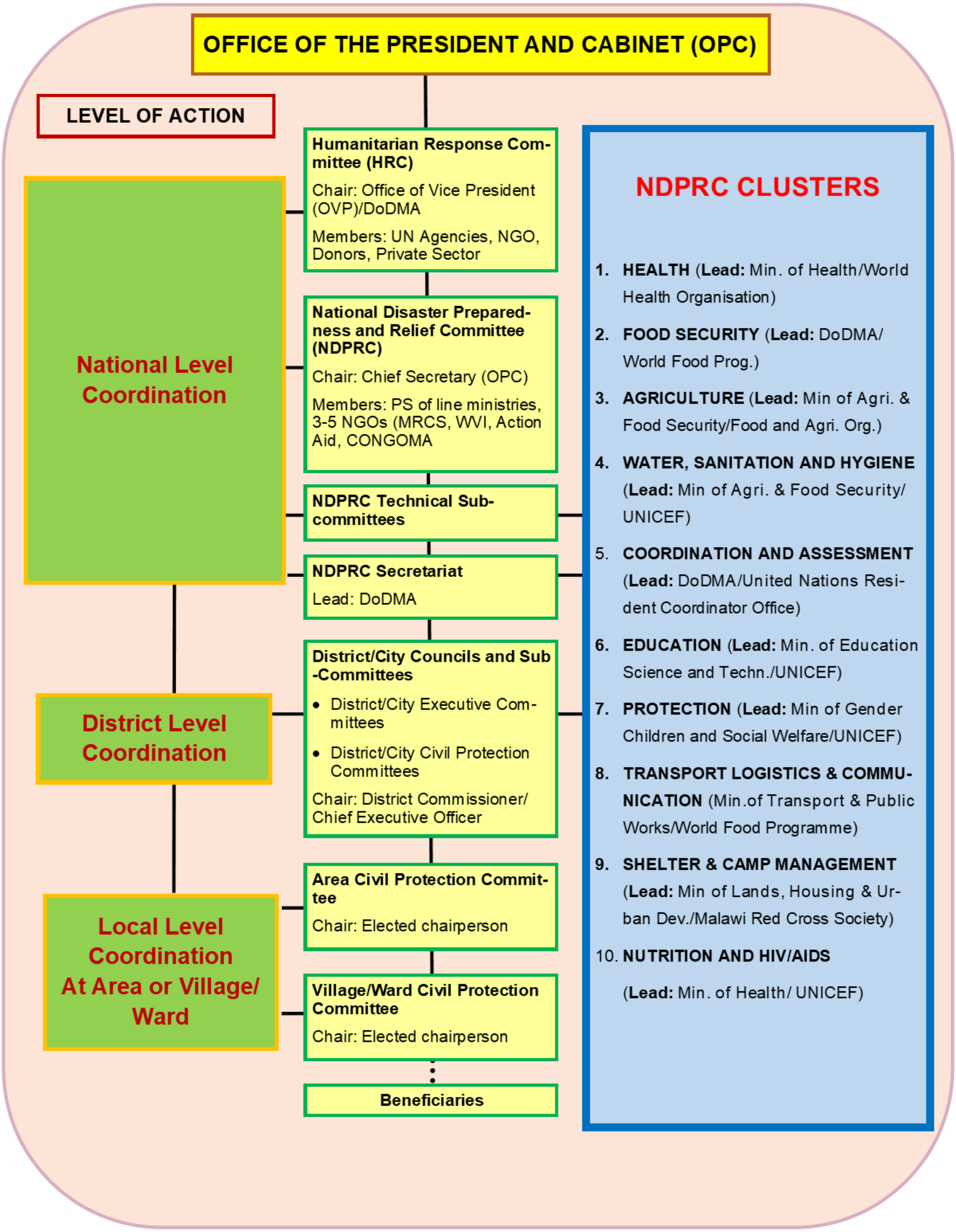

Figure 5. DRM Institutional Structure in Malawi. Adapted from GoM (2015b); Botha et al. (2018) and Blantyre City Council (2019c)

2.6 Resilience and flood resilience

The term "resilience" shares its origins from ecology being applied to human society, used in many disciplines, such as ecology itself, materials science, sociology, geography, psychology, urban engineering, disaster management among others (Serre, 2016; Rezende et al., 2019). One of the first scientists to conceptualise resilience was Holling in 1973 (McClymont et al., 2020b), who defined it as the ability of a system to absorb changes of variables and parameters, and still persevere (Gourbesville & Batica, 2013), and in recent times the term is increasingly used in integrated urban drainage management (Rezende et al., 2019).

The complexity of resilience emanates from its adaptable usage in several disciplines. Nonetheless from the 100 Resilient Cities project, McClymont et al. (2020) highlighted that the concept is three-fold – engineering resilience, systems resilience and resilience in complex adaptive systems (figure 6) which are also in tandem with other frameworks as reported by Douven et al. (2012), described as engineering resilience, ecological resilience and socio-ecological/revolutionary resilience. Engineering resilience is conceptualised as maintaining the status quo and defined as the ability to withstand a large disturbance without, in the end, changing, disintegrating, or becoming permanently damaged; systems resilience, as maintaining system function in the event of a disturbance and complex adaptive systems is the ability to withstand, recover from, and reorganise in response to crisis (McClymont et al., 2020b).

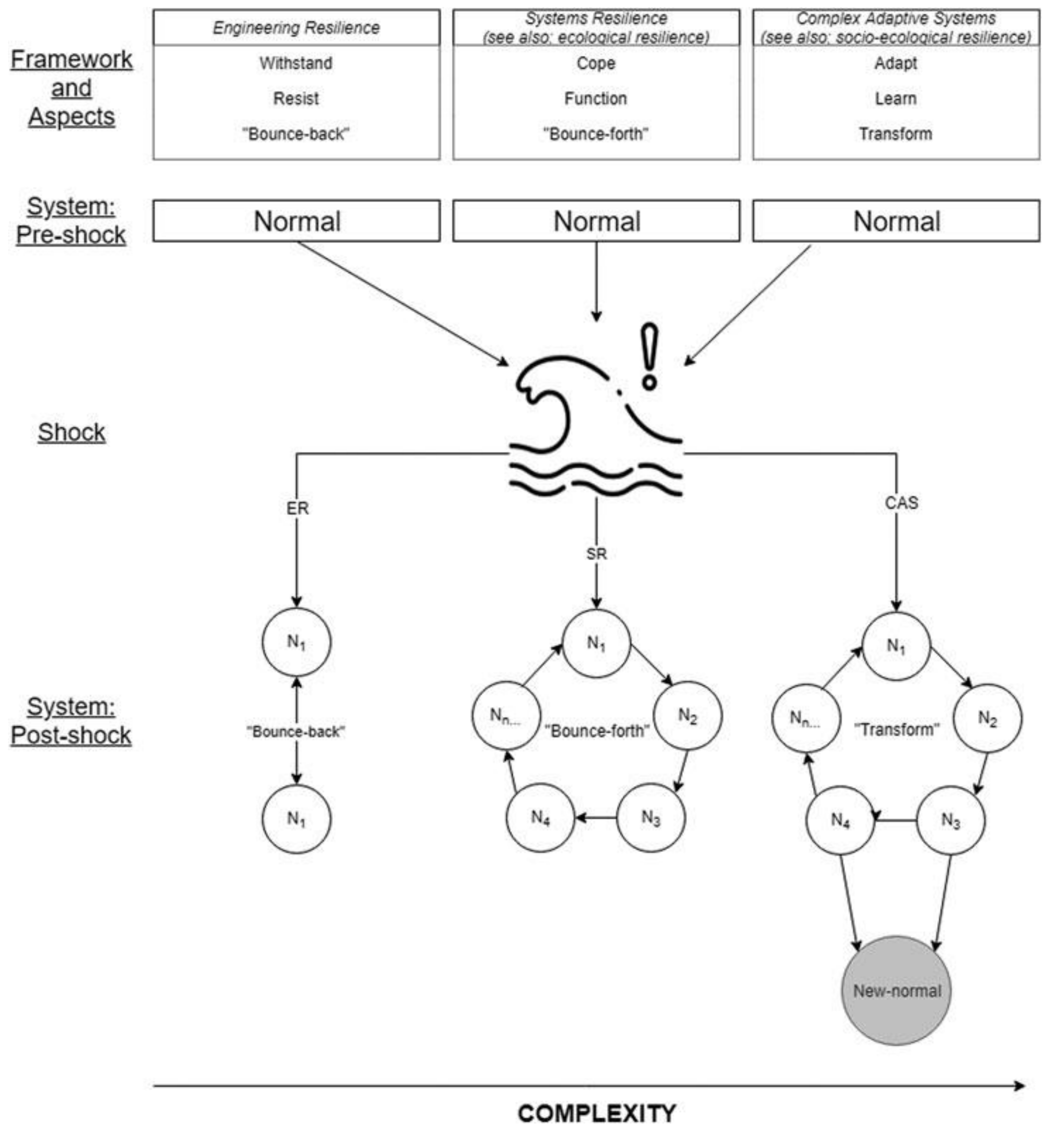

Figure 6. Resilience concept in three perspectives. Source: McClymont et al. (2020)

It is important that the term resilience be defined and described, otherwise as Miettinen (2017) reported, "If everything is resilience, nothing is resilience" which in simple terms sought that the term be fully conceptualised and institutionalised. Resilience as defined by the UN (United Nations, 2016) is ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management.

In broader sense, Murdock et al. (2018) agreed with the UN that resilience involves ability to prepare and plan for, absorb, recover from and adapt to adverse effects, such as flooding.

Restemeyer et al. (2014) clarified further that resilience is a function of robustness, adaptability and transformability in case of cities, which were explained in such manner: robustness is for a city to be able to withstand an event such as a flood, by means of physical barriers like dikes, sluices and storm surges; adaptability implies that the hinterland is adjusted to flooding so that a flood event may come without leaving substantial damage; and transformability being the capacity of a city to make a shift from dealing with the disaster to living with it.

To be precise, in this study of flood resilience, we applied resilience as in the definition by the UN, where flood resilience would mean the ability of a system, community or society exposed to floods to resist, absorb, accommodate, adapt to, transform, and recover from the effects of the flood in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through FRM. Flood resilience, according to McClymont et al. (2020) in their systematic review of literature is a multi-contextual and a dichotomous approach, including, resilience versus resistance; reactive or proactive; flood control or flood adaptation; robustness versus flexibility; structural or functional; and resilience versus anticipation; and defined as a strategy to minimise flooding consequences.

Various scholars and organisations agree that it is important to measure resilience using defined indicators to form a platform for benchmarking. For example, Murdock et al. (2018) indicated that many policy documents stress the need to increase resilience and that organisations such as the Rockefeller Foundation are working tirelessly with cities to achieve the same. Other organisations or programmes working on tangibility of resilience include the COllaborative Research on Flood resilience in Urban areas (CORFU), the Zurich, Community and Regional Resilience Institute (CARRI) and ICLEI – Local Government for Sustainability. Measurement of resilience uses indicators which assist in measurement of the effectiveness of programmes, policies and interventions earmarked to improve disaster resilience, (Cutter et al., 2010).

2.7 Methods for flood resilience assessments

Resilience against a hazard such as floods must have a way of measurement, which is vital in performance review, management and improvement in terms of flood resilience-building (Oladokun et al., 2017; Keating et al., 2016). The scholars and international organisations that had planned and devised techniques for resilience measurements did so by applying certain composite indicators – which are individual variables meant to produce an aggregate measure of disaster resilience (Cutter et al., 2010). The Scholars asserted and further defined the term indicator as a quantitative measure derived from observed facts that simplify and communicate the reality of a complex system.

The Rockefeller Foundation engaged Arup International Development (ARUP) to carry out research in their Programme, the City Resilience Framework (Rockefeller Foundation, 2014) and found a list of eight city functions that are critical to resilience which proposed that a resilient city: delivers basic needs; safeguards human life; protects, maintains and enhances assets; facilitates human relationships and identity; promotes knowledge; defends the rule of law, justice and equity; supports livelihoods; and stimulates economic prosperity. This framework was applied in the 100 Resilient Cities studies such as at Delft University of Technology (Spaans & Waterhout, 2017).

Restemeyer et al. (2014) devised a strategy-based framework for assessing flood resilience of cities. The framework underscores six intersecting factors that emanate from two aspects; resilience parameters and resilience dimensions, thus resilience being a multi-dimensional phenomenon. This framework is a matrix of resilience parameters (robustness, adaptability, and transformability) and strategy-based dimensions (content, context and process). Other scholars are able to isolate a particular societal system or function and assess their resilience by applying specific methodical approaches. Murdock et al. (2018) applied a response curve approach in assessing resilience of critical infrastructure to flooding. As a matter of comprehensiveness, Table 2 presents a list of some of approaches or tools for resilience measurement.

The reviewers of the climate resilience measurement tools in the table 2 categorised the tools into those that were conceptual frameworks (15) and those with index development and application (72) (Summers et al., 2017). From the seventy-two (72) tools with developed indices, the researchers isolated the tools which were spatially scalable index models, twenty-seven (27) as presented in the table 2. Most of the indices in the table measure vulnerability to climatic shocks as it is a factor related to resilience. From the list of resilience assessments, the most specific to floods is the FRI which was preferred for use in this study.

The FRI was developed in the University of Nice Sophia Antipolis and tested under the 7th Framework Programme (FP7) of the European Union, CORFU and Preparing for Extreme And Rare events in coastaL regions (PEARL) (Batica & Gourbesville, 2016) which was particularly implemented on eight case study Cities in Asia and Europe: Barcelona in Spain; Beijing in China; Genoa in Italy; Hamburg in Germany; Nice in France; Châtelaillon-Plage in France; Rethymno in Greece and Taipei in Taiwan. The Cities are characterised with various levels of economic progresses, social systems, infrastructure, age and decision making processes (Batica & Gourbesville, 2012).

The FRI tool however had its own suitability for selection and application in this study. Firstly it is multi-scalar in terms of application, as it works on parcel, block, district or city level and recognises urban systems (Gourbesville & Batica, 2013). Secondly, it beams more on city planning and governance and further on investment in terms of flood preparedness (Summers et al., 2017). In comparison with other tools in the table above, the Climate Disaster Resilience Index (CDRI) has the highest domain of application and its metrics; the FRI applies same indicators on a city scale as the CDRI: physical, natural, social, economic and institutional, and is a tool specific for floods and a derivation from the CDRI (Sharifi, 2016). Fourthly, the index is a comprehensive in the flood risk management (FRM) as it fits to the five elements of relief, resist, response, recovery, reflect (5R) of the FRM (Batica, 2015).

For the most part, the FRI at city assessment scale applies five (5) dimensions of an urban system: physical, natural, social, economic, and institutional dimensions. According to Batica (2015), the meanings of each dimension are as in Table 3. Evaluation of the dimensions utilises the Aggregate Weighted Mean Index or AWMI for each dimension.

Table 2 Climate resilience measurement tools, (the Number of domains/indicators, and metrics used in each measure) Source: Summers et al. (2017)

Index	Indicators	Metrics	Index	Indicators	Metrics
Agriculture Resilience Index [*Ciani*, 2012]	11	27	Composite Measure of Ecological Integrity [*Vickerman and Kagan*, 2014]	22	22
Artic Water Resource Vulnerability Index [*Alessa et al.*, 2008]	9	22	Displacement Risk Index [*Esnard et al.*, 2011]	15	51
Baseline Resilience Indicators for Communities [*Cutter et al.*, 2014]	49	49	EJ Screen Index [*US EPA*, 2015]	12	12
City Resilience Index [*ARUP*, 2014]	12	12	Environmental Performance Index [*Hsu et al.*, 2016]	20	20
City Resilience Index to Sea Level Rise [*Abdrabo and Hassaan*, 2014]	6	13	Environmental Sustainability Index [*Esty et al.*, 2005]	21	76
Climate Disaster Resilience Index [*Joerin and Shaw*, 2011] [*Peacock et al.*, 2010]	2538	12082	Environmental Vulnerability Index [*Pratt et al.*, 2004]	50	50
Community Resilience Index [*Kafle*, 2012; *Renschler et al.*, 2010]	6	29	Flood Resilience Index [*Batica*, 2015]	43	91
Community Resilience Index for the Gulf of Mexico [*Baker*, 2009]	30	30	Flood Vulnerability Index [*Balica*, 2012]	19	19
Community Risk Index [*Daniell et al.*, 2010]	27	46	Household Resilience Index [*Cassidy and Barnes*, 2012]	16	16
Composite Measure of Coastal Community Resilience [*Li*, 2011]	6	27	Metrics for Community Resilience to Disaster [*Burton*, 2015]	22	75
Composite Measure of Community Resilience [*Meher et al.*, 2011]	52	130	Resilience Factor Index [*Ainuddin and Routray*, 2012]	16	17
Composite Measure of Regional Resilience [*Martini*, 2014]	7	27	Resilience Inference Measurement Model [*Li*, 2013; *Lam et al.*, 2016]	10	33
Composite Measure of Resilience to Disasters [*Kusumastuti et al.*, 2014]	22	63	Sustainable Society Index [*van de Kerk and Manuel*, 2014]	21	21

Table 3. Urban/City Dimensions for flood resilience assessment

Dimension	Meaning/Description
Physical	For each sub variable the variable availably is evaluated according to structural measures protection, communication network (telephone, internet, transport…), human safety (ex. emergency shelter), equipment for service and available networks in building location.
Natural	Describes the space where urban area is located with different ranges for variables: available water bodies, percentage of existing slope or flat areas, drainage density, rainfall duration, existing watershed
Social	Also, explore available resources, health status, knowledge and flexibility as well as connections within the community
Economic	Increase of households is in line with population growth rates. Employment is a direct link to economic growth of the area and triggers urban growth. This implies that that long term benefits of planning policies disaster management and mitigation plans are important tools for increasing resilience and reducing losses
Institutional	Existence of flood management plans, policies, regulations, evacuation plans. Is the population in this area taken into account for existing migration plans for the emergency

In addition to that, a structured questionnaire, with closed questions and ratings of 0-5 is developed and administered to city council (local authority) officials. The questions are tailor-made to fit into the 5R for integrated FRM inquiry. The questionnaire is created to describe all dimensions of the system which are evaluated using the Aggregate Weighted Mean Index or AWMI (for each dimension). The resulting values for the index have ranges described in table 4. Each dimension (natural, physical, social, economic, institutional) corresponds to various variables for resilience measurement (Batica & Gourbesville, 2014).

2.8 Unpacking flood resilience strategies – systematic review

The systematic review renders characteristics that enable deeper research synthesis (Berrang-Ford et al., 2015). Systematic reviews can be broadly defined as a type of research synthesis that is conducted by review groups with specialized skills, who set out to identify and retrieve international evidence that is relevant to a particular question or questions and to appraise and synthesize the results of this search to inform practice, policy and in some cases, further research (Aromataris & Pearson, 2014). A comprehensive systematic review is able to assess all available literature on a particular subject using a defined search strategy (Lichtenstein et al., 2008). Systematic reviews help to draw conclusions based on multiple studies and offer trends while also express conflicting results across different studies (Smith et al., 2011). Berrang-Ford et al. (2015) reported that the methodology was first coined within the social sciences, then commonly used in the health sciences and related disciplines; and further acknowledged that other disciplines do apply the methodology too. This review methodology was selected for use in this study based on its broad indications as enlisted by Munn et al. (2018) that systematic reviews: uncover the international evidence, confirm current practice/address any variation/identify new practices, identify and inform areas for future research, identify and investigate conflicting results and produce statements to guide decision-making. The technique enables knowledge synthesis of what already exists and is known on a subject as we try to answer a new research question. A Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) diagram can be used to display literature search results at various stages of analysis. In this study the PRISMA diagram was applied, figure 9. Munn et al. (2018) further informed, that as a process the systematic review follow this array of procedure; (1) definition of the research question and scope of the study, (2) document selection, including development of inclusion and exclusion criteria, (3) critical appraisal of study quality, (4) analysis and synthesis of evidence, quantitative and/or qualitative, and (5) presentation of results. In this case, the last specific objective and research questions are part of the procedure, step number 1, where the research question was defined.

CHAPTER THREE: MATERIALS AND METHODS

3.1 Introduction

This section describes the study area, type of the study and its process leading to derivation of data for analysis and proposed actions. The study applied mixed methods, where survey design involved use of a questionnaire and key informant interviews (KII), while other secondary analysis methods employed review of literature. Both methods required stationery materials, such as envelopes, plain papers, printing services and internet use. Most significant expenses were those of questionnaire administration and data access for literature review. Thus, to be specific, the three specific objectives in the study applied different methods of data analysis: first two, statistical analysis and last one, systematic review.

3.2 Blantyre City

Blantyre City, Malawi is the study city in this research. It has been selected based on its size as one of the Malawi's two largest Cities, the economic and industrial hub for Malawi and its history of being flood-stricken. It is located in the Southern part of Malawi, has a population of 800,264 people,191,676 households and is the second largest city after the capital Lilongwe (National Statistical Office - NSO, 2018). Its specific location on the globe is within 35^0 00' 20.10" to 35^0 07' 15" East and 15° 42" to 15^0 53' 05" South and is the oldest city in Malawi and Southern Africa. The map of Malawi (Figure 7) shows the location of Blantyre City. The City covers an area of 228 square kilometres on a hilly and rugged terrain with an elevation of about 780 to 1,612 metres above sea level (Blantyre City Council, 2015b; Zeleza & Eyoh, 2003).

The City is Malawi's hub for commerce and industries, (Maoulidi, 2012). In terms of transport network, it links to all parts of Malawi, as well as to the neighbouring countries of Mozambique, Zimbabwe, South Africa, Zambia, Kenya, and Tanzania, by road, rail and air. The climate of Blantyre City is classified by Köppen-Geiger climate classification system as a Tropical climate, more specifically a Tropical Savanna Climate (Blantyre City Council, 2015b; Zeleza & Eyoh, 2003). This climate is greatly influenced by its location in the tropical zone and altitude which lead to tropical continental climate with two distinct seasons in the year, characterised by light drizzle in the cold dry season, called Chiperoni, caused by moist maritime air. Temperatures are cool, ranging from an average of 13^0C in the cold season to 21^0C in the hottest months of September, October and November (GoM, 2017). The rainy season is from November to April, with continuing light cold showers locally known as Chiperoni from the end of May to July; the dry season is from May to October. In terms of rainfall, the City receives average rainfall of 1,122mm per annum of which 80% falls within 3 $^{1}/_{2}$ months between November and March (Blantyre City Council, 2015b; Zeleza & Eyoh, 2003).

Being on a hilly terrain comprising Soche, Ndirande, Michiru, Sanjika, Nyambadwe, Bangwe Mpingwe and Mzedi Hills, the City is characterised by various drainage channels which catch water to lower areas then to the River Shire (Blantyre City Council, 2015). The rivers in Blantyre City arise from the mountainous terrain forming a natural drainage system with nine distinct catchment areas: Likhubula, Lunzu, Mombezi and Khombwi, which drain the northern part of the city; and Mudi, Chisombezi, Limbe, Luchenza and Mwampanzi draining the middle and southern parts (Appendix 2). The rivers arising from the hilly areas, are therefore narrow and deep which widen as they run farther from the city area. The main rivers include; Nasolo, Mudi, Naperi, Marambalala, Malingamoyo, Luchenza, Chisombedzi, Limbe, Chirimba, Likhubula, Matabi, Lunzu and Mombesi Rivers (Blantyre City Council, 2015). These catchment characteristics can be attributed to being the principal cause of increased occurrence and impact of flash flooding, as the velocity of rainwater is higher than on lower river courses. In addition to that, Blantyre City has relatively higher rainfall, representing 45% of the maximum National average which raises likelihood of flooding in the city especially in the low-lying areas.

Rapid urbanisation has been rated a problem for all Cities in Malawi because of their limited coping capacities which makes these cities victims of informal housing sector upsurge (GoM & GSURR, 2016). Weak infrastructure resulting from the settlement patterns and low income levels, in terms of housing is a chief cause of disaster catastrophes' deaths and losses of household property (United Nations & Mpoola, 2011; Blantyre City Council, 2019a). On a further note, the City's geographical features such as topography, geology and hydrometeorology expose it to hydrogeological hazards and disasters (Blantyre City Council, 2018).

National and local efforts to manage the climatic and anthropogenic hazards and catastrophic events in the City exist, where the DoDMA and BCC engage in different platforms and implement frameworks for building disaster resilience (Blantyre City Council, 2019b). Figure 8 shows urban land use, natural and topographic features on the map of Blantyre City.

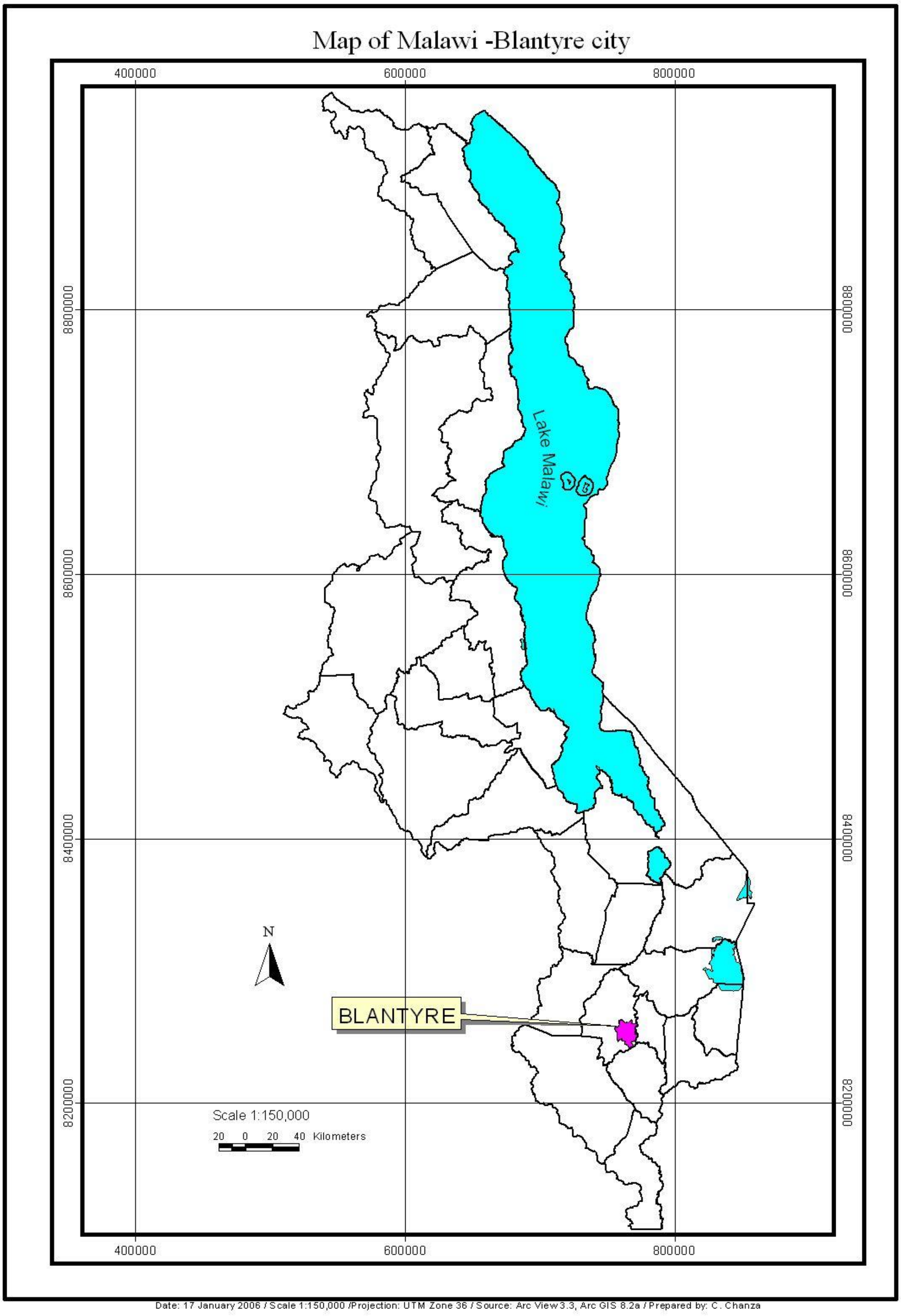

Figure 7 Map of Malawi showing position of Blantyre City. Source: Blantyre City Council (2015).

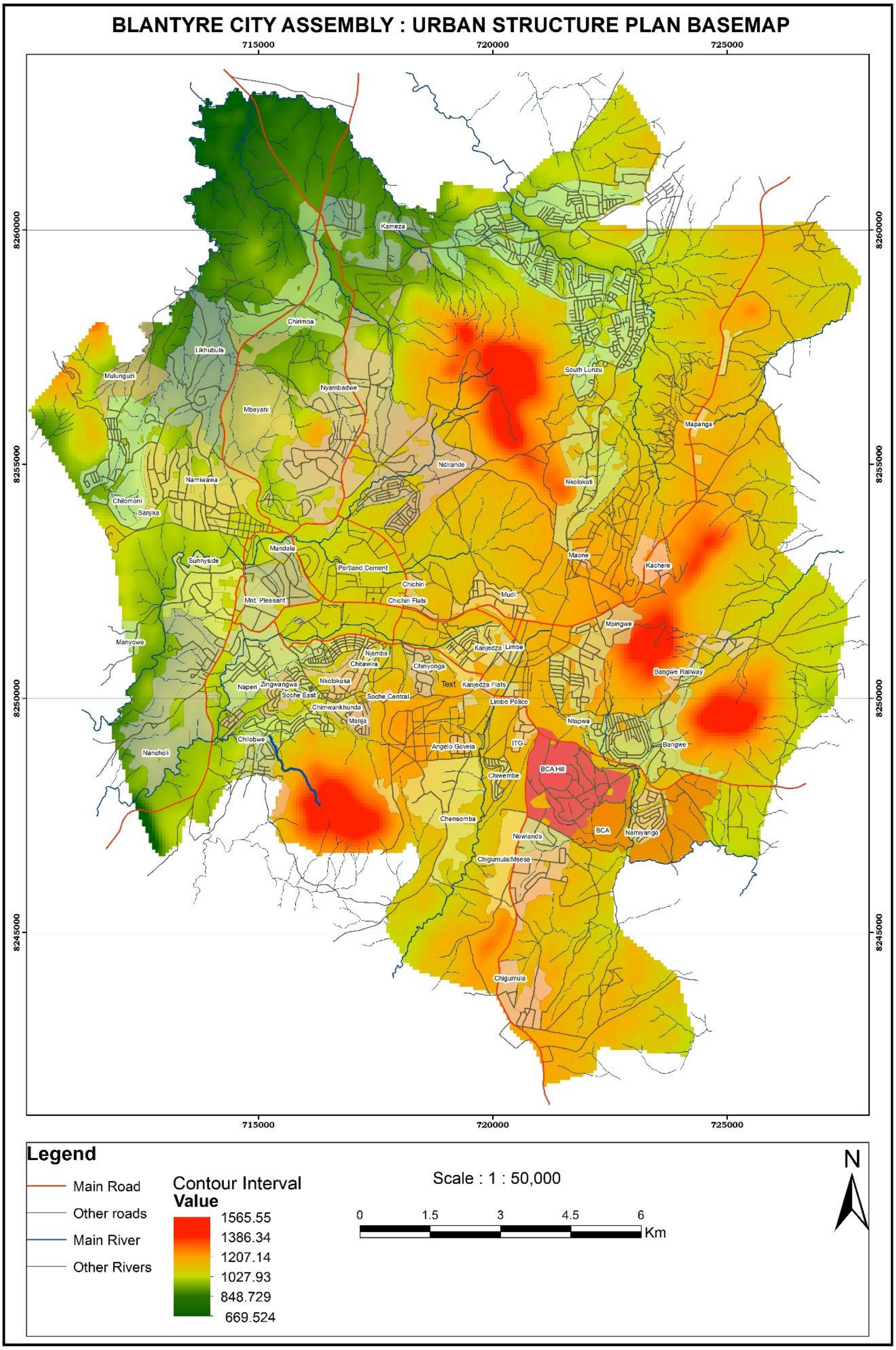

Figure 8. Map of Blantyre City showing, natural and built environment including topography, accessibility, and land use plans. Source: Blantyre City Council (2015).

3.3 Determination of City dimensions of Blantyre City

To find the levels of City dimensions for Blantyre City, primary data were collected and analysed. Specifically, the data were collected by administering a questionnaire to key informants. Firstly, a questionnaire was developed focusing on city dimensions of natural, physical, social, economic, and institutional under which were variables corresponding to each dimension as in Table 4. This process was performed to answer the question, what are the levels of urban dimensions for Blantyre City: physical, social, natural, economic, and institutional?

Table 4. List of variables considered in FRI five dimensions

Dimension	Variable
Physical	electricity, environmental degradation, water supply, sanitation, solid waste disposal, internal road network, housing and land use, community assets, warning system and evacuation, history, location, accessibility, infrastructure, and utilities
Social	population, health status, education and awareness, social capital, knowledge and awareness
Economic	income, employment, households' assets, access to financial service, savings and insurance, budget, and subsidy
Institutional	internal institutions and development plan, effectiveness of internal institutions, external institutions and networks, institutional collaboration, and coordination
Natural	topography, hazard intensity, hazard frequency, natural environment degradation, hydro-meteorological situation

3.3.1 Questionnaire design

The questionnaire was devised in structured and undisguised format; the questions were clear, direct, and sequenced in a logical order to allow smooth transition from one topic to the next. Topics were subdivided according to the dimensions under study which were characterised by their corresponding variables that in turn determined the questions. The questionnaire, with 115 questions filled by average scores from the five participating institutions is attached as Appendix 1.

Research assistants were engaged to assist with the questionnaire administration, who were given an introductory orientation to ensure deeper understanding and uniformity in performing the tasks. In addition to their technical and administrative work of questionnaires, they were taught to protect the data by placing the questionnaires in sealed envelopes labelled, “private and confidential” and in locked or and not easily accessible places. To allow easy administration, coding and analysis, and also according to the FRI method, questionnaire was close ended, which dominates application of quantitative manipulation. To guide respondents in assigning weights to variables and to measure the degree of difference in terms of resilience for each variable, ordinal-ranked scale (five-point Likert scale) was assigned to each of the questions, where 0 meant nothing available, 1 meant the lowest level and lowest application of the variable (the factor in the question) and 5 the highest score for highest or full application of the variable.

The questions were based on flood residence topic, mostly probing participants’ knowledge, and experience. Beforehand in the introductory stages, classification and identification questions were asked. To ensure reliability and validity of responses/results wording of questions was precise and unambiguous, thus short, simple, and single-barrelled. The questionnaire was further improved by subjecting it to a pilot survey before actual administration.

3.3.2 Sampling technique

Clear understanding of study variables and city dimensions (table 4) enabled determination of the relevant respondents, leading to a pre-determined respondent. Thus, the participants for the study were non-probabilistic and purposively selected using expert sampling method. The FRI method recognise city officials only as relevant experts for the survey but in Malawi city service delivery is shared with other institutions, which were hence considered. These institutions were those involved in urban governance, climate change and environmental management and DRM. These institutions apart from the BCC were Malawi Housing Corporation (MHC), Ministry of Lands, Housing and Urban Development (MoLHUD), Department of Disaster Management Affairs (DoDMA) and the Environmental Affairs Department (EAD).

3.3.3 Mode of delivery of Questionnaire for FRI Assessment

Questionnaires were administered in face-to-face interviews and electronic delivery, where applicable. Initially, respondents were contacted to build rapport and raise motivation for them to participate in the survey. Where respondents were outside Blantyre City, e-mail was mostly utilised as opposed to those that were within the City. At an institution, a courtesy call was arranged where the head of the institution or their representative was contacted or met to participate. Where the institutional head or their representative identified the relevant officer, they were requested to participate.

3.3.4 Error management

Efforts to minimise errors, such as non-response errors were made by building a better rapport with respondents and making reminders, by phoning, e-mailing, and doing physical follow ups. All respondents gave out their full participation and required feedback.

3.3.5 Questionnaire data management and computation for city dimensions' evaluation

Seal-enveloped questionnaires were opened and the data from the five institutions entered using a password protected personal laptop computer. Those that were administered in electronic form were password protected. Since the FRI utilises statistical measures of central tendency (simple statistics), Windows Microsoft Excel ® 2013 (Excel 2013) was utilised to compute and analyse the data and the resulting file also protected by encryption.

3.4 Determination of the Flood Resilience Index (FRI)

Evaluation of the City's resilience was done through the Flood Resilience Index Method. Data captured in Section 3.3 (city dimensions) were further subjected to statistical analysis using a formula for FRI evaluation shown in Section 3.6.

3.5 Exploration of flood resilience strategies for Blantyre City

To explore flood resilience strategies for Blantyre City, the questionnaire responses and literature review using a systematic review methodology was applied, thus utilising primary and secondary data from the literature pools. A Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) diagram was utilised under this objective to display literature search results at various stages of analysis. The experts' knowledge evaluated in the questionnaire was also used to concretise strategies in place for Blantyre City and align them to those in the literature.

3.5.1 Literature search process for FR Strategies

The review applied systematic literature search to answer the question on the recommended FR strategies in cities by utilising three electronic databases and search engines. These sources, Research4life (HINARI), Google Scholar and Google Search were used because they contain a greater depth of literature, are inclusive and easily accessible databases, where specific keywords were utilised. The keywords and combination phrases were determined in advance from the research question. The search threads with key words and phrases were, “flood resilience strategies" OR “flood resilience methods" OR “flood resilience mechanisms" OR “flood resilience measures" AND city OR cities OR urban, which were entered in the search engines and databases mentioned. The data searching was done in the month of December 2019 with the final search performed on 26th December 2019.

Sources of literature targeted were peer reviewed or published journal articles, books (book chapters) and international organisations’ reports. These sources therefore included the research-based peer-reviewed facts and realistic practices from implementing entities of the FR strategies. In terms of time specification, five (5) years period was selected to capture comprehensive and recent data, thus 2014 to 2019.

3.5.2 Eligibility criteria for inclusion and exclusion of literature

The gathered literature was grouped into relevant and irrelevant for further processing. Inclusion and exclusion criteria were as described in Table 5. All subheadings from the selected papers were included and results limited to the English language.

Table 5. Eligibility criteria for literature sources

Include	Exclude
• papers which enlist flood resilience strategies • papers which discuss specific flood resilience such as engineering structures or systems or non-engineering aspects	• papers which do not discuss resilience strategies • papers which do not enlist resilience mechanisms • papers which discuss resilience strategies for other risks (unlike floods) or climate change in general

Later, abstract, and full-text reviews followed. The abstract review ensured that articles that were selected from the search process got checked to confirm potential relevance to the question and allow for further full-text review. Full-text review of articles that passed the abstract review was performed and then flood resilience strategies were lastly extracted and enlisted.

3.6 Data analysis

3.6.1 City dimensions for Blantyre City

To find the indices for city dimensions, ratings of respondents to the questionnaire were used. Questionnaire data in form of the ratings 0 to 5 for each question were computed in Excel 2013. Aggregate Weighted Mean Index (AWMI) for each dimension was calculated by using the Weighted Mean Index (WMI). The calculated AWMI of one dimension represented the FRI for that dimension. The WMI was calculated by summing the product of the weights (given by respondents) to the index of each variable (obtained from the sum of rating scales under any given variable divided by the number of elements) and finally dividing the whole by the number of variables in each dimension. Weights assigned in this study for each dimension were as follows: physical 25, natural 10, social 20, economic 30 and institutional 15 which was based on number of variables and their corresponding questions.

3.6.2 Flood Resilience Index for the City

Appendix 3 shows data and formulae used for the analysis. Overall FRI values were obtained after averaging each of the five dimensions' indices. To find FRI, formulae $\sum w_i$; $\sum(x_i*w_i)$; and $\sum(x_i*w_i)/\sum(w_i)$ were used, where: w_i is weight assigned for each dimension determining the value of each variable (question) and x_i is the index of a variable. This FRI entails the level of flood resilience, which can be analysed as being very low, low, medium, or high, according to the scale in Table 6 below.

Table 6. Scales for Flood Resilience Index

FRI level	Description
Very low 0-2	The activities are not clear and coherent in an overall flood risk management (5R). Awareness is very low on the issues and motivation to address them. Interventions have a short-term character. Actions limited to crisis response.
Low 2-3	Awareness of the issues and motivation to address them exist. Capacity building of human resources remains limited. Capacity to act is improved and substantial. Interventions are more numerous and long term. Development and implementation of solutions.
Medium 3-4	Integration and implementation of solutions is higher. Interventions are extensive, covering all main aspects of the ‘problem’, and they are linked within a coherent long-term strategy.
High 4-5	A ‘‘culture of safety’’ exists among all stakeholders, where the resilience concept is embedded in all relevant policies, planning, practice, attitudes, and behaviour.

3.7 Flood resilience strategies

3.7.1 Selection of relevant study sources

Analysis of sources identified in the search process was done as illustrated in the PRISMA flow diagram in figure 9 for the systematic review process. Data extraction was performed from articles that were selected from the above search and analysis process. Initially, duplicates and irrelevant titles were removed leading to abstract or introduction or executive summary screening. The criterion for abstract inclusion was that the articles be based on the theme of flood resilience and that the content enlists flood resilience strategies. However, enlisting some flood resilience strategies was the major determinant for inclusion than the theme, such that absence of clear resilience strategies resulted to exclusion even if the theme was flood resilience.

3.7.2 Analysis of selected resilience strategies

FR strategies were extracted from the 39 selected literature sources. The strategies were categorised into two broader groups, structural or engineering and non-structural or systematic strategies. These groups were further split into those for all flood types (including flash floods) and other floods (excluding flash floods) as shown in figure 16. More to that, the strategies were tabulated as in appendix 6 with coding “All” for all flood types and “Other” for other flood types.

From the 39 selected sources (Table 11), more than 200 strategies were identified and presented in table 12 which shows authors against FR strategies they cited. Some strategies were mentioned by more than one author and some authors also indicated more than one class of strategies. This is where one author is cited under both columns of the table, structural and non-structural. However, another analysis by expert judgement was done to isolate all the strategies and present them once, regardless being repeatedly mentioned by different authors and thus presented in tables 9 and10 and further discussed under the results and discussion section.

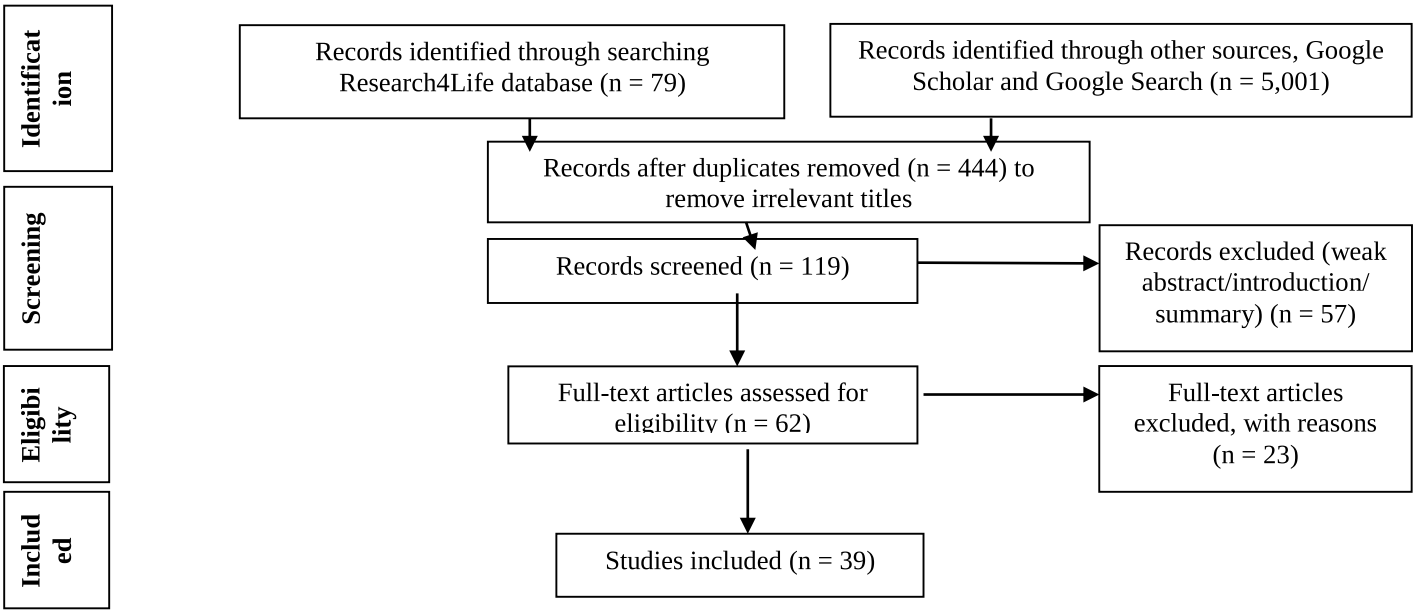

Figure 9. PRISMA diagram showing studies selected for systematic review and selection criteria

3.8 Limitations of the study

In this work noticeable limitation include was lack of relevant data cities in Africa and Malawi which share common characteristics with Blantyre City. This affected comparative analysis of its performance to similar cities. In addition to that, use of KII strategy made data acquisition a challenge when respondents failed to submit within the set time scale.

3.9 Ethical issues

In this paper ethical aspects were considered and addressed, which included the confidentiality of participants that played a role of respondents during the questionnaire survey. There was official identification of people as survey respondents or participants, other than survey subjects. Gender, health status, ability status and other characteristics were also treated with confidentiality.

Further to that, the participants in the survey were well informed that the study is academic and only befitting related or academic motives and that they were only participating to present and express their full expert knowledge on resilience of cities to floods and FRM. At data analysis individuals that represented institutions which were purposively selected had their names hidden and only that of the institution represented appearing. Lastly, the questionnaires had important introductory guide to direct the research team and respondents well in advance before they tackled the work.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Introduction

In this chapter, findings are presented for all the three specific objectives. The objective on levels of urban dimensions and FRI are presented in tables and figures while resilience strategies are presented in tables and plain text. The other aspect of this chapter is discussion of the results based on the analysed data.

4.2 Levels of city dimensions for Blantyre City

4.2.1 Results for city dimensions for Blantyre City

Calculated City Dimensions gave out results as in table 7. The dimensional variables are also displayed in figures 10 to 14. Each variable contributed to the dimensional index based on response ratings given by the experts that participated.

Table 7 Dimensional weights and indices

Dimension	∑wi	∑(xi*wi)	Dimension Index ∑(xi*wi)/∑(wi)
Physical	25	45.85	1.83
Natural	10	17.43	1.74
Social	20	48.74	2.44
Economic	30	56.71	1.89
Institutional	15	29.01	1.93

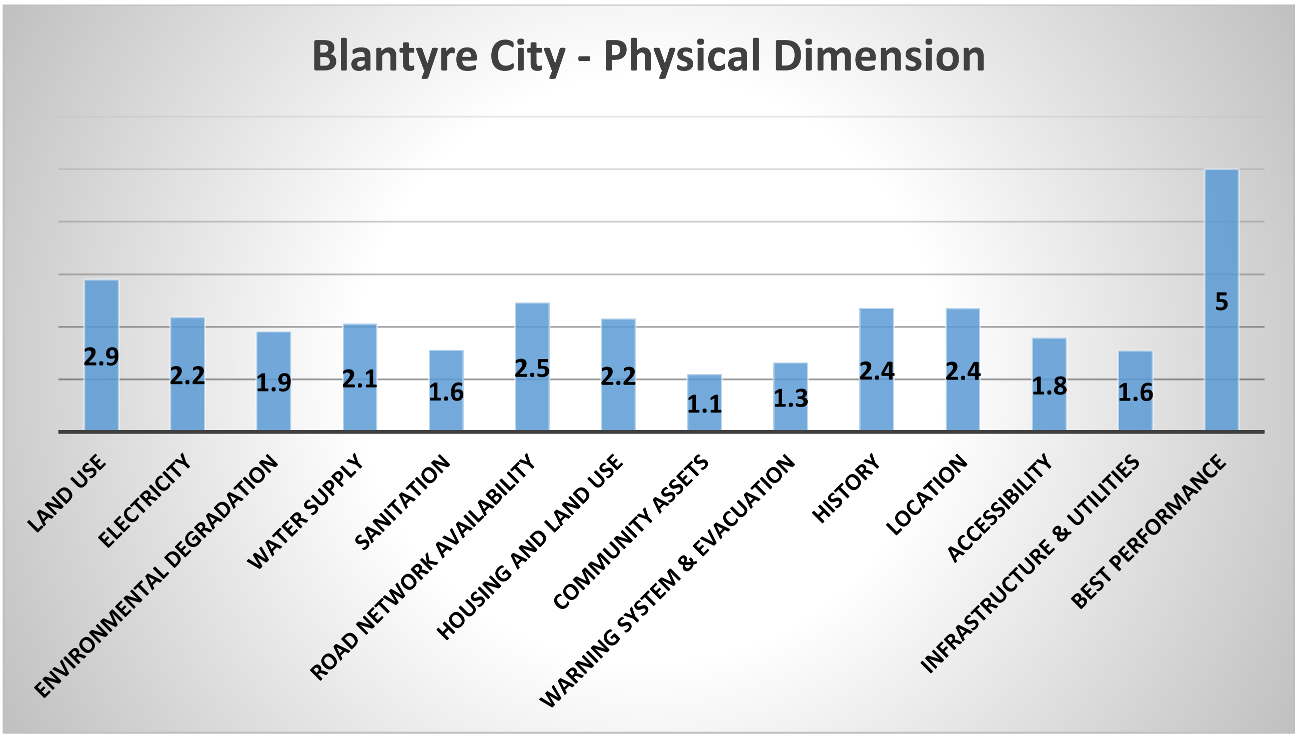

Figure 10. Physical City dimension - indices of individual variables

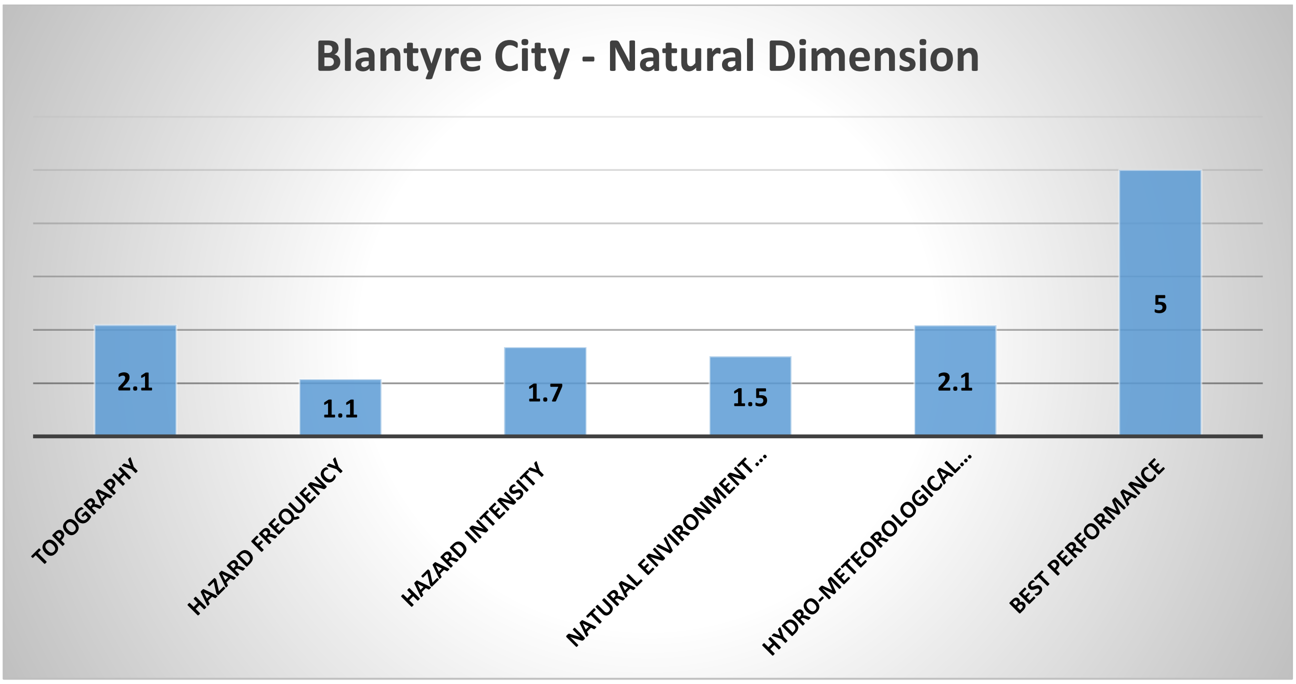

Figure 11. Natural City dimension-indices of individual variables

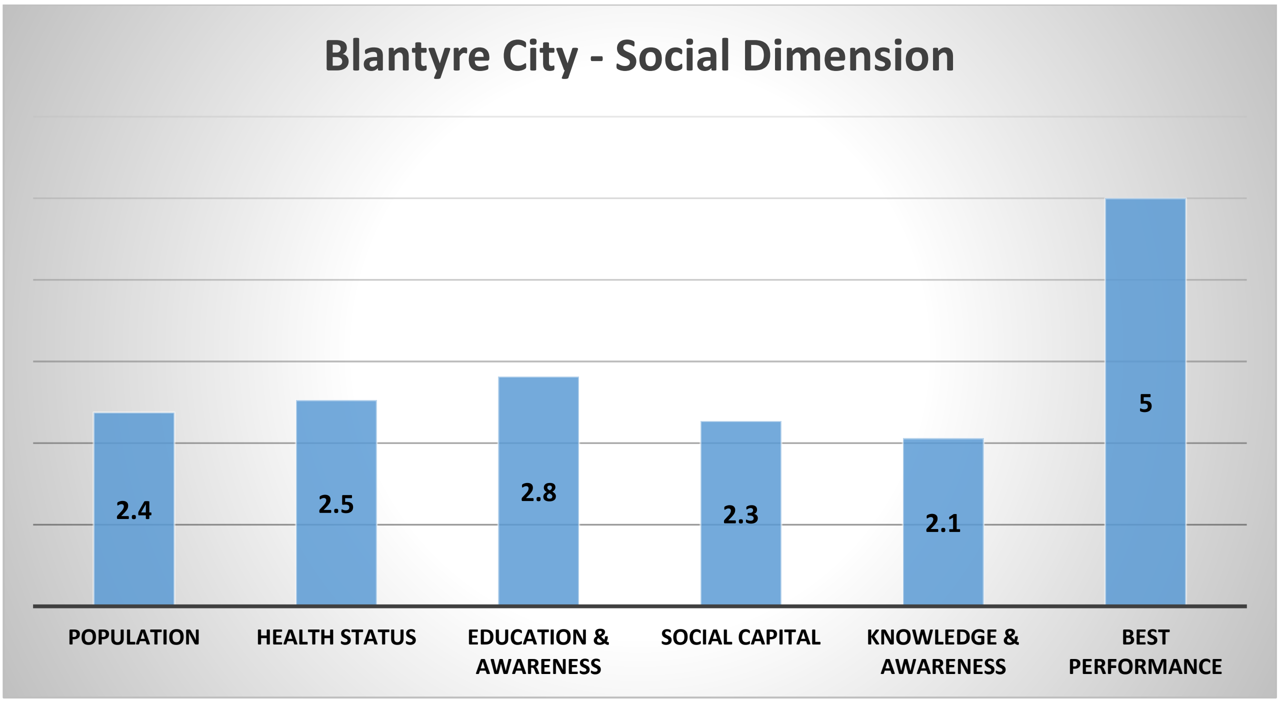

Figure 12. Social City dimension-indices of individual variables

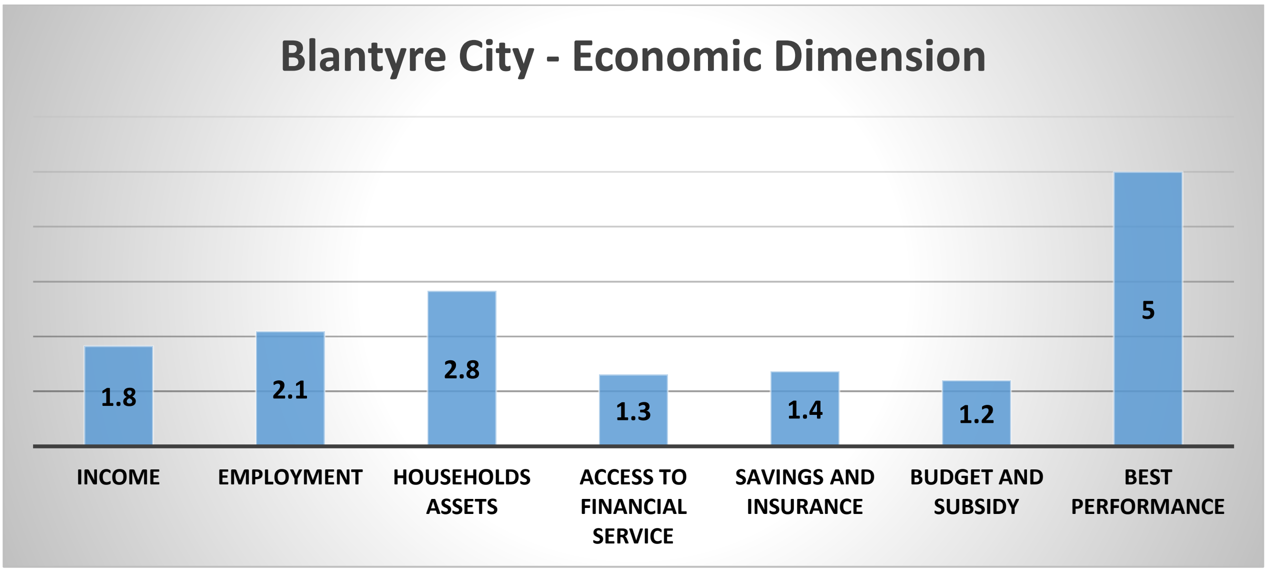

Figure 13. Economic City dimension - indices of individual variables

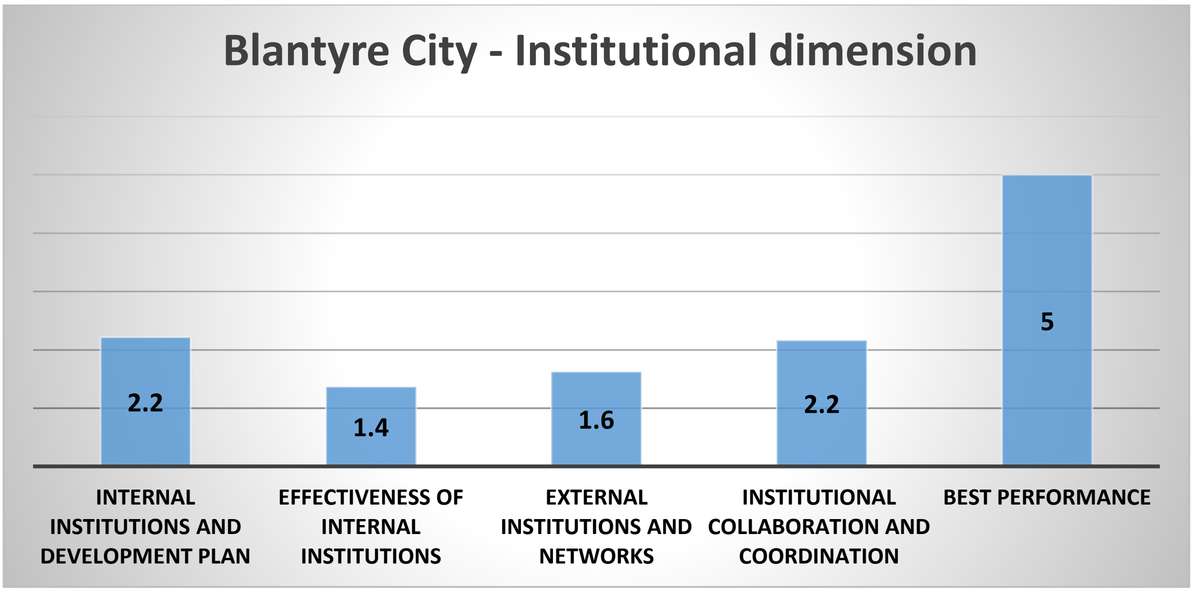

Figure 14. Institutional City dimension - indices of individual variables

From the table 8, the highest dimensional index is for social dimension, followed by institutional, while the least is the natural dimension. Under each dimension, the best variable performance is 5. None of the variables scored 5 and those that performed at least half-way were only 5 out of 33 variables, namely: land use and road network availability (physical), health status and education and awareness (social) and household assets (economic).

4.2.2 Discussion for City dimensions for Blantyre City

In this study, variables with ratings of below 2 (below 40%) were discussed and recommended to be improved to contribute to an improved the City's dimensional and overall resilience levels. The discussions are based on variables and individual questions in the questionnaire.

4.2.2.1 Physical dimension

Under physical dimension, land use planning and implementation is recognised as playing a pivotal role in FRM and done by the BCC, MHC, and GoM through MoLHUD, which is further reflected in its (BCC's) Urban Structure Plan and Strategic Plan (Blantyre City Council, 2015). However, the plans seldom highlight the existence and significance of flood hazard and FRM aspects, of which there is need to incorporate and explicitly expound on to ensure priority-setting.

Other variables under this dimension that required enhancing were environmental management services such as urban forestry and environmental enforcement, robust community assets' creation and maintenance such as disaster/emergency operation centres and standards enforcement on construction of infrastructure and sanitation services, especially on solid and liquid waste disposal. On warning systems and evacuation, there is need to develop a robust EWS that should be user-friendly, modifiable, and highly decentralised. In addition to that, the city should have purpose-built evacuation centres with ease of access and be well maintained. In terms of services' accessibility, the City always requires rescue facilities with clear system procedures and transport links for ease of access.

Under the variable *infrastructure and utilities*, there is need to protect critical infrastructure such as hospitals, schools, water supply systems and marketplaces from floods. Additionally, designs for building infrastructure should consider flood and water proofing. Further to that, waste management infrastructure should be adapted to operating during and after floods. Lastly, the city requires enhanced flood recovery mechanisms that embrace timely building back better and smarter (BBBS) after floods.

4.2.2.2 Natural dimension

Regarding the natural dimension of the city, three variables, hazard frequency, hazard intensity and natural environmental degradation need significant focus. In terms of hazard frequency and intensity, floods seem to occur frequently, hitting the City harder than before, according to the experts' knowledge and experience. This therefore necessitates institution and mainstreaming of integrated FRM in the City's governance.

On natural environmental degradation, fragile areas are reported to have been encroached with settlement, farming, and other human activities. Such flood hotspots are supposed to be conserved with natural and nature-based infrastructure (NNBI) to mitigate the flood risk. The city managers are supposed to ensure compliance to protection of fragile areas and control of human activities that are detrimental to the state of the already fragile areas. In addition to that, deforestation being a national-wide and global contemporary issue, Blantyre City is also facing it, where inhabitants seek cheaper energy sources and building materials from forest resources, which exacerbates the flood risk. There is therefore need that the city governance embraces designation, restoration, and management of nature-enhanced areas.

In terms of waste management practices, waste which is not well disposed of does drain to rivers and other drainage channels. Solid waste blocks drainage channels thereby limiting their draining capacity, which in-turn leads to localised floods. Improved waste management services are therefore imperative for the city.

4.2.2.3 Social dimension

Regarding the social dimension, knowledge and awareness required up-scaling. Information including plans on flood risk and flood events is rarely shared with the local community in the City's wards. City authorities need to ensure disaster risk knowledge-sharing is practised and be made or incorporated into relevant policy. In addition to that, there is need to raise community participation in DRM/FRM and embrace a blend of top-down and bottom-up approaches (Kita, 2017).

4.2.2.4 Economic dimension

Key aspects to consider under economic dimension include income; access to financial services; savings and insurance; and budgets and subsidies. In terms of income, national indices describing individual citizens indicate a significant proportion of Malawians living below the poverty line (International Monetary Fund, 2017); the very same applies to the urban poor (United Nations & Mpoola, 2011). In addition, and as a matter of cause, income sources in the city are not much diversified which has negative bearings in case of economic or political failure. Thus, poverty alleviation policies and practices are required, for example improved frameworks on small and medium scale enterprises and diversification of income sources for City residents, such as a "must do" business policy.

Another source of low economic performance is that the very little household income and assets are seldom protected from flood damage. This is exacerbated by weak household infrastructure and ineffective financial risk sharing such as banking. The city inhabitants need to be considered on income protection and banking. Considering the access to financial services for flood prevention and preparedness, credit facilities for the vulnerable are not ring-fenced, and adequately accessible for such. There is need to create and diversify access to financial services for FRM.

The other weakness is that financial services are dismally utilised and only for the sole purpose of survival and other uses considered "development" but not for DRR. Further to that, on saving and insurance, most property and household assets are not insured against risks. There is need to implement a property and household asset protection fund. Making the situation worse, it has been noted that the "savings culture" where income consumption is spared for later use and/or investment, is not a priority by most of the City's inhabitants.

Lastly, regarding budgets and subsidies, DRM programmes do not receive sufficient financing and most of BCC's budgetary priorities do not place DRM a priority. There is need for devolution of DRM financing to the Council of which the Council requires to particularly ring-fence all such financing for the DRM programmes. On a similar note, resilient infrastructure can require more resource investment for both construction and maintenance; it is required that there be subsidies sufficient to ensure resilient infrastructure development, such as for housing and other critical infrastructures.

4.2.2.5 Institutional dimension

The last dimension, institutional dimension, variables that scored very low included effectiveness of internal institutions and the work of external institutions and networks. Concerning internal institutions, BCC instituted DRM committees (Civil Protection Committees – CPCs) including a DRM desk officer, but the committees have not been adequately trained in DRM such that there is a need to build technical capacity for the committees in place. As a result of limited committees' knowledge, they seemed not active in responding to flood emergencies.

Another internal element is the central level decision making which is satisfactorily a role of BCC's controlling office. There is need to improve priority in FRM programmes through political will and mainstreaming because impacts of flooding impair the service provision mandate of local and national authorities, significantly. Further to that, external institutions that support socio-economic development of the city better mainstream DRM in their programmes to amplify the DRR.

4.3 Flood Resilience Index for Blantyre City

4.3.1 Results for Flood Resilience Index for Blantyre City

In the analysis, the flood resilience index for city dimensions: physical, social, economic, natural, and institutional as shown in the previous section were calculated. The mean derived from the five-dimensional indices gave out the final index, the FRI. Calculations for the FRI are as summarised in Table 8 and Figure 15 shows a polygon/web diagram showing dimensional resilience indices and the final FRI for the study City.

Table 8. Dimensional weights and calculation of FRI

Dimension	**w_i**	**$x_i * w_i$**	**Dimension Index x_i**	**Overall FRI (Mean of dimension indices)**
Physical	25%	45.85	1.83	
Natural	10%	17.43	1.74	
Social	20%	48.74	2.44	**1.97**
Economic	30%	56.71	1.89	
Institutional	15%	29.01	1.93	
Sum	**$\sum w_i$ =100**	**$\sum(x_i * w_i)$ = 197**	**$\sum(x_i * w_i)/\sum(w_i)$ = 1.97**	

The degree of these dimensional indices average out to give an overall resilience index of 1.97, the FRI for the City.

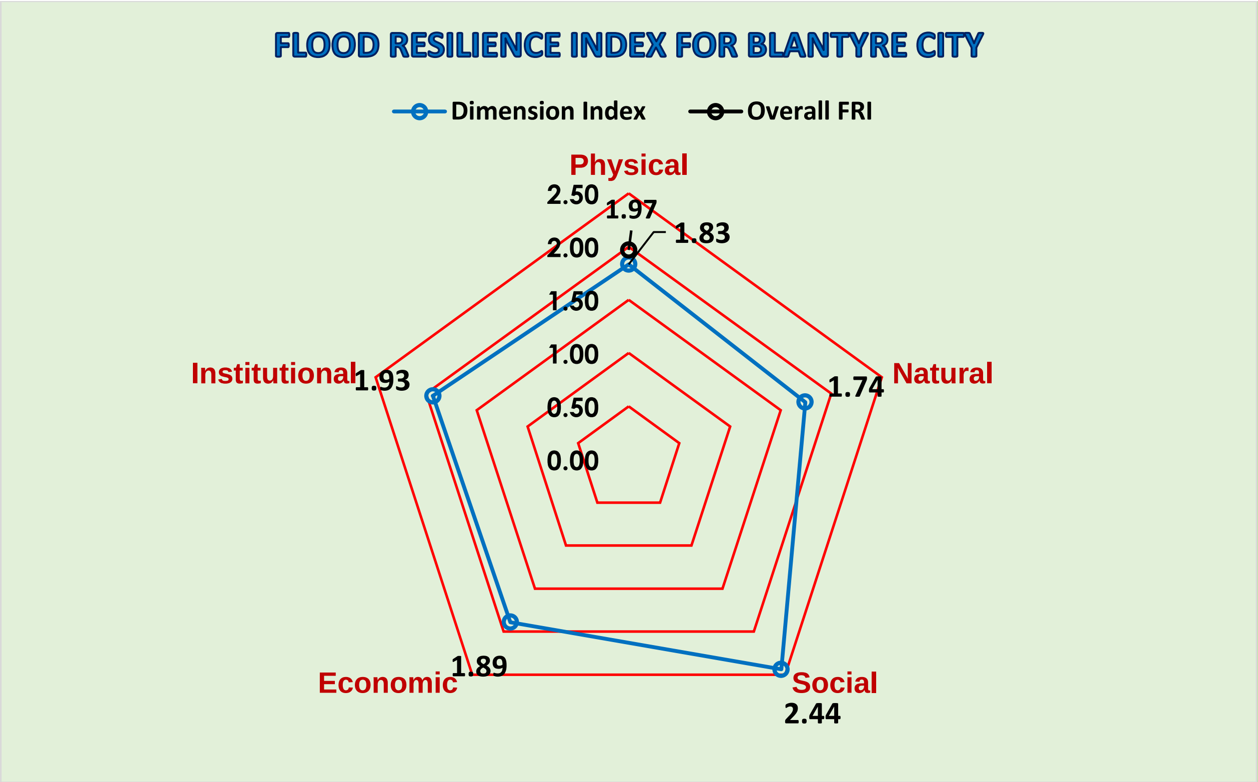

Figure 15. Results for flood resilience indices for Blantyre City

4.3.2 Discussion for flood Resilience Index for Blantyre City

According to the set scale of 0 to 5 with four levels (Very Low, Low, Medium, and High), 1.97 represents 49.19% flood resilience. This meant that certain variables show lack of and low availability hence lowering the resilience indices. In that context, for Blantyre City to achieve full flood resilience (to fill the deficit), there is need to enhance determining variables with FRI at 3.03 which is equivalent to 50.81%.

As indicated in table 4, a level of 0-2 shows that most indicator variables in the questionnaire were rated *very low*, meaning that the Blantyre City's activities and features are not clear and coherent in an overall FRM (5R); awareness is very low on the issues and motivation to address them; interventions have a short-term characteristic; and that actions are limited to crisis response (Batica, 2015). More details on indicators and their variables are in the questionnaire attached as Appendix 1.

In other countries this assessment was carried out at different levels. City of Nice was assessed on FRI with the focus on both property FRI (micro) and city (macro) scale. Barcelona, Hamburg, Beijing, and Taipei Cities were assessed on macro scale as Blantyre City in this study and they showed different levels of flood resilience. The Cities had FRI performance of: Nice 3.45 (Medium), Hamburg 4.27 (High), Barcelona 3.51 (Medium), Beijing 2.48 (Low) and Taipei 3.05 (Medium), which are all on higher levels than that of Blantyre City. For City of Nice in France and on a micro-scale of assessment, there is a significant increase in FRI value for the implementation of flood preparedness measures on property/building level, specifically on flood-proofing, where water is prevented from entering buildings.

Hamburg City in Germany, with the high FRI of 4.25 already achieved high levels of dimensional indices, especially the social aspect. The only weakness was in the natural dimension (3.5). The City on borderline immediately above Blantyre was Beijing (2.48) in China. The lowest indicator was that of social dimension while under physical, land use planning which is a part of flood preparedness measures is contributing to increase of FRI for Beijing. The possible cause of discrepancy for Blantyre and other assessed cities is their wide varying socio-economic characteristics.

Cities like Blantyre, such as Lilongwe and other African Cities have not been assessed using the tool to give a comparative perspective with Blantyre City. However, this assessment is phenomenal, where milestones would be built for similar cities in relation to advanced Cities that utilised the FRI tool.

4.4 Suitable strategies for flood resilience for Blantyre City

4.4.1 Results on suitable Strategies for flood resilience for Blantyre City

The systematically selected 39 literature sources (Table 11) revealed that flood resilience strategies are either structural (engineering), which involve physical construction or non-structural (systems) strategies, which involve natural, social or behavioural, policy or legal and financial interventions (Berchum et al., 2019). These strategies, some are suitable for other types of floods such as riverine and coastal, while other strategies are for flash floods. The strategies in Tables 9 and 10 were extracted from the bulk list of strategies in the “flood resilience table” as shown in Table 12.

Table 9. List of structural flood mitigation strategies cited by different authors/writers

AUTHOR(S)/SOURCE	STRUCTURAL RESILIENCE STRATEGIES
(Climate Just, n.d.; Yumpu.com, 2019; POST, 2016; Egremont Scheme, 2018)	• Design and use of sustainable urban drainage systems (SUDS) (All) • Adaptive placement of indoor assets and fittings, such as electrical sockets be higher up the wall (1.5 metres) (Other) • Application of water repellents or resistant materials such as water-resistant skirting boards and horizontal plasterboard or lime-based plaster be used in preference to gypsum (Other) • Using flood resistant products including flood gates, airbrick covers and non-return valves for your bathroom, which prevent sewage coming up through the pipes (All) • Installing a stainless steel kitchen, using waterproof plaster, and installing concrete or floor tiles or floorboards instead of carpets since these are quicker and easier to clean and rugs may also be an option since these can be removed or replaced more easily (Other)
(POST, 2016);	• Catchment led approach – construction of water ditches and purpose-built reservoirs and embankments upstream which help to store water and reduce volumes flowing downstream (All) • Ensuring property resistance and resilience in terms of physical barriers and placement of valuable household items and accessories on raised platforms or walls (All)
(Moudrak & Feltmate, 2019; Flood Ark, 2017)	• Isolation of electrical circuits – for multi-level parkades, electrical circuits can be isolated for each parking level. (All)
(Aerts et al., 2014; Vojinović & Huang, 2014)	• Use of moderate local flood protection measures, such as levees and beach nourishment. The local protection measures and building codes for new structures are adjustable to future climate change, as they can be upgraded if flood risk increases in future. (All) • Structural measures involving physical construction and include: Soft structures – Sustainable Urban Drainage Systems (SUDs), Low Impact Developments (LIDs), Water Sensitive Urban Design (WSUD), Best Management Practices (BMP) (All)
(Berchum et al., 2019)	• Large, complex coastal regions often require a combination of interventions to lower the risk of flooding to an acceptable level. Structural and non-structural measures as one combination and damage restricting measures and changes in policy as the other. (All)
(White et al., 2018; White, 2018; Queensland	• Employment of permanent large scale measures which are flood alleviation schemes providing flood protection to the City. Common types are:

Reconstruction Authority, 2019)	◦ Schemes which involve raising of river banks providing a greater flow capacity before overtopping or inundation occurs (All) ◦ Schemes which provide an additional channel running parallel to the main river channel (All) • Permanent small-scale measures – providing permanent flood protection to individual properties or structures ◦ Gardens or site landscaping to divert flood waters away from the property (Other) ◦ Revised local drainage layouts (All) ◦ Low bunds around the site or property (All) ◦ Periphery walls/fencing (All) ◦ Flood resistant gates (All) ◦ Periscope air vents (Other) ◦ Outside wall renders and facings including veneer walling (Other) ◦ Resistant external doors (All) • Use of robust materials and finishes in construction (All) • Raising the minimum floor level of the property or development above expected flood levels (Other)
(Buxton, 2015)	• Publishing flood maps indicating the Flood Zones is very important as these flood zones indicate the areas that could be at risk of flooding from rivers or the sea but ignoring the presence of defences. (All) • Designing buildings for flood risk – building design improvements that can be used to reduce the effects of flooding. Different approaches can be implemented, depending on whether they are added to an existing building or constructed as part of a new building. (All) • Use of floating or amphibious structures. These are lightweight structures, which rest on a buoyant base or foundation designed to rise and fall with the level of the water. (Other) • Ensuring safe access and egress: particularly relevant for emergency vehicles, which are likely to be called upon during times of flood, and it is a key planning requirement (All)

Table 10. List of non-structural flood resilience strategies cited by different authors/writers

AUTHOR(S)/SOURCE	NON-STRUCTURAL RESILIENCE STRATEGIES
(Tagg et al., 2016; Krishnan et al., 2019)	• Undertaking regular updates of building regulations to ensure that all new or refurbished buildings in high flood-risk areas are flood resistant or resilient (All) • Institutional capacity development and programme targeting for FRM which helps, for example in allocation of substantial resources to managing risk (All) • Local authorities being able to support high flood-at-risk residents access loans and grants for home improvement (All) • Local authorities to ensure development of standards for building designs, construction and maintenance, including standards for undertaking flood risk assessment (FRA), internal buildings features and external retrofits should also encourage the take-up of property flood resistance and resilience by businesses (All)
(Rijke et al., 2016; King & Steinhilber, 2017)	• Ensure mainstreaming of flood risk management in projects (All) • FRM Financing – funds earmarked for flood risk management achieved through various initiatives such as competitions or donations (All) • Incorporating/Mainstreaming Sea Level Rise and Recurrent Flooding into Comprehensive Plan. (Other) • Decentralisation of resilience efforts – Resilience, at its heart, is a community issue, and many localities need to lead the way in developing and implementing flood resilience strategies. (All) • Institutional capacity development – establishment of FRM/DRM offices and staff in Cities authorities such as Norfolk, named in the Rockefeller Foundation's first round of "100 Resilient Cities" (All) • Utilizing university resources – forming strong partnerships and collaborations on diverse research projects with institutions of higher learning (All) • Integrations of tide gauges and other water level gauges (All) • Formulation of high resolution state-of-the-art street-level flood modeling (All) • Establishment of resiliency data portal for Flood Information Management Systems thus developing a data portal, such as the "Adapt Virginia," that integrates a wide range of resiliency resources for the commonwealth's agencies and local governments. (All)
(Vojinović & Huang, 2014)	• Application of initiatives such as ''Green Cities Development" which is about creating vibrant, environment-friendly, livable cities. Green cities development aims at holistic planning and management of water, flood, solid waste, storm water, and another wastewater. (All)

(Moon, 2015; Bonfield, 2016)	• Developing and utilising information portals for education and awareness such as independent web-portal that provides a one-stop shop for information on property level resilience (All)
(POST, 2016; Ronchi & Arcidiacono, 2018)	• Woodland planting in the upper river courses to reduce surface runoff and store water (All) • Green infrastructure within the city such as parks reduces runoff by increasing infiltration of rainwater (All) • Having 'sacrificial' storage area of excess water which in dry months could be used for other purposes such as playing field (Other)
(Ronchi & Arcidiacono, 2018)	• Green mitigation measures which are nature-based solutions such as: o Green roofs– roofs covered with vegetation placed over waterproofing material with drainage and irrigation systems. (All) o Green permeable paving consisting of pre-cast locks made of concrete or hard plastics with voids (All)
(Moudrak & Feltmate, 2019; Rinne & Nygren, 2016)	• Making plans and procedures readily available offer preparedness to flood disaster events. These may include emergency preparedness and response plans in place and include flood event procedures (All) • Practice drills for building operations staff – being trained in on flood event response procedures (All) • Having emergency funds in place for emergency operations (All) • Ensuring active communication channels for people's use such as toll-free lines and robust telecommunication infrastructure in cities (All) • Establishment and maintenance of Emergency Operations Centres (EOCs): designate space for building operations centre to use during emergency. This space is equipped with water, non-perishable food supplies and emergency kits and is located above expected flood levels (All) • Generating emergency response supply contracts for various goods and services affected by the floods (All) • Insurance documentation: documentation to access business interruption insurance (e.g., financial statements, lease agreements and inventory counts) regularly updated, backed-up electronically and stored offsite (All) • Equipment and supplies for use need to be readily available; including critical supplies (sandbags, sump pumps, portable generators, fuel, portable lights, extension cords, dehumidifiers, protective clothing, etc.), portable flood barriers and sandbags, backup power generation equipment and fuel, emergency lighting (battery operated), elevator water sensors, backwater valves on storm and sanitary sewer pipes and hazardous material storage (All)

(Christopher, 2016)	• Adopt a comprehensive storm water ordinance and accompanying technical standards to properly regulate existing and future storm water control measures (All)
(Restemeyer et al., 2019; Moore, 2018)	• The main emphasis on structural flood defences can be complemented with other, non-structural measures o land use planning (All) o development control for flood risk areas is a key tool to reduce flood impacts (All) • Raise public awareness to facilitate emergency planning and response (All) • Shifting discourses on flood governance towards integrated flood risk management (IFRM)- An important characteristic of IFRM is its special applicability to managing flood risk in large urban areas. IFRM attempts to address population density, spatially concentrated socio-economic deprivation, differentiated residential land-use classes, and protection of strategic infrastructure, such as transport links, hospitals, and administrative centres (All)
(Rodriguez-Salinas et al., 2014)	• Application of Water-Sensitive Urban Design (WSUD) is a multidiscipline approach to urban water management that aims to holistically consider the environmental, social, and economic consequences of water management strategies (All)

Table 11. List of selected literature sources by different authors/writers from PRISMA analysis (titles only)

No.	Title
1.	Adapting buildings: what can be done? Climate Just
2.	A guide to resistant and resilient repair after a flood
3.	A new standard for flood resistance and resilience of buildings: new build and retrofit
4.	A Study on the Floating House for New Resilient Living
5.	Adaptation mainstreaming for achieving flood resilience in cities
6.	Adapting Urban Areas to Flooding - POST Note - UK Parliament
7.	Adopting an Ecosystem Services-Based Approach for Flood Resilient Strategies: The Case of Rocinha Favela (Brazil)
8.	Ahead of the Storm: Developing Flood-Resilience Guidance for Canada's Commercial Real Estate
9.	City of Tipton, IN Flood Resilience Plan - Tipton County, Indiana
10.	Civil society contributions to local level flood resilience: Before, during and after the 2015 Boxing Day floods in the...
11.	Contributing to urban resilience to floods with neighbourhood design: the case of Am Sandtorkai/Dalmannkai in Hamburg
12.	Cumbria Flood Resilience Project – RTC Group – Remedial ... https://www.rtcgroup.co.uk/cumbria-flood-resilience-project/
13.	Decentralized Implementation of Flood Resilience Measures ...
14.	Effective adaptation to rising flood risk
15.	egremont flood risk management scheme - The Flood Hub
16.	Evaluating Flood Resilience Strategies for Coastal Megacities ...
17.	Evaluation of flood risk reduction strategies through combinations of interventions
18.	Flood Mitigation - Foundation for Water Research
19.	Flood Resilience Measures in Buildings on the Flood ...
20.	Flood resilience technology in Europe: identifying barriers and co-producing best practice
21.	Flood Resilient Building Guidance for Queensland Homes
22.	Flood resilient cities
23.	Flood resilient cities–A Jakarta case study
24.	Flooding Resilience in the Commonwealth
25.	flood-resilience-bonfield-action-plan-2016 (FROM: Resilience Works)

26. From Resistance to Resilience: Media Discourses on Urban Flood Governance in Mexico
27. How Kenyan communities embrace flood resilience strategies ...
28. Incorporation and application of resilience in the context of water-sensitive urban design: linking European and Australian perspectives
29. Interdisciplinary Design of Vital Infrastructure to Reduce Flood Risk in Tokyo's Edogawa Ward
30. Investing in Natural and Nature-Based Infrastructure: Building Better Along Our Coasts
31. Is Bangkok becoming more resilient to flooding? A framing analysis of Bangkok's flood resilience policy combining...
32. Is There a Reluctance to Embrace Flood Resilience Measures?
33. Living with flooding: action plan - gov.scot
34. Metric Handbook Planning and Design - 12 Flood-aware design
35. Property flood resilience database: an innovative response for the insurance market
36. Resilience strategies for flash flooding - C2es
37. Saving lives and livelihoods-The urgent need to invest in flood ...
38. The political economy of flood management reform in China
39. Unflooding Asia the Green Cities Way

Table 12. Flood resilience table showing comprehensive flood resilience strategies from literature

Sources and resilience strategies – type A. *Structural or engineering strategies (measures involve physical construction)*	**Sources and resilience strategies – type B. *Non-structural or natural strategies (measures involve social or behavioural, policy or legal and financial interventions)***
(Climate Just, 2020); Yumpu.com, 2019; POST, 2016; Egremont Scheme, 2018) • Implementing sustainable urban drainage systems (SUDS) **All** • Adaptive placement of indoor assets and fittings, such as electrical sockets be higher up the wall (1.5 metres) **Other** • Application of water repellents or resistant materials such as water-resistant skirting boards and horizontal plasterboard or lime-based plaster be used in preference to gypsum **Other** • Using flood resistant products including flood gates, airbrick covers and non-return valves for your bathroom, which prevent sewage coming up through the pipes **All** • Installing a stainless steel kitchen, using waterproof plaster, and installing concrete or floor tiles or floorboards instead of carpets since these are quicker and easier to clean and rugs may also be an option since these can be removed or replaced more easily **Other** (POST, 2016); • Catchment led approach – construction of water ditches in the upper courses of streams to slow surface runoff **All** • Purpose built reservoirs and embankments upstream helps store water and reduce volumes flowing downstream **All**	(Yumpu.com, 2019) • For businesses, stock can be raised off floor level or stored in a way that enables you to move it easily **All** • Having furniture that is easily removable from the ground floor so it can be taken upstairs **All** (Tagg et al., 2016; Krishnan et al., 2019) • Resilient approaches for buildings – undertaking regular updates of building regulations to ensure that all new or refurbished buildings in high flood-risk areas are flood resistant or resilient; **All** • Institutional capacity development and programme targeting is vital – allocation of substantial resources to managing risk **All** • All local authorities being able to support high flood-at-risk residents access loans and grants for home improvement **All** • Local authorities to ensure development of standards for building designs, construction and maintenance, including standards for undertaking flood risk assessment (FRA), internal buildings features and external retrofits should also encourage the take-up of property flood resistance and resilience by businesses **All** (Moon, 2015; Bonfield, 2016)

• Ensuring property resistance and resilience in terms of physical barriers and placement of household items and accessories on raised platforms or walls **All**
(Moudrak & Feltmate, 2019; Flood Ark, 2017)
• Major Retrofits such as:
  ○ Elevating and flood-proofing critical equipment: heating, cooling, ventilation, and air conditioning (HVAC) equipment; electrical transformers, switchgear, and service panels, as well as communication systems are elevated above expected flood levels. If not feasible to elevate, these systems are flood-proofed (e.g., with equipment elevated off the ground and drains at the lowest points on the floor). **Other**
  ○ Protecting server rooms: server rooms are located on higher floors, preferably on a raised platform, with a sump pump installed at the lowest point. Water sensors are installed for leak detection. **All**
  ○ Protecting high-voltage and telecommunication pull rooms: high-voltage and telecommunication pull rooms are better waterproofed and equipped with drainage. **All**
  ○ Isolating electrical circuits: for multi-level parkades, electrical circuits can be isolated for each parking level. **All**
• Electrical panel upgrades: electrical panels can be equipped with WIFI enabled breakers to allow for remote shut off. **All**
• Some of the features which are incorporated into the properties to improve their resilience include: **Other**
	• Construction of floating houses in coastal or water habitats which is important for Buoyancy for the hydrological disaster such as floods and the earthquakes **Other**
	• Flood resilient property such as kitchen. Flood resilient kitchen: good design can create attractive kitchens and incorporate flood resilient features. These can include raising appliances above likely flood levels, use of appropriate materials for cabinets and resilient floor tiles. **Other**
	• Information portals for education and awareness. Developing and promoting an independent web-portal that provides a one-stop shop for information on property level resilience **All**
	• Formulation of flood resilience standards for building materials, services and products that are used as standard **All**
	• Securing and utilising funding for resilience **All**
	
	(Rijke et al., 2016; King & Steinhilber, 2017)
	• Ensure mainstreaming of flood risk management in projects **All**
	• FRM Financing – funds earmarked for flood risk management achieved through various initiatives such as competitions or donations such as the Virginia Shoreline Resiliency Fund. **All**
	• Incorporating/Mainstreaming Sea Level Rise and Recurrent Flooding into Comprehensive Plan. **Other**
	• Initiating deliberate subsidies such as the Living Shorelines Local Tax Exemption passed

○ Water resistant wall and floor membranes ○ Water resistant insulation ○ Flood resistant doors and windows ○ Flood resilient kitchen ○ Drains and sumps that disperse water quickly • Toilet and sink non-return valves **All** (RTC Group, 2019) • Use of Storm dry Masonry Protection Cream, to the external walls up to a height of 1.2m, to waterproof the brickwork and help prevent the ingress of water in the future **Other** • Application of Uni-Mortar 1 Joint Fill Compound around the perimeter of the floor to wall juncture. This helps waterproof one of the structures weakest points **Other** • Internally, use of two re-plastering systems **Other** ○ the Dryzone Damp Resistant Plaster Flood System, which is a waterproof and salt retardant plaster which owing to its porous structure and will dry down very quickly should future flooding occur; and ○ the Dryzone Drygrip Waterproof Adhesive Express Flood System, which is a plasterboard system using a waterproof and salt retardant adhesive. The advantage of this system is that it can be replaced very quickly with minimal disturbance should future flooding occur. • The walls can then be skimmed using Dryzone Hi-Lime Finishing Plaster and then application of 2 coats of Drybase Liquid-Applied DPM to the floor. Once applied this product cures to form a waterproof membrane that is flexible and elastic. **Other**	in 2016 by the Virginia General Assembly, HB 526 (Ch. 610 of the 2016 Acts of Assembly) **All** • Decentralisation of resilience efforts – Resilience, at its heart, is a community issue, and many localities have led the way in developing and implementing flood resilience strategies. **All** • Institutional capacity development – establishment of FRM offices and staff in Cities authorities such as Norfolk, named in the Rockefeller Foundation’s first round of “100 Resilient Cities” **All** • Utilizing University Resources – Virginia for example, boasts many leading institutions of higher education. ODU and William and Mary (W&M), both located in Virginia’s flooding hot spot of Hampton Roads, have formed a strong partnership and are collaborating on diverse research projects. **All** • Integrations of tide gauges and other water level gauges All • Formulation of high resolution state-of-the-art street-level flood modeling. **All** • Establishment of resiliency data portal for Flood Information Management Systems thus developing a data portal, such as the “Adapt Virginia,” that integrates a wide range of resiliency resources for the commonwealth’s agencies and local governments. **All** • Community Rating System Open Space Mapping. **All** (POST, 2016; Ronchi & Arcidiacono, 2018)

(Aerts et al., 2014; Vojinović & Huang, 2014)
• Use of moderate local flood protection measures, such as levees and beach nourishment. The local protection measures and building codes for new structures are adjustable to future climate change, as they can be upgraded if flood risk increases in future. **All**
• Structural measures involve physical construction and include: **All**
  ○ Soft structures – Sustainable Urban Drainage Systems (SUDs), Low Impact Developments (LIDs), Water Sensitive Urban Design (WSUD), Best Management Practices (BMP)
  ○ Flood proofing
  ○ River and Coastal Flood Protection
  ○ Urban Drainage
 	
(Berchum et al., 2019)
• Large, complex coastal regions often require a combination of interventions to lower the risk of flooding to an acceptable level. Structural and non-structural measures as one combination and damage restricting measures and changes in policy as the other. **Other**
  ○ Flood defences such as levee storm surge barrier **All**
  ○ Damage restricting measures such as slab elevation flood-proof buildings **All**
 	
(White et al., 2018; White, 2018; Queensland Reconstruction Authority, 2019)
• Here, structural resilience is seen in flood 'resistance' measures that attempt to keep water
	• Woodland planting in the upper river courses to reduce surface runoff and store water **All**
	• Green infrastructure within the city such as parks reduces runoff by increasing infiltration of rain water **All**
	• Adaptive designing of drainage systems – roads made to carry excess water during extreme rainfall **All**
	• Having 'sacrificial' storage area of excess water which in dry months could be used for other purposes such as playing field **Other**
	• Improve routine assessments of property to ensure pro-active action in case of reduced resistance and resilience of the property **All**
	
	(Ronchi & Arcidiacono, 2018)
	• Green mitigation measures which are nature-based solutions such as:
	  ○ Green roofs – roofs covered with vegetation placed over waterproofing material with drainage and irrigation systems. **All**
	• Green permeable paving consisting of pre-cast locks made of concrete or hard plastics with voids **All**
	(Moudrak & Feltmate, 2019; Rinne & Nygren, 2016)
	• Making plans and procedures readily available offer preparedness to flood disaster events. These may include emergency preparedness and response plans in place and include flood event procedures. **All**

out of buildings, often referred to as dryproofing. These are directly applied to building apertures, such as door guards and air brick covers, and resist the entry of water to a property (usually to a depth of around 600 mm). Perimeter barriers may also be deployed to hold back and resist flood water at the community scale. **All**
• Alternatively, flood 'resilience' measures may allow water ingress and are designed to limit damage and to facilitate the recovery process. This more functional approach is also referred to as wet-proofing. Complicating this dichotomy, whilst FRe measures prevent floodwater from entering a property to certain depths, they can also slow the rate of water ingress, thus affording more time to evacuate buildings. In some cases, therefore, resistance technologies can increase the resilience to flooding. **All**
• The upper floor is raised and the ground level is designed to meet wet-proofing principles. The associated construction details focus on creating an insulated single skin timber framed wall system with water-resistant flooring options. **Other**
• Temporary flood resistance measures
  ○ Free standing barriers. These may protect a wide area from flooding and are best suitable for river overbank flooding where depths are modest say up to 1m and road flooding due to inadequate drainage facility **All**
  ○ Adaptations to properties – individual properties may be adapted to provide resistance. These are effective where floods depths are not excessive and floods are of
	• Practice drills for building operations staff – being trained in on flood event response procedures **All**
	• Having emergency funds in place for emergency operations **All**
	• Active communication channels for people's use **All**
	• Emergency operations centres: designated space is available for building operations staff to use as emergency operations centres. This space is equipped with water, non-perishable food supplies and emergency kits and is located above expected flood levels. **All**
	• Emergency response supply contracts for various goods and services affected by the floods **All**
	• Emergency contact information: contact information of risk management personnel, insurance adjusters and insurance brokers important and needs to be maintained and updated. **All**
	• Insurance documentation: documentation to access business interruption insurance (e.g., financial statements, lease agreements and inventory counts) regularly updated, backed-up electronically and stored offsite. **All**
	• Equipment and supplies for use need to be readily available; including critical supplies (sandbags, sump pumps, portable generators, fuel, portable lights, extension cords, dehumidifiers, protective clothing, etc.), portable flood barriers and sandbags, backup power generation equipment and fuel, emergency lighting (battery operated), elevator

short duration, such as door guards and airbrick covers, also flood skirts. **All**
• Permanent Large Scale measures – these are flood alleviation schemes which provide flood protection to the City. Common types are:
  ○ Schemes which involve raising of river banks providing a greater flow capacity before overtopping or inundation occurs **All**
  ○ Schemes which provide an additional channel running parallel to the main river channel **All**
  ○ Schemes which provide storage for flood waters upstream of an area at risk **All**
  ○ Schemes in coastal areas which help to prevent overtopping by waves and tides
• Permanent small scale measures – provide permanent flood protection to individual properties or structures
  ○ Gardens or site landscaping to divert flood waters away from the property **Other**
  ○ Revised local drainage layouts **All**
  ○ Low bunds around the site or property **All**
  ○ Periphery walls/fencing **All**
  ○ Flood resistant gates **All**
  ○ Periscope air vents **Other**
  ○ Outside wall renders and facings including veneer walling **Other**
  ○ Non-return valves on waste pipes and outlets **All**
  ○ Resistant external doors **All**
• Resilience measures for a property are those measures that aim to minimise damage to property and its contents during flooding and include:
	water sensors, backwater valves on storm and sanitary sewer pipes and hazardous material storage **All**
	• Shifting Discourses on Flood Governance towards Integrated Flood Governance Strategies **All**
	(Christopher, 2016)
	• Update floodplain regulations to prevent future development activities from causing increased flood damages **All**
	• Further define or refine flood risk modeling and mapping to guide the regulatory process for planning and building permits **All**
	• Adopt a comprehensive storm water ordinance and accompanying technical standards to properly regulate existing and future storm water control measures **All**
	  ○ Update, integrate, and revise plans, policies, and regulations as noted in the strategies for the individual flood resilience planning areas **All**
	  ○ Conduct regular audits of policies and programs and update plans and ordinances for consistency **All**
	• Participate in the Community Improvement Programs **All**
	
	(Forrest et al., 2019)
	• Pre-flood mechanisms be in place such as:
	  ○ Mitigation measure – spatial planning measures **All**
	  ○ Prevention measures – permanent and temporary physical barriers **All**

○ Waterproof and water resistant internal doors **Other** ○ Water resistant membranes to protect walls **Other** ○ Concrete floors, especially when fitted with a waterproof membrane **Other** • Raising heights of internal fixtures and fittings such as kitchen and domestic appliance, electrical sockets and consumer units **All** (Ezeokoli et al., 2019; Scottish Government, 2019) *Resilience of buildings and related property* • Property Flood Resilience (PFR) measures are designed to make property more resilient to the physical impacts and people to the emotional impacts of flooding. They either help prevent water entering a building, for example, by installing a flood guard across a doorway or they limit the damage to the property if the water enters, for example, by water-proofing the brickwork or replacing carpets with flooring that can be retained after the flood event. These measures make the clean up as easy as possible and allow people to return to their homes and re-open businesses as quickly as possible. **All** • Both types of measures for PFR, examples include: ○ flood doors **Other** ○ flood barriers **All** ○ air brick covers **Other** ○ pointing or waterproofing brickwork **Other** ○ installing non-return valves **All** ○ moving vulnerable features, such as sockets, above floor level **All**	○ Preparedness measures – flood risk awareness and readying resources/planning, moving assets, PLP, warnings **All** • During floods mechanisms: ○ Robustness measures – monitoring barriers and reinforcing them against failures **All** ○ Response measures – reacting to immediate dangers of floodwaters, safeguarding people, limiting asset loss (cleaning/decontaminating/repairing) **All** • Post-flood mechanisms: ○ Recovery – reducing the immediate impacts of floodwaters **All** ○ Adaptation measures (small shifts in existing measures) or transformation (larger shifts in practices/perceptions/social networks). **All** • At any level of flood cycle – capacity development of communities (mobilising, improving social cohesion, increasing knowledge and retaining flood memories). **All** (Queensland Reconstruction Authority, 2019; Serre et al., 2018) • Flood resilient design. It involves adapting the design, construction and materials incorporated into buildings to minimise damage caused by floodwaters. Incorporating resilient building design can significantly reduce the effort, cost and time to return

- Replacing carpets with flooring that does not need to be replaced after a flood, **Other**

- Using materials for kitchen cupboards that are less likely to need replaced after a flood. **Other**
- Raised building floor level or platform **All**
- Use of concrete floor and tiling **All**
- use of embankments **All**
- re-routing flood water channels **All**
- building walls and floors with none/low permeability materials, **Other**
- raised kitchen appliances **All**
- low walls or barriers between streetscape, **All**
- Automatic window opening panels (flood inlets), water sensors within and outside buildings **Other**

In addition regarding flood resilient buildings:

- Robust materials and finishes should be used. **All**
- Finishes can be designed to be removable or sacrificial and easily replaced in the zone affected by flooding **All**
- Special vent covers can be used to close ventilation bricks to prevent under floor voids and cavities becoming flooded **All**
- Solid walls finish render in cement rendering systems or tiling, at least up to dado level should be used in preference to timber stud partitions finished in plaster board **Other**
- Solid concrete floors are preferable to suspended floor construction as they can provide an effective seal against water rising up through the floor, provided they are adequately designed. **Other**
- Raising the minimum floor level of the property or development above expected flood levels. That people to their homes and workplaces following a flood. **All**
- Resilience in terms of design of transport connections leading to improved capacities:
  - Transportation connection infrastructure comprising multiple and public modes of transport, connecting the neighbourhood and its environment **All**
  - Transportation infrastructure involving `soft' modes of transport connecting the neighbourhood and its environment **All**
  - Transportation infrastructure between the neighbourhood and its environment higher than the reference water level **All**
  - Green area and open public space connection – Connection diminishing possible amount and speed of water transmitted between the neighbourhood and its environment **All**

(Restemeyer et al., 2019; Moore, 2018)

- Context of flood risk management, spatial planning and, more recently, the turn towards localism can be advantageous for flood resilience, for several reasons: **All**
  - has adopted a diverse set of flood risk management measures, with land use planning as a key tool,
  - holds long-standing experience with a plurality of actors, in which responsibilities are divided among the state, market and individuals,
  - offers the possibility for locally tailor-made solutions

is, insisting that all habitable rooms/spaces within residential accommodation be raised above the height of the design flood level or raise land levels to a point at which the ground level is effectively above the flood design level. **All** (Laeni et al., 2019) Strategy (flood risk management strategy) – Resilience in an equilibrium perspective prioritizes protecting cities from flooding by keeping water out of urban areas. The focus is on reducing flood probabilities and increasing robustness and resistance through structural flood protection measures such as dikes, dams and levees. **All** (Buxton, 2015) • Designs tailor-made for flood risks. Flooding cannot always be prevented, so designing developments that work with and make space for water is becoming increasingly important. The optimum solution to reducing and managing flood risk may require a combination of different design measures. **All** • Sustainable drainage. Reducing flood risk requires consideration of both factors. For instance, it is possible to reduce the probability of flooding by installing defences, but increase the consequence of a flood by building more homes behind the defences. However, if the homes are designed to be flood resilient then the consequence of them flooding is low and the overall risk reduced. Equally, it is possible to increase the probability of flooding by removing defences but reduce the	• the main emphasis on structural flood defenses can be complemented with other, non-structural measures **All** • flood warning systems **All** • flood alleviation schemes (insurance) **All** • 'softer engineering approaches' like floodplain rehabilitation and flood storage areas **All** • land use planning **All** • development control for flood risk areas is a key tool to reduce flood impacts **All** • Raise public awareness to facilitate emergency planning and response **All** • Integrated flood risk management (IFRM) - An important characteristic of IFRM is its special applicability to managing flood risk in large urban areas. IFRM attempts to address population density, spatially concentrated socio-economic deprivation, differentiated residential land-use classes, and protection of strategic infrastructure, such as transport links, hospitals and administrative centres **All** (Jongman, 2018; Sutton-Grier et al., 2018) • Effective adaptation to rising flood risk requires a diversified approach of interventions, which may include structural flood protection measures, early warning systems, risk-informed land planning, nature-based solutions, social protection and risk financing instruments **All** • Physical flood protection measures, such as dikes and levees, are generally cost-effective in areas with high population and asset concentrations **All**

consequence by relocating occupants and changing to natural wetlands. **All** • Publishing flood maps indicating the Flood Zones in is very important as these flood zones indicate the areas that could be at risk of flooding from rivers or the sea but ignoring the presence of defences. The maps also indicate flood defences and the areas that benefit from them e.g. The Scottish Environment Protection Agency (SEPA) and the Rivers Agency in co-operation with the Department of the Environment (DOE) publish similar maps for Scotland and Northern Ireland respectively. Planning by means of zoning according to high to low levels of risk is only a first step. **All** • For areas potentially affected by deeper floodwaters, buildings may need to be elevated high above the ground or designed to float with the rising water. **Other** • For areas with substantial flood risk, the solution may be for regional flood storage areas and wetlands to be provided. Other • Some other structural measures include flood defences (soft and hard), building resilience, drainage systems including Sustainable Urban Drainage Systems (SuDS), and temporary barriers. **All** • Designing buildings for flood risk – building design improvements that can be used to reduce the effects of flooding. Different approaches can be implemented, depending on whether they are added to an existing building or constructed as part of a new building. **All**	• Such nature-based solutions include widening of natural flood plains, protecting and expanding wetlands, restoring oyster and coral reefs and investing in urban green spaces to reduce run-off. **All** • Building Better Coastal Infrastructure **-** Natural coastal infrastructure, including beaches, dunes, oyster and coral reefs, sea grass beds, and marshes, can reduce wave energy, coastal erosion, and flood hazards. There are also numerous opportunities to combine built and natural infrastructure in hybrid Natural and Nature-Based Infrastructure (NNBI) designs to provide additional storm erosion and flooding risk reduction, as well as the additional co-benefits that built infrastructure typically fails to deliver. **Other** • Coastal NNBI co-benefits include the creation of habitats for commercially and recreationally valuable fishes, maintenance and enhancement of biodiversity, improved aesthetics and access to “nature” that can increase tourism and recreation, and improved water quality, with estimated benefits valued at over $100 billion annually. **Other** (Aerts et al., 2014; Wals, 2015) • Development of resilience strategic plans such as (The Resilient Open City strategy (S1) is a cluster of measures to enhance building-code strategies in NYC by elevating, or dry or wet flood-proofing, both existing and new buildings. Storm surge barrier strategies aim to lower flood probabilities in NYC and parts of

• Flood avoidance. Flood avoidance is the most usual building design measure with many examples of buildings on stilts or raised ground throughout the world. For flood avoidance to be effective, the ground floor level of the building must be set above the design flood level, including an allowance for climate change and tolerance (freeboard). **All**
  ○ For residential units the floor level is typically required to be set above the 1 per cent (1 in 100) flood level + 300 mm (climate change allowance) + 300 mm (freeboard).
  ○ For commercial units, the floor level is typically required to be set above the 5 per cent (1in 20) flood level + 300 mm (climate change allowance) + 300 mm (freeboard).
  ○ For residential car parking, the flood level is typically required to be set above the 1 per cent (1 in 100) flood level.
  ○ For commercial car parking, the flood level is typically required to be set above the 5 per cent (1 in 20) flood level.
• Flood resistance/dry proofing. Flood resistance and resilience measures are not normally acceptable for new buildings other than to manage residual flood risk. This is because it is safer to avoid flood risk rather than relying on flood defences to keep water out or allowing floodwater into a building that carries obvious health risks. Flood resistance measures include flood defences, flood barriers, door guards and back flow drains with the purpose of preventing water from entering the property – hence keeping it dry. Typically flood resistance measures are only
	New Jersey (NJ), with barriers, levees, and beach nourishments **All**
	• Strategic Mechanisms for Flood Resilience e.g. the Jakarta Coastal Defense Strategy (JCDS) in 2009 to prevent and reduce floods. **All**
	• National Flood Risk Management Programmes e.g. National Integrated Coastal Development Program (NDICD) (NCICD, 2015). **All**
	
	(Berchum et al., 2019)
	• Large, complex coastal regions often require a combination of interventions to lower the risk of flooding to an acceptable level. Structural and non-structural measures as one combination and damage restricting measures and changes in policy as the other. **Other**
	• Non-structural measures – Economic benefit and safety provided by these measures are hard to quantify, while they often offer co-benefits like ecological value or a better living-environment. These types of measures are mostly used to reduce waves for damage reduction or to reduce wave impact on nearby flood defences as a part of a hybrid solution.
	  ○ Nature-based solutions such as wetland soyster reefs are one aspect of non-structural measures **All**
	  ○ Changes in policy such as zoning evacuation **All**
	
	(Ezeokoli et al., 2019)
	• Formation and enforcement of standards – use of acceptable materials for flood resilient buildings; use of concrete, reinforced concrete

effective for short duration shallow flooding (below 300 mm in depth or below 600 mm in depth depending on structural assessment). **All** • **Flood resilience/wet proofing -** Flood resilience measures or wet proofing involves constructing a building in such a way that although floodwater may enter the building, its impact is minimised, the structural integrity is maintained, and the time to clean up and use is minimised. Thus using building materials that can survive being waterlogged without requiring repair or replacement according to the Communities and Local Government guidance *Improving the flood performance of new buildings*. Flood resilience measures are typically used where flood depths are greater than 600 mm. Water resistance, impermeability, drying ability, rot avoidance, mould resistance and replacement are all key considerations for materials to provide resilience. Resilience measures include: **All** ○ raise susceptible infrastructure above flood level (such as electric sockets and supply); ○ non-return valves (fitted to drains); ○ secure drainage (such as sealed drain covers and concrete man holes to prevent pollution and floatation); ○ impervious/wash down materials (such as tiled floors, plastic doors, rendered masonry walls); ○ solid core materials, (such as use of solid kitchen units instead of chipboard, or solid wall construction below potential flood levels);	and engineering brick is most suitable for structural component of building with respect to any form of flooding. Timbers or woods should be avoided for structural elements but if it must be used it should be treated properly. **All** (White et al., 2018) • FRM approaches that help to contextualise the use of FRe. For example, the Scottish Executive's '4 As' approach to flood management is a linear process ranging from awareness, alleviation, assistance and, finally, avoidance. The delineation is designed to focus attention on specific key points, such as the initial awareness of flood risk amongst the general public, professionals, and decision makers to an appreciation of the potential alleviation measures that could reduce or avoid risk, for instance, decisions concerning the implementation of FRe. **All** • Also a model of the European Commission documents that advocate the 3Ps and E and R: 'Prevention, Protection and Preparedness, Emergency Response, Recovery and Lessons Learned' as well as the '4 Capacities' in the Netherlands, which has a focus on adapting to the flood risk. All of these approaches similarly capture critical stages in managing floods: from promoting public awareness and improving risk literacy to providing a range of possible managerial options and enabling stakeholders to take meaningful remedial action. **All** (Balmforth, 2016)

- replaceable materials (such as horizontally fitting plasterboard where just the lowest boards can be replaced).

- **Floating or amphibious structures** Floating or amphibious structures are unlikely to be an option for managing flood risk in most cases due to the need to site the building in water, which is often a high flood risk area, incompatible with the vulnerability of the use. A floating building is, typically, a lightweight structure, which rests on a buoyant base or foundation designed to rise and fall with the level of the water. The benefit of this form of construction is that it can be designed to cope with significant flood depths and can respond to variable flood levels, beneficial where there may be uncertainty in predictions. An amphibious structure is a floating building set on or within the ground. It can rest on the ground, only floating when the water level rises. These types of construction require careful assessment, design and engineering to provide sufficient resistance to flood flows, debris and manage services. **Other**

- **Safe access and egress** With all of these building types it is important to provide safe access and egress in the event of a flood. This is particularly relevant for emergency vehicles, which are likely to be called upon during times of flood, and it is a key planning requirement. Safe access and egress is not required to be dry but it is required to be safe. The Defra document *Flood Risk Assessment Guidance for New Development* (Defra 2005)

- Better forecasting and warnings **All**
- Improved modelling and visualisation of impending floods **All**
- Making space for flood water so that it can safely pass through communities and be stored in "sacrificial" flood areas **All**
- Making buildings and infrastructure more resistant and resilient to flooding **All**
- Improved engagement of the public, business and other stakeholders so that they become part of the solution **All**
- Better preparation for installing temporary measures and for responding to floods **All**
- Improved recovery and better support for those affected **All**

(Gullet, 2016)

- Innovation in practice – Strengthening a community developed warning system, whereby three rain and river gauges were placed in schools upstream. The data from the rain and river gauges were monitored daily by a trained focal person. In the event that the river levels rise due to heavy rainfall, indicating possible flooding downstream, the light and buzzer placed on an electronic dish on the roof of the school would send warning signals to exposed communities. This innovation excited the community as they had designed the idea while the Kenya Red Cross Society and other partners supported its execution. **All**
- Most of our disaster risk management programs have a component of floods

identifies conditions for creating safe access and egress into developments. **Other** • **Sustainable Drainage Systems (SuDS)** In addition to flood resilience measures, it is also important to mitigate flood risk through drainage control. Sustainable Drainage Systems provide the means to manage rainwater run off so that it emulates natural drainage systems. The various devices can be summarised as: **All** ○ The aim of infiltration devices, such as permeable paving and underground soakaways, is to facilitate infiltration of rainwater into the ground. A soakaway is typically a stone filled circular chamber, shallow linear trenches or perforate pipes depending on the depth of the groundwater and permeability of the ground. **All** ○ Permeable paving may be used in parking areas or paths to allow infiltration into the ground or into below ground detention tanks. It is important that pollution control measures are used to intercept contaminants from vehicles or other sources, before they have the potential to pollute groundwater. Filter strips may be used between parking areas to control run-off **All** ○ Retention and detention devices are storm water storage facilities such as ponds or below ground cellular storage devices, which detain water during a storm before releasing via a controlled outflow. They need to be designed to remain	awareness and mitigation both in rural and urban settings. For example, we have supported farmers in Kitui, Makueni and Garissa to learn how to uninstall their pumps at the river beds so that they do not get flooded, which results in high repair costs. **All** • Looking forward through technology – technology is useful when it comes to early warning, ensuring communities are better prepared and thereby become less prone to or affected by disasters. Kenya is a technologically-savvy country with over 80 percent mobile ownership, and the population has embraced SMS as a communication tool. The Trilogy Emergency Relief Application SMS platform allows us to send geographically targeted messaging, which means communities can better prepare for potential flooding situations, and encourages them to get in touch with emergency responders when they need assistance. For instance, during the El Nino rains in 2015, and using the TERA SMS platform, we sent early warning messages to flood prone communities in western Kenya and the coastal region. **All** (Rodriguez-Salinas et al., 2014) • Water-Sensitive Urban Design (WSUD) is a multidiscipline approach to urban water management that aims to holistically consider the environmental, social, and economic consequences of water management strategies **All**

(predominantly) dry at other times to provide effective storage during a storm. **All** o Conveyance devices, such as swales and filter strips, are channels (typically landscaped) that transfer water from one device into another such as the run-off from a roof into an infiltration pond. **All** o Constructed wetlands, such as ponds and lakes, are neighbourhood and regional control measures that emulate the natural benefits of wetlands and are usually the last device in larger SuD systems. **All** o Vegetated SuDS devices (such as green roofs, walls and planted swales) can also provide environmental benefits, such as cooling through evapotranspiration, habitat and visual enhancement. SuDS can enhance masterplanning through increasing the opportunity for landscaping, greater provision of amenity and better place making. **All** (Garvin et al., 2016) • Dry-proofing or resistance: Water is prevented from entering the property or penetrating into the structure by sealing the building or by using flood protection products. **Other** • Wet-proofing or resilience: Water is allowed to enter the building but the building fabric and the contents are 'waterproofed' by application of flood-resilient materials. **All** • Use of aperture technologies are property-level protection barriers, designed to prevent the ingress	• It also means that human actors have an important role in managing and adapting physical elements (e.g., embankments and structures). In this sense, resilience to floods includes aspects of social resilience (i.e., the degree to which the system is capable of self-organization); institutional resilience (i.e., the degree to which the system could build and increase capacity for learning and adaptation); and economic resilience (i.e., the degree to which thesystem is able to access and use economic resources efficiently). **All** • A vision for WSUD to include flood resilience includes: o Managing water to deal with both water scarcity and water excess (managing both water quantity and quality and system resilience) concurrently and in an integrated way **All** o Managing and utilizing the water cycle as locally as possible as all aspects/occurrences of water are potential opportunities (exploit local opportunities) **All** (Laeni et al., 2019) There are three key aspects essential for flood resilience building, namely strategy, process and outcome which in literature have different interpretations in the equilibrium perspective and the evolutionary perspective. • Strategy (flood risk management strategy) – emergency management and recovery are well strengthened. **All**

of flood water into a building by protecting the openings such as windows, doors and air bricks. The specific technologies could include: air brick covers, door guards, building-fixed flood guards, non-return valves. **Other** • Building aperture products, used for all openings within a building, could combine to create a flood resistant system for the property. Innovation in this area has resulted in the availability of a range of flood doors, flood windows, self- closing vents and automatically operated air bricks. If flood water is present for more than a few hours, it may begin to seep through the walls. **Other** • To develop a flood resistant system for the whole building, the application of waterproofing materials to the walls may be necessary. Flood-resistant materials used for building aperture technologies are generally metals or plastics which are durable and have low water permeability. The joints between barrier sections and between the barrier and the aperture are the weakest points and as such, special care should be taken to ensure that a tight seal is achieved. **Other** • Many companies offer standard-size barriers for doors and garage doors, windows and air bricks, but specialist sizes can often be manufactured for bespoke openings. **Other** • Construction. During the construction phase, permanent framework or supports of aperture barriers should be fully fixed and sealed to the receiving building. Permanently installed technologies, such as automatic air bricks, or non-return valves for plumbing systems, will also be installed in this phase. In the event of a flood	• Strategies aimed at reducing flood consequences and adjusting to climate change uncertainties. **All** • Process is the second. Adaptive and spatial flood risk management strategies, such as smart spatial design of flood-prone areas, increasing flood awareness among communities, and strengthening abilities for learning and continuous improvement, requires an inclusive approach. **All** • Outcome is the third and final, it is important that a critical perspective of resilience building efforts identifies unequal anticipated outcomes of flood resilience building. The focus on structural flood protection, particularly in economic significant areas, could lead to resilience policy promoting economic growth and competitiveness of a city. **All** (Buxton, 2015) • Non-structural measures include early warning systems, • flood forecasting, • land use planning, • insurance, • evacuation and recovery plans. **All** (C2ES, 2018) • Traditional (or gray) stormwater infrastructure solutions are such as pipes, tunnels, and treatment plants, an important component of managing storm water, and is already implemented across cities, and its application as

warning, the temporary or demountable FRe technology parts must be installed. This will include door boards which are attached to fixed rails, barrier sections which are slotted into fixed supports and demountable air brick covers. **Other**	a resilience strategy is usually in conjunction with the strategies outlined below. **All**
Resilience • Wet-proofing and resilient materials are used to create a resilient system which will reduce flood vulnerability and will be more easily returned to its original state after a flood event, as cleaning and drying times are greatly reduced and necessary repair work is minimised. **Other** • An innovative flood resilient property design, The Flood Resilient Property (5), two wall to floor options were considered. Option A includes a primary and secondary layer of waterproofing: water tanking below slab to resist water pressure and cavity drainage for water collection after flood. Option B proposes water proof concrete in place of a water proof membrane: concrete slab and wall with water resistant additive, full cavity waterproof insulation and cavity drainage for water collection after flood. **Other** • Internal masonry walls and partitions have good resilience to floodwater, but the plaster and plasterboard finishes may deteriorate. Timber and steel-frame partitions are generally clad with plasterboard, although earlier examples may be fibreboard. There is a risk of water leakage into the partitions which could cause rotting and corrosion. Gypsum plaster should be replaced on masonry walls with hydrated cement:lime or hydraulic lime:sand based equivalents. Gypsum plasterboard could be replaced on masonry	• Green infrastructure uses vegetation, soils, and natural processes to manage water and improve urban environment. Site-integrated designs manage storm water onsite with structures that enable infiltration, filtration, storage, and uptake by vegetation structures. **All** • Site-Integrated Green Infrastructure (combing green and gray infrastructure) – the site-integrated features can be added to green spaces, to retain greater quantities of storm water. Property owners and local governments both have a role in installing green infrastructure and reducing impervious surfaces. **All** (Flood Resilience Alliance, 2019) • Increase funding for disaster risk reduction and adaptation so communities and countries reduce the potential impacts of natural hazards. **All** • Ensure domestic and international funding reaches the community level. The impacts of floods are felt most immediately at the local level, and communities and local authorities hold important knowledge on where and how to build resilience. By ensuring funds reach the local level and decisions on disaster risk reduction (DRR) and adaptation measures engage the community, resilience can be built more effectively. Such strengthened capacities at the local level can make tangible impacts on people's lives. **All**

partitions with resilient plasters (as for the inner leaf of external masonry walls). Alternatively, cement-based boards should be used. **Other**

- Hanging plasterboard horizontally rather than vertically should be considered. **Other**
- Wet-applied plaster in not an option for frame construction - plasterboard should be used as for masonry partitions. The junctions between walls and partitions and floors should be sealed with good-quality sealants. **Other**
- Mineral wool insulation in internal partitions should be replaced with closed-cell type insulation. **Other**

Community measures

- There are a range of community measures that are used to protect groups of properties. These measures are variable, they can be classified as perimeter barriers that are used to divert flood water away from property, sustainable drainage that can help to manage surface water in urban areas and flood management activities such as warning systems and organised local flood groups. **All**

Perimeter barriers

- Perimeter barriers are installed along or around developed areas to protect them from flood actions. For example, the barriers can be used to prevent flood water from approaching a building (or group of buildings) located by a river or the coast, or to divert flood water to a storage area. **All**
- Perimeter technologies can be temporary, demountable, or permanent, but all are designed to protect a building, series of buildings or critical

- Align existing policies and institutional structures across sectors and geographic levels and integrate new risk reduction measures. The integration of flood risk reduction policies with development practices, for example, can reduce risk while also advancing community development goals. Likewise, the integration of disaster risk management and climate change adaptation policies and institutional structures can reduce duplication of efforts. By aligning laws and policies, countries and communities can build flood resilience in a more integrated way. **All**
- Global and national level actors can shift funding priorities and increase investment in prevention and community-level engagement in resilience to reduce losses from floods in the future. The integration of risk reduction policies into existing development and adaptation efforts can limit flooding impacts and prevent risk being created by risk-blind or conflicting policies. **All**
- Proven resilience-building measures range from ‘softer’ interventions to hard infrastructure and can include:
    - end-to-end warning systems (which ensure early warning reaches the community level); **All**
    - livelihood diversification options; **All**
    - bio-dykes (for example to prevent erosion of river banks); **All**
    - climate sensitive and participatory risk assessments; **All**
    - community capacity building; **All**

infrastructure during a flood event. These products operate by fully surrounding and separating the area from the source of flood risk to create a resistant barrier. Its effectiveness will depend on whether it is activated or installed in sufficient time. The amount of warning time, and hence installation time, will be governed by the type of flood and the location to be protected. **Other**

- Perimeter barriers are also able to protect at community level. A local authority or local champions group may be best placed to coordinate and organise efforts to implement a community perimeter system. Its successful implementation is often dependent on flood warning systems, and the time and resources available for installation. **Other**
- Materials that are not susceptible to the ingress of water (e.g. metals and plastics) should be used for perimeter barriers. Special care should be taken when designing and specifying materials for the joints between sections of the barrier as these joints will be the weakest points in the barrier. A plastic seal is usually specified for this reason. Careful workmanship is required to ensure a tight seal. **Other**

Sustainable drainage

- Sustainable drainage is a departure from the traditional piped approach to draining sites **All**
- Sustainable Drainage Systems (SUDS) mimic natural drainage through: **All**
  - storing run-off rainwater and releasing it slowly (attenuation)

  - communication to raise risk awareness; **All**
  - financial protection (such as flood insurance, forecast-based financing); and planning and avoiding development in high-hazard areas. **All**

(Vojinović & Huang, 2014)

- The Green Cities Way of Managing Floods in Urban Areas – A new, holistic way of thinking is needed to unflood Asia. ‘‘Green Cities Development” is about creating vibrant, environment-friendly, livable cities. Green cities development calls for holistic planning and management of water, flood, solid waste, storm water, and wastewater. **All**
- The storm water is treated and used for nondrinking water purpose (e.g. flushing of toilets, washing, and irrigation of green spaces). **All**
- Storing of rainwater at multifunctional sites can be implemented in such a way to enable greater efficiency of land use. **All**
- As an efficient way of dealing with scarcity of available spaces (which is a common problem in urban areas), the actual water surface has been used in a multifunctional way through the construction of floating buildings. Other
- Furthermore, internal sources of water, energy and nutrients within an urban area are utilized first. **All**
  - Urban wastewater is used as fertilizer for urban agriculture purposes.

○ allowing water to soak into the ground (infiltration) ○ slowly transporting (conveying) water on the surface ○ filtering out pollutants ○ allowing sediments to settle out by controlling the flow of the water. • Soakaways are one of the key technologies for SUDS. They enable stormwater to be dealt with at source rather than being diverted directly into the sewer system, and satisfy the criteria listed in the bullet points above. **All** • Soakaways can be used on their own or as part of a larger SUDS development. Considering SUDS at the earliest stages of site selection and design makes it easier to integrate them into developments. SUDS can influence other aspects of the site (ie design, layout, function). **All**	○ It is also used as a source of heat and for biogas production. ○ At the same time, the wastewater treatment process is connected to productive landscapes as the efficient way of providing nutrients. The productive landscapes are designed for multifunctional purposes (i.e. they serve not only amenity and recreational purposes but also for keeping urban sites fresh and cool during heat waves as well as for urban farming and aquaculture). • Non-structural measures involve social or behavioral, policy or legal and financial interventions. These: ○ Capacity building of stakeholders **All** ○ Land use control and regulation **All** ○ Flood preparedness action planning **All** ○ Emergency plans **All** • Reopening Rivers in a Highly Urbanized Area **All** • Holistic Planning for Flood Resilience **All** • Holistic Rainwater Management **All** • Multipurpose Areas for Excess Flow **All**

4.4.2 Discussion on suitable strategies for flood resilience for Blantyre City

Principally, it was observed that strategies that apply to flash floods also apply to all flood types, thus naming being “All” and “Other” types. From the tables 9 and 10, there are 61 flood resilience strategies, categorised as in the Figure 16 below.

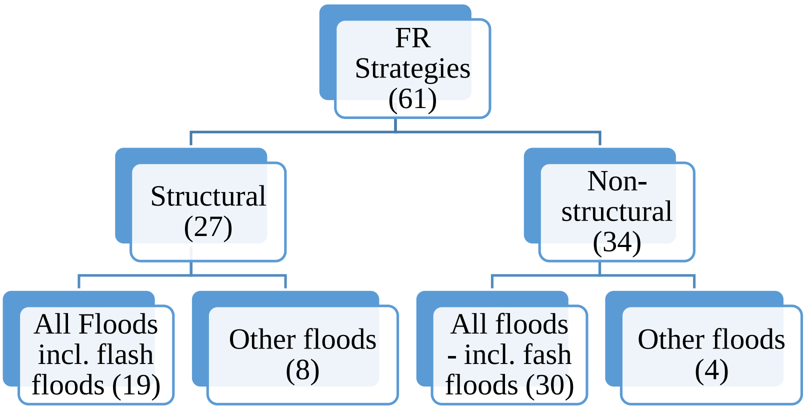

Figure 16. Categorised FR Strategies from 39 selected literature sources (numbers in the figure are the number of strategies of that type or category)

Of the 61 strategies in figure 16 and the flood resilience table (Table 12), all strategies that apply to flash floods also apply to other floods, therefore 49 (80.3%) strategies apply to Blantyre City. Additionally, the strategies are a blend of structural and non-structural strategies, which is important in ensuring substantial flood resilience (Restemeyer et al., 2019; Moore, 2018). Blantyre City with its hilly topography and history of flash floods is recommended for the 49 strategies in the tables 9 and 10 that apply to "All" types of floods which include flash floods, and both structural and non-structural types of strategies.

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter summarises results and presents the authors' recommendations important for stakeholders' (BCC, DoDMA, private sector and community leaders, scholars, and individual residents of Blantyre) decision making and implementation.

5.2 Conclusions

Blantyre's city dimensional variables scored below 50 percent, save for only 5 of 33, land use (2.9/5); road network availability (2.5/5); health status (2.5/5); education and awareness (2.8/5); and household assets (2.8/5). This performance also led to low scores for city dimensions, where the highest index was the social dimension (2.44/5), followed by institutional (1.93/5), while the least was the natural dimension (1.74/5). The city is prone to floods and its flood resilience level is very low (FRI 1.97/5). It is also lower than the Cities under the CORFU Project where the FRI was tested, possibly due to their advanced socio-economic development than Blantyre.

5.3 Recommendations

To raise the resilience level, there is need for stakeholders to improve on: planning and development (plans to include FRM issues, waste management systems that work during and after floods and restoration of natural resources in hills, forests and rivers); **regulatory systems (national laws and municipal bylaws to be implemented and enforced such as for land-use,** construction standards, business operations and other socio-economic regulations); **DRM mainstreaming** (undertake risk research and prioritise managing top level risks, construct emergency centres for evacuation and operations, form and capacitate DRM committees, robust EWS, mobilise and ring-fence financing for DRM, enhance disaster recovery to ensure BBBS; **community services** (creation of community recreation centres, critical infrastructure, raising community participation in DRM/FRM and embracing a mix of top-down and bottom-up approaches); **socio-economic development** (small and medium scale enterprises, asset protection and banking and "savings culture" for households). Lastly, there are 49 literature-explored flood resilience strategies suitable for Blantyre City where 19 are structural while 30 are non-structural. These are enlisted in tables 9 and 10 which if put in place and/or improved can raise the flood resilience levels above the low level (0-2) to high (4-5) – “a culture of safety”.

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APPENDICES

Appendix 1 Questionnaire for flood resilience assessment - completed with aggregated responses

THE POLYTECHNIC

QUESTIONNAIRE FOR CITY FLOOD RESILIENCE ASSESSMENT

CASE STUDY OF BLANTYRE CITY

A. INTRODUCTION

My name is William Chimzinga. I am conducting a study to assess the "Resilience of Blantyre City to floods" in partial fulfilment of a Master of Science degree in Environmental Protection and Management qualification at the Polytechnic, University of Malawi. This questionnaire is being administered to institutions and departments which deal with planning and development of cities and manages disaster risks in Malawi. Your institution is therefore relevant to participate in order to help understand the level of flood disaster resilience of cities, in this case Blantyre City.

Questions in this survey carry weights (0 and 1-5) which participants based on the experience in the above-said resilience fields assign to them.

Please note that the information supplied in this questionnaire including personal details, such as names of participants will be treated with integrity and total confidentiality.

B. CONTROL PANEL IDENTIFICATION

1.	Name of the Interviewee	AGGREGATE RESPONSE SCORES FOR ALL PARTICIPANTS (BCC, MHC, MoLHUD, DoDMA & EAD)

2.	Position	
3.	Name of the Institution	
4.	Field of expertise	
5.	Email address	
6.	Phone number	
7.	Starting time	
8.	Ending time	
9.	Date of the Interview	
10.	Name of Interviewer	

C. QUESTIONS (FLOOD RESILIENCE)

Please note that questions in this questionnaire are categorised into urban or city dimensions: *physical, natural, social, economic and institutional.* Participants are expected to answer all the questions. In case of lack of adequate information on a particular question under a dimension, participants are free to ask relevant work colleagues (from the same institution) to give an appropriate response.

The answers on a scale of 0 to 5 have the following interpretation in terms of resilience availability/possibility/strength of an indicator:

0 = No (not available/possible or negligible)

1 = Yes (very low availability/possibility)

2 = Yes (low availability/possibility)

3 = Yes (medium availability/possibility)

4 = Yes (high availability/possibility)

5 = Yes (very high availability/possibility)

Maximum time to answer questions on all the five dimensions is estimated as follows: Physical – 10 minutes; Natural – 5 minutes; Social – 5 minutes, Economic – 5 minutes; and Institutional – 10 minutes. Thus making the session to last about 35 minutes.

In the questions that follow:

- *Floods* or *flood* means all types of flooding water; pluvial, fluvial or flush, etc. at their least destructive potential
- Note that the elevation and physical features of Blantyre City are conducive for causing flash floods (sudden and fast occurring floods at high speeds within a short duration – roof-top effect)
- *Before floods* means a period without flood incident to a period when flooding starts
- *During floods* means the time floods are occurring to the immediate time when they stop.

DIMENSIONS AND INDICATORS	***No (0)***	***Yes (1-5)***				
City Dimension 1. PHYSICAL (maximum 10 minutes)						
Land use • Does land use and management in the City play significant role in flood risk prevention and management?	0 ☐	1 ☐	2 ☐	3 ☒	4 ☐	5 ☐
Overall	**0** ☐	**1** ☐	**2** ☐	**3** ☒	**4** ☐	**5** ☐
Electricity • Is electricity made adequately available to users during floods just as during normal circumstances?	0 ☐	1 ☐	2 ☒	3 ☐	4 ☐	5 ☐
• Is electricity accessible by residents immediately after floods?	0 ☐	1 ☐	2 ☐	3 ☒	4 ☐	5 ☐

• If electricity supply is distorted by any cause, is/are there reliable alternative energy source(s) or capacity available?	0 ☐	1 ☐	2 ☒	3 ☐	4 ☐	5 ☐
Overall	**0** ☐	**1** ☐	**2** ☒	**3** ☐	**4** ☐	**5** ☐
Environmental degradation • Is City Council able to undertake satisfactory environmental management practices that reduce flood risks?	0 ☐	1 ☐	2 ☒	3 ☐	4 ☐	5 ☐
• Are the City's natural and built environments intact? (implying that to-date there is little or no damage done to the City's environmental resources – land, water, soil, vegetation, air, etc.?)	0 ☐	1 ☐	2 ☒	3 ☐	4 ☐	5 ☐
Overall	**0** ☐	**1** ☐	**2** ☒	**3** ☐	**4** ☐	**5** ☐
Water • Does water supply capacity reliably remain intact during flooding?	0 ☐	1 ☐	2 ☒	3 ☐	4 ☐	5 ☐
• Is water made available to users during floods adequately as during time without floods?	0 ☐	1 ☐	2 ☒	3 ☐	4 ☐	5 ☐
• Is the water accessible by residents immediately after floods?	0 ☐	1 ☐	2 ☐	3 ☒	4 ☐	5 ☐
• If water supply is distorted by any means, is/are there reliable alternative source(s) or capacity available?	0 ☐	1 ☒	2 ☐	3 ☐	4 ☐	5 ☐
Overall	**0** ☐	**1** ☐	**2** ☒	**3** ☐	**4** ☐	**5** ☐
Sanitation (including solid waste disposal) • Is access to sanitation services normal (up-to-standard) before floods?	0	1	2	3	4	5

	0	1	2	3	4	5
	☐	☐	☒	☐	☐	☐
• Is solid waste properly collected during floods as in normal situations without floods?	0 ☐	1 ☒	2 ☐	3 ☐	4 ☐	5 ☐
• Is effluent (waste water from homes, business places, institutions and industries) properly collected during floods just as in normal situations without floods?	0 ☐	1 ☐	2 ☒	3 ☐	4 ☐	5 ☐
• Is waste treatment done during floods just as in normal situations without floods?	0 ☐	1 ☒	2 ☐	3 ☐	4 ☐	5 ☐
• Is access to sanitation services sufficiently available immediately after floods?	0 ☐	1 ☐	2 ☒	3 ☐	4 ☐	5 ☐
Overall	**0** ☐	**1** ☐	**2** ☐	**3** ☒	**4** ☐	**5** ☐
Road network availability • Do road networks make the most available mode of transport system	0	1	2	3	4	5
• Are most roads made of permanent construction materials such as quarry stones and bitumen?	0 ☐	1 ☐	2 ☐	3 ☒	4 ☐	5 ☐
• Are most roads accessible during flooding?	0 ☐	1 ☐	2 ☒	3 ☐	4 ☐	5 ☐
• Where there is road damage and service interruption after intense rains or floods, is the road maintenance period conveniently short?	0 ☐	1 ☒	2 ☐	3 ☐	4 ☐	5 ☐
• Do most roadsides have drains with drain covers?	0 ☐	1 ☐	2 ☒	3 ☐	4 ☐	5 ☐
Overall	**0**	**1**	**2**	**3**	**4**	**5**

	☐	☐	☒	☐	☐	☐
Housing and land-use • Are most buildings (residential, commercial or institutional premises) in the City made of permanent construction materials?	0 ☐	1 ☐	2 ☐	3 ☒	4 ☐	5 ☐
• Are most of the urban residents living away from polluted industries?	0 ☐	1 ☐	2 ☒	3 ☐	4 ☐	5 ☐
• Does construction of buildings fully adhere to building codes?	0 ☐	1 ☒	2 ☐	3 ☐	4 ☐	5 ☐
• Are dwelling and business premises and their surroundings well-kept in terms of good environmental management practices?	0 ☐	1 ☐	2 ☒	3 ☐	4 ☐	5 ☐
Overall	**0** ☐	**1** ☐	**2** ☒	**3** ☐	**4** ☐	**5** ☐
Community assets • Are there adequate disaster emergency operation centres at community level?	0 ☐	1 ☒	2 ☐	3 ☐	4 ☐	5 ☐
• Are there clear flood maps at community level?	0 ☐	1 ☒	2 ☐	3 ☐	4 ☐	5 ☐
• Are communities' assets (building infrastructure, crop fields, social fields, business assets, etc.) including basic services fully operational or intact during flood disaster?	0 ☐	1 ☐	2 ☒	3 ☐	4 ☐	5 ☐
• Are most of community assets located in flood-safe zones?	0 ☐	1 ☐	2 ☒	3 ☐	4 ☐	5 ☐
• Are most community assets constructed using hazard resistant methods and structural mitigation measures?	0	1	2	3	4	5

	☐	☒	☐	☐	☐	☐
Overall	**0** ☐	**1** ☒	**2** ☐	**3** ☐	**4** ☐	**5** ☐
Warning system and evacuation Do clear flood early warning systems exist at: • City level?	0 ☐	1 ☐	2 ☒	3 ☐	4 ☐	5 ☐
• Community (ward) level?	0 ☐	1 ☒	2 ☐	3 ☐	4 ☐	5 ☐
• Are the flood early warning systems sufficiently effective?	0 ☐	1 ☒	2 ☐	3 ☐	4 ☐	5 ☐
• Are well maintained evacuation centres available?	0 ☐	1 ☒	2 ☐	3 ☐	4 ☐	5 ☐
• Are the evacuation centres fully accessible in times of need?	0 ☐	1 ☒	2 ☐	3 ☐	4 ☐	5 ☐
Overall	**0** ☐	**1** ☒	**2** ☐	**3** ☐	**4** ☐	**5** ☐
History • Does BCC have reliable information management system?	0 ☐	1 ☐	2 ☐	3 ☒	4 ☐	5 ☐
• Does BCC have full outline of documented disaster risks and past disaster occurrences?	0 ☐	1 ☐	2 ☒	3 ☐	4 ☐	5 ☐
• Did local community members fully contribute to documentation of flood history for the City if any?	0 ☐	1 ☐	2 ☒	3 ☐	4 ☐	5 ☐

Overall	**0** ☐	**1** ☐	**2** ☒	**3** ☐	**4** ☐	**5** ☐
Location • Is the City located in a low risk region (considering the City being at risk to floods in relation to rivers and mountains)?	0 ☐	1 ☐	2 ☒	3 ☐	4 ☐	5 ☐
Overall	**0** ☐	**1** ☐	**2** ☒	**3** ☐	**4** ☐	**5** ☐
Accessibility • Do clear transport links exist to access flooded areas during floods?	0 ☐	1 ☐	2 ☒	3 ☐	4 ☐	5 ☐
• Are well managed facilities for rescue available?	0 ☐	1 ☐	2 ☒	3 ☐	4 ☐	5 ☐
• Are rescue facilities and services well positioned?	0 ☐	1 ☐	2 ☒	3 ☐	4 ☐	5 ☐
Overall	**0** ☐	**1** ☐	**2** ☒	**3** ☐	**4** ☐	**5** ☐
Infrastructure and utilities • Are local trade and transport links with markets for products, labour and services well protected against floods?	0 ☐	1 ☒	2 ☐	3 ☐	4 ☐	5 ☐
• Do reliable facilities for water level monitoring exist?	0 ☐	1 ☒	2 ☐	3 ☐	4 ☐	5 ☐
• Are most infrastructures adjustable to flood water levels?	0 ☐	1 ☐	2 ☒	3 ☐	4 ☐	5 ☐

	0	1	2	3	4	5
• Are reliable facilities for waste removal immediately after floods available?	0 ☐	1 ☒	2 ☐	3 ☐	4 ☐	5 ☐
• Are there good, purpose-built facilities for flood water distribution?	0 ☐	1 ☐	2 ☒	3 ☐	4 ☐	5 ☐
• Are buildings built at proper levels to withstand flood water?	0 ☐	1 ☐	2 ☒	3 ☐	4 ☐	5 ☐
• Can most of City's infrastructure damaged by floods be reconstructed and renovated immediately?	0 ☐	1 ☒	2 ☐	3 ☐	4 ☐	5 ☐
Overall	**0** ☐	**1** ☐	**2** ☒	**3** ☐	**4** ☐	**5** ☐
City Dimension 2. NATURAL (maximum 5 minutes)						
Topography • Is Blantyre City composed of numerous water drainage channels including rivers that convey water to lower areas?	0 ☐	1 ☐	2 ☐	3 ☒	4 ☐	5 ☐
• Are land cover features having enough capacity to reduce water velocity by infiltration and water retention?	0 ☐	1 ☐	2 ☒	3 ☐	4 ☐	5 ☐
Overall	**0** ☐	**1** ☐	**2** ☒	**3** ☐	**4** ☐	**5** ☐
Hazard frequency • Has frequency of occurrence of floods been low in Blantyre City with reference to past knowledge and experience?	0 ☐	1 ☒	2 ☐	3 ☐	4 ☐	5 ☐
Overall	**0**	**1**	**2**	**3**	**4**	**5**

	☐	☒	☐	☐	☐	☐
Hazard intensity • Is flood intensity reasonably low not to affect life and property in Blantyre City?	0 ☐	1 ☐	2 ☒	3 ☐	4 ☐	5 ☐
Overall	**0** ☐	**1** ☐	**2** ☒	**3** ☐	**4** ☐	**5** ☐
Natural environment degradation • Are flood prone areas sufficiently free from human manipulation including settlement?	0 ☐	1 ☒	2 ☐	3 ☐	4 ☐	5 ☐
• Is urban green space adequately restored and sustained?	0 ☐	1 ☐	2 ☒	3 ☐	4 ☐	5 ☐
• Is pollution well controlled in the City?	0 ☐	1 ☒	2 ☐	3 ☐	4 ☐	5 ☐
• Are good environmental management practices reflected in development plans?	0 ☐	1 ☐	2 ☒	3 ☐	4 ☐	5 ☐
Overall	**0** ☐	**1** ☐	**2** ☒	**3** ☐	**4** ☐	**5** ☐
Hydro-meteorological situation • Does flood prediction mechanisms (forecasts) always give accurate results?	0 ☐	1 ☐	2 ☐	3 ☒	4 ☐	5 ☐
• Is weather forecasting effective in flood preparedness and mitigation?	0 ☐	1 ☐	2 ☒	3 ☐	4 ☐	5 ☐
	0	1	2	3	4	5

• Does rainfall pattern in Blantyre City complement flood reduction efforts?	☐	☒	☐	☐	☐	☐
Overall	**0** ☐	**1** ☐	**2** ☒	**3** ☐	**4** ☐	**5** ☐
City Dimension 3. SOCIAL (maximum 5 minutes)						
Population • Are most City residents able to undertake flood risk management roles?	0 ☐	1 ☐	2 ☒	3 ☐	4 ☐	5 ☐
• Are most City dwellers capable to safely evacuate from a flood disaster?	0 ☐	1 ☐	2 ☒	3 ☐	4 ☐	5 ☐
• Do most City dwellers live in flood-safe areas?	0 ☐	1 ☐	2 ☐	3 ☒	4 ☐	5 ☐
Overall	**0** ☐	**1** ☐	**2** ☒	**3** ☐	**4** ☐	**5** ☐
Health status • Are most people free from water-borne diseases during floods?	0 ☐	1 ☐	2 ☒	3 ☐	4 ☐	5 ☐
• Are people suffering water-borne diseases able to access health care services?	0 ☐	1 ☐	2 ☐	3 ☒	4 ☐	5 ☐
• Do people have adequate access to primary health facilities during floods just as normal?	0 ☐	1 ☐	2 ☐	3 ☒	4 ☐	5 ☐
Overall	**0** ☐	**1** ☐	**2** ☐	**3** ☒	**4** ☐	**5** ☐
Education and awareness	0	1	2	3	4	5

• Is literacy rate sufficiently high in Blantyre City?	☐	☐	☐	☒	☐	☐
• Is the urban population fully aware of flood disasters?	0 ☐	1 ☐	2 ☐	3 ☐	4 ☒	5 ☐
• Are programmes and schedules for flood disaster drills available?	0 ☐	1 ☐	2 ☒	3 ☐	4 ☐	5 ☐
• Is there normal access to internet in times of floods?	0 ☐	1 ☐	2 ☐	3 ☒	4 ☐	5 ☐
• After floods, do schools function just as before floods?	0 ☐	1 ☐	2 ☒	3 ☐	4 ☐	5 ☐
Overall	**0** ☐	**1** ☐	**2** ☐	**3** ☒	**4** ☐	**5** ☐
Social capital • Do most people actively participate in community activities/clubs?	0 ☐	1 ☐	2 ☒	3 ☐	4 ☐	5 ☐
• Are community leaders elected to the satisfaction of most members of that community (ward)?	0 ☐	1 ☐	2 ☒	3 ☐	4 ☐	5 ☐
• Are communities able to build consensus and participate in decision making process?	0 ☐	1 ☐	2 ☒	3 ☐	4 ☐	5 ☐
• Do people of different ethnicity ably live together in harmony?	0 ☐	1 ☐	2 ☐	3 ☐	4 ☒	5 ☐
• Do community representatives attain special skills in flood risk management?	0 ☐	1 ☐	2 ☒	3 ☐	4 ☐	5 ☐
Overall	**0**	**1**	**2**	**3**	**4**	**5**

	☐	☐	☒	☐	☐	☐
Knowledge and awareness • Did City Council successfully carry out disaster (flood) assessment and mapping for Blantyre City?	0 ☐	1 ☐	2 ☐	3 ☒	4 ☐	5 ☐
• Do results from the disaster assessments get shared with communities?	0 ☐	1 ☒	2 ☐	3 ☐	4 ☐	5 ☐
• Are community members able to implement activities that raise resilience to floods?	0 ☐	1 ☐	2 ☒	3 ☐	4 ☐	5 ☐
Overall	**0** ☐	**1** ☐	**2** ☒	**3** ☒	**4** ☐	**5** ☐
City Dimension 4. ECONOMIC (maximum 5 minutes)						
Income • Do most households live above the poverty line?	0 ☐	1 ☐	2 ☒	3 ☐	4 ☐	5 ☐
• Are most households having numerous income sources?	0 ☐	1 ☒	2 ☐	3 ☐	4 ☐	5 ☐
• Is significant income generated from informal sector (simple crafts, casual work etc.)?	0 ☐	1 ☐	2 ☐	3 ☒	4 ☐	5 ☐
• Is households' income well protected from damage during and after floods?	0 ☐	1 ☒	2 ☐	3 ☐	4 ☐	5 ☐
Overall	**0** ☐	**1** ☐	**2** ☒	**3** ☐	**4** ☐	**5** ☐

	0	1	2	3	4	5
Employment • Is high proportion of the City's population under formal employment in categories as below: ▪ Youth?	☐	☐	☒	☐	☐	☐
▪ Women?	☐	☐	☒	☐	☐	☐
▪ Men?	☐	☐	☐	☒	☐	☐
• Are most people that work in the City coming from outside City boundaries?	☐	☐	☒	☐	☐	☐
• Is there negligible to nil child labour in the City?	☐	☐	☒	☐	☐	☐
Overall	**0** ☐	**1** ☐	**2** ☒	**3** ☐	**4** ☐	**5** ☐
Households assets • Do most people own…? ○ television	☐	☐	☐	☒	☐	☐
○ mobile phone	☐	☐	☐	☐	☒	☐
○ motorised vehicle	☐	☐	☒	☐	☐	☐
○ non-motorised vehicle	☐	☐	☒	☐	☐	☐

○ basic furniture	0 ☐	1 ☐	2 ☐	3 ☒	4 ☐	5 ☐
Overall	**0** ☐	**1** ☐	**2** ☐	**3** ☒	**4** ☐	**5** ☐
Access to financial services • Are there credit facilities adequately available for flood prevention and preparedness?	0 ☐	1 ☒	2 ☐	3 ☐	4 ☐	5 ☐
• Credit facilities (if available), are they readily accessible by the community members?	0 ☐	1 ☒	2 ☐	3 ☐	4 ☐	5 ☐
• Are there other significant financial services available for communities' access?	0 ☐	1 ☐	2 ☒	3 ☐	4 ☐	5 ☐
• Are community members able to access the financial services to use including for flood risk management?	0 ☐	1 ☒	2 ☐	3 ☐	4 ☐	5 ☐
Overall	**0** ☐	**1** ☒	**2** ☐	**3** ☐	**4** ☐	**5** ☐
Savings and insurance • Do households have a sustainable saving culture?	0 ☐	1 ☐	2 ☒	3 ☐	4 ☐	5 ☐
• Are household assets and properties insured?	0 ☐	1 ☒	2 ☐	3 ☐	4 ☐	5 ☐
Overall	**0** ☐	**1** ☒	**2** ☐	**3** ☐	**4** ☐	**5** ☐
Budget and subsidy	0	1	2	3	4	5

	0	1	2	3	4	5
• Do disaster risk management (DRM) programmes receive funding for operationalisation?	☐	☒	☐	☐	☐	☐
• Is the Council's budget dedicated to DRM sufficient for flood risk resilience?	0 ☐	1 ☒	2 ☐	3 ☐	4 ☐	5 ☐
• Are subsidies or incentives available for residents to rebuild their houses?	0 ☐	1 ☒	2 ☐	3 ☐	4 ☐	5 ☐
Overall	**0** ☐	**1** ☒	**2** ☐	**3** ☐	**4** ☐	**5** ☐
City Dimension 5. INSTITUTIONAL (maximum 10 minutes)						
Internal institutions and development plan • Does Blantyre City Council have a specific plan for flood risk management which is reliable for risk management?	0 ☐	1 ☐	2 ☐	3 ☒	4 ☐	5 ☐
• Is the Central Government committed in assisting Council's DRM programmes?	0 ☐	1 ☐	2 ☒	3 ☐	4 ☐	5 ☐
• Do communities (wards) have specific, effective committees for DRM?	0 ☐	1 ☐	2 ☒	3 ☐	4 ☐	5 ☐
• Were communities adequately involved in coming up with DRM plans (if available)?	0 ☐	1 ☐	2 ☒	3 ☐	4 ☐	5 ☐
• Did BCC mainstream flood risk management in its development programmes?	0 ☐	1 ☐	2 ☒	3 ☐	4 ☐	5 ☐
Overall	**0** ☐	**1** ☐	**2** ☒	**3** ☐	**4** ☐	**5** ☐

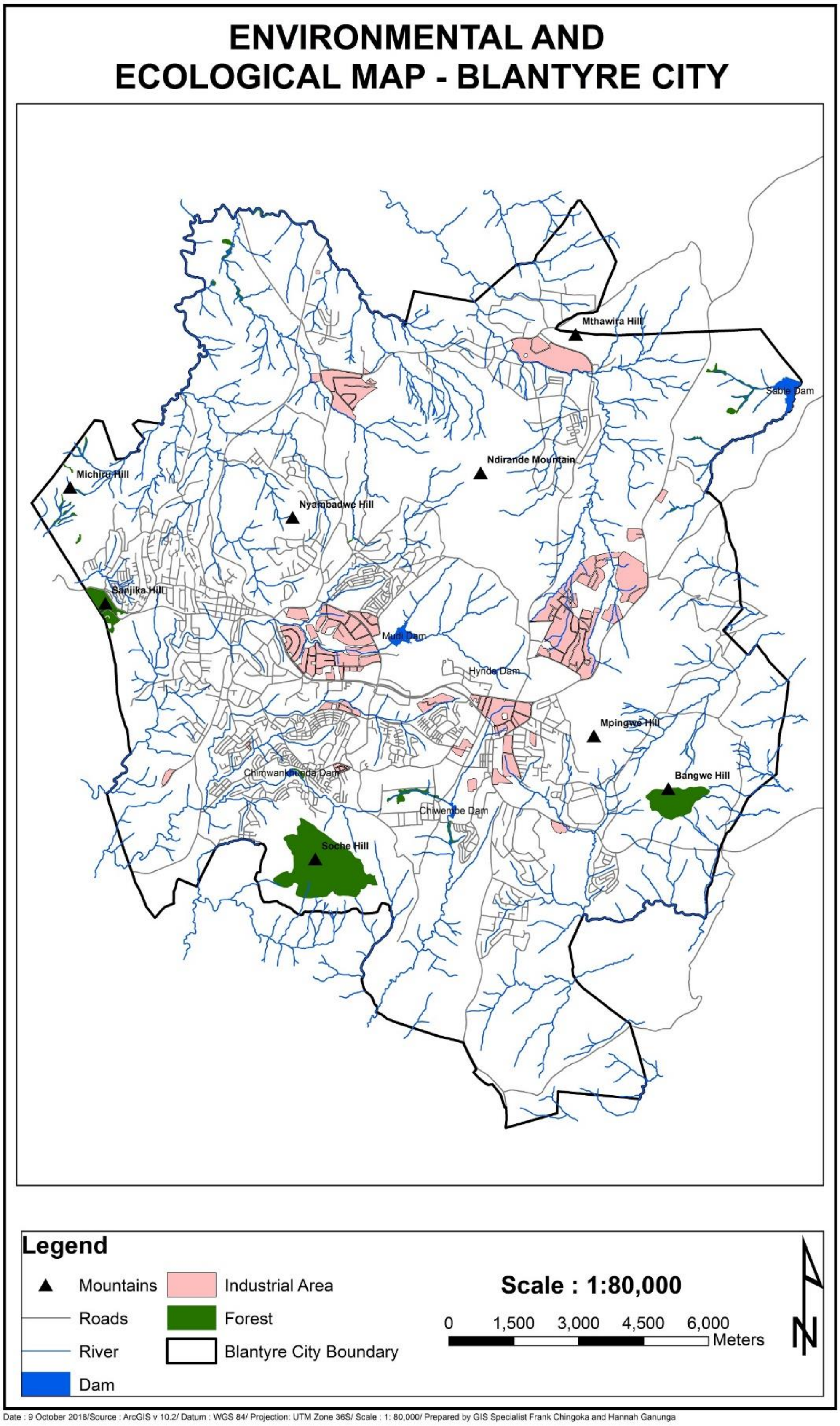
	0	1	2	3	4	5
Effectiveness of internal institutions • Were the City and Ward Civil Protection Committees trained DRM?	☐	☒	☐	☐	☐	☐
• Are civil protection committees effective in responding to flood emergency situations?	☐	☐	☒	☐	☐	☐
• Is an alternative decision making personnel (management or controlling officer) effective in tackling flood risk management?	☐	☒	☐	☐	☐	☐
Overall	**0** ☐	**1** ☒	**2** ☐	**3** ☐	**4** ☐	**5** ☐
External institutions and networks • Are efforts by other public institutions (such as Ministries, Departments and Agencies, e.g. MHC, BWB, Universities) in DRM effective?	0 ☐	1 ☐	2 ☒	3 ☐	4 ☐	5 ☐
• Did other institutions, corporate and civil society mainstream DRM in their operations?	0 ☐	1 ☐	2 ☒	3 ☐	4 ☐	5 ☐
Overall	**0** ☐	**1** ☐	**2** ☒	**3** ☐	**4** ☐	**5** ☐
Institutional collaboration and coordination • Is BCC's dependency on other institutions to an optimal level?	0 ☐	1 ☐	2 ☐	3 ☒	4 ☐	5 ☐
• Are wards interdependent of each other in times of flood crisis?	0 ☐	1 ☐	2 ☒	3 ☐	4 ☐	5 ☐
• Are wards able to undertake preliminary flood risk management efforts on their own?	0 ☐	1 ☒	2 ☐	3 ☒	4 ☐	5 ☐
• Do NGO and private sector actively work with BCC in flood risk management?	0 ☐	1 ☐	2 ☒	3 ☐	4 ☐	5 ☐

Overall	**0**	**1**	**2**	**3**	**4**	**5**
	☐	☐	☒	☐	☐	☐

THANK YOU VERY MUCH FOR YOUR PARTICIPATION

END

Appendix 2 Environmental and ecological map



Source: *Blantyre City Council, 2018*

Appendix 3 Computed questionnaire data and formulae for FRI analysis

Dimension	Variable	Dim. Qn. no.	All Qn. No.	Respondent 1 BCC	Respondent 2 MHC	Respondent 3 DoDMA	Respondent 4 MoLHUD	Respondent 5 EAD	No. of Variables	Variable index (x_i)	Var. weight (w_i)	$x_i * w_i$
PHYSICAL	*land use*	1	1	3	1	3	3	5	1		1.00	
	var. sum			2.50	1.00	3.00	3.00	5.00				
	var. index			2.50	1.00	3.00	3.00	5.00		**2.9**	**0.52**	**1.51**
	electricity	2	2	2	0	3	2	4	2		3.00	
		3	3	3	0	3	3	4				
		4	4	3	1	1	1	3				
	var. sum			7.75	1.00	7.00	6.00	11.00				
	var. index			2.58	0.33	2.33	2.00	3.67		**2.18**	**1.56**	**3.41**
	environmental degradation	5	5	4	4	0	1	3	3		2.00	
		6	6	3	0	1	2	2				
	var. sum			6.13	4.00	1.00	3.00	5.00				
	var. index			3.06	2.00	0.50	1.50	2.50		**1.91**	**1.04**	**1.99**
	water supply	7	7	3	0	2	3	3	4		4.00	
		8	8	2	0	2	1	3				
		9	9	3	5	3.5	3	1				
		10	10	2	2	2	0	1				
	var. sum			9.75	7.00	9.50	7.00	8.00				
	var. index			2.44	1.75	2.38	1.75	2.00		**2.06**	**2.08**	**4.30**
	sanitation (including solid waste disposal)	11	11	3	1	2	2	1	5		5.00	
		12	12	2	0	3	1	1				
		13	13	2	1	2	1	2				
		14	14	2	1	2	0	1				
		15	15	2	1	2	3	1				
	var. sum			11.00	4.00	11.00	7.00	6.00				
	var. index			2.20	0.80	2.20	1.40	1.20		**1.56**	**2.60**	**4.06**
	road network availability	16	16	4	4	4	4	3	6		5.00	
		17	17	3	1	3	5	2				
		18	18	2	1	3	3	3				
		19	19	2	0	1	2	2				
		20	20	2	1	2	3	1				
	var. sum			13.50	7.00	13.00	17.00	11.00				
	var. index			2.70	1.40	2.60	3.40	2.20		**2.46**	**2.60**	**6.41**
	housing and land use	21	21	3	1	3	5	3	7		4.00	
		22	22	2	1	2	2	4				
		23	23	2	1	2	0	2				
		24	24	2	1	2	3	2				
	var. sum			9.13	4.00	9.00	10.00	11.00				

Dimension	Variable	Dim. Qn. no.	All Qn. No.	Respondent 1 BCC	Respondent 2 MHC	Respondent 3 DoDMA	Respondent 4 MoLHUD	Respondent 5 EAD	No. of Variables	Variable index (x_i)	Var. weight (w_i)	x_i*w_i
	var. index			2.28	1.00	2.25	2.50	2.75		**2.16**	**2.08**	**4.49**
	community assets	25	25	1	0	0	2	1	8		5.00	
		26	26	1	0	0	1	1				
		27	27	2	1	2	0	3				
		28	28	2	3	2	0	1				
		29	29	2	1	1	0	1				
	var. sum			7.50	5.00	5.00	3.00	7.00				
	var. index			1.50	1.00	1.00	0.60	1.40		**1.10**	**2.60**	**2.86**
	warning system and evacuation	30	30	1	1	1	3	3	9		5.00	
		31	31	1	0	1	1	1				
		32	32	2	0	2	1	2				
		33	33	0	0	2	2	2				
		34	34	1	0	3	1	2				
	var. sum			5.13	1.00	9.00	8.00	10.00				
	var. index			1.03	0.20	1.80	1.60	2.00		**1.33**	**2.60**	**3.45**
	history	35	35	2	1	4	3	3	10		3.00	
		36	36	3	1	3	3	2				
		37	37	2	0	4	2	2				
	var. sum			7.38	2.00	11.00	8.00	7.00				
	var. index			2.46	0.67	3.67	2.67	2.33		**2.36**	**1.56**	**3.68**
	location	38	38	2	4	1	3	2	11		1.00	
	var. sum			1.75	4.00	1.00	3.00	2.00				
	var. index			1.75	4.00	1.00	3.00	2.00		**2.35**	**0.52**	**1.22**
	accessibility	39	39	3	1	3	2	2	12		3.00	
		40	40	1	0	2	2	3				
		41	41	1	0	2	3	2				
	var. sum			4.88	1.00	7.00	7.00	7.00				
	var. index			1.63	0.33	2.33	2.33	2.33		**1.79**	**1.56**	**2.80**
	infrastructure and utilities	42	42	2	1	2	0	2	13		7.00	
		43	43	1	0	2	1	2				
		44	44	1	0	3	1	3				
		45	45	2	0	1	2	2				
		46	46	2	1	1	4	2				
		47	47	2	2	2	2	3				
		48	48	1	0	1	3	2				
	var. sum			9.25	4.00	12.00	13.00	16.00			**48.00**	
	var. index			1.32	0.57	1.71	1.86	2.29		**1.55**	**3.65**	**5.65**
											25.00	

Dimension	Variable	Dim. Qn. no.	All Qn. No.	Respondent 1 BCC	Respondent 2 MHC	Respondent 3 DoDMA	Respondent 4 MoLHUD	Respondent 5 EAD	No. of Variables	Variable index (x_i)	Var. weight (w_i)	x_i*w_i
	∑(xi*wi)											**45.85**
	∑(xi*wi)/∑wi											**1.83**
NATURAL	*Topography*	1	49	3	1	2	2	5	1		2.00	
		2	50	2	1	2	2	1				
	var. sum			4.88	2.00	4.00	4.00	6.00				
	var. index			2.44	1.00	2.00	2.00	3.00		**2.09**	**1.82**	**3.80**
	hazard frequency	3	51	1	1	0	2	1	2		1.00	
	var. sum			1.38	1.00	0.00	2.00	1.00				
	var. index			1.38	1.00	0.00	2.00	1.00		**1.08**	**0.91**	**0.98**
	hazard intensity	4	52	1	4	0	2	1	3		1.00	
	var. sum			1.38	4.00	0.00	2.00	1.00				
	var. index			1.38	4.00	0.00	2.00	1.00		**1.68**	**0.91**	**1.52**
	natural environment degradation	5	53	1	1	0	1	1	4		4.00	
		6	54	2	1	0	4	4				
		7	55	2	0	0	2	0				
		8	56	3	0	1	4	3				
	var. sum			8.00	2.00	1.00	11.00	8.00				
	var. index			2.00	0.50	0.25	2.75	2.00		**1.50**	**3.64**	**5.45**
	hydro-meteorological situation	9	57	3	1	3	3	3	5		3.00	
		10	58	3	1	2	4	2				
		11	59	1	0	1	2	2				
	var. sum			7.25	2.00	6.00	9.00	7.00			11.00	
	var. index			2.42	0.67	2.00	3.00	2.33		**2.08**	**2.73**	**5.68**
											10.00	
	∑(xi*wi)											**17.43**
	∑(xi*wi)/∑wi											**1.74**
SOCIAL	*population*	1	60	2	2	1	3	2	1		3.00	
		2	61	2	2	2	3	2				
		3	62	2	4	3	3	3				
	var. sum			5.63	8.00	6.00	9.00	7.00				
	var. index			1.88	2.67	2.00	3.00	2.33		**2.38**	**3.16**	**7.50**
	health status	4	63	2	1	3	2	2	2		3.00	
		5	64	2	1	4	3	3				
		6	65	3	2	4	2	4				
	var. sum			6.88	4.00	11.00	7.00	9.00				
	var. index			2.29	1.33	3.67	2.33	3.00		**2.53**	**3.16**	**7.97**

Dimension	Variable	Dim. Qn. no.	All Qn. No.	Respondent 1 BCC	Respondent 2 MHC	Respondent 3 DoDMA	Respondent 4 MoLHUD	Respondent 5 EAD	No. of Variables	Variable index (x_i)	Var. weight (w_i)	x_i*w_i
	education and awareness	7	66	3	2	4	3	5	3		5.00	
		8	67	3	3	4	5	3				
		9	68	2	0	4	2	2				
		10	69	4	1	4	4	3				
		11	70	2	0	3	3	2				
	var. sum			13.38	6.00	19.00	17.00	15.00				
	var. index			2.68	1.20	3.80	3.40	3.00		**2.82**	**5.26**	**14.82**
	social capital	12	71	3	1	2	2	2	4		5.00	
		13	72	3	1	1	3	2				
		14	73	2	0	1	2	3				
		15	74	3	4	4	4	3				
		16	75	2	1	2	2	3				
	var. sum			13.75	7.00	10.00	13.00	13.00				
	var. index			2.75	1.40	2.00	2.60	2.60		**2.27**	**5.26**	**11.95**
	knowledge and awareness	17	76	3	1	3	4	2	5		3.00	
		18	77	2	0	1	2	2				
		19	78	2	0	2	3	3				
	var. sum			7.88	1.00	6.00	9.00	7.00			**19.00**	
	var. index			2.63	0.33	2.00	3.00	2.33		**2.06**	**3.16**	**6.50**
											20.00	
	∑(xi*wi)											**48.74**
	∑(xi*wi)/∑wi											**2.44**
ECONOMIC	*income*	1	79	2	0	0	2	5	1		4.00	
		2	80	2	0	1	1	3				
		3	81	3	4	4	1	2				
		4	82	2	0	2	0	3				
	var. sum			8.50	4.00	7.00	4.00	13.00				
	var. index			2.13	1.00	1.75	1.00	3.25		**1.83**	**5.22**	**9.52**
	employment	5	83	2	0	1	2	4	2		5.00	
		6	84	2	0	2	2	3				
		7	85	3	2	3	4	5				
		8	86	2	0	4	1	2				
		9	87	3	1	1	2	2				
	var. sum			11.38	3.00	11.00	11.00	16.00				
	var. index			2.28	0.60	2.20	2.20	3.20		**2.10**	**6.52**	**13.66**
	households assets	10	88	3	2	3	5	3	3		5.00	
		11	89	4	2	4	5	3				

Dimension	Variable	Dim. Qn. no.	All Qn. No.	Respondent 1 BCC	Respondent 2 MHC	Respondent 3 DoDMA	Respondent 4 MoLHUD	Respondent 5 EAD	No. of Variables	Variable index (x_i)	Var. weight (w_i)	x_i*w_i
		12	90	2	1	2	3	3				
		13	91	2	3	1	4	2				
		14	92	4	2	2	2	4				
	var. sum			14.75	10.00	12.00	19.00	15.00				
	var. index			2.95	2.00	2.40	3.80	3.00		**2.83**	**6.52**	**18.46**
	access to financial service	15	93	1	0	2	1	2	4		4.00	
		16	94	1	0	2	0	1				
		17	95	2	0	2	3	2				
		18	96	1	0	2	2	2				
	var. sum			5.13	0.00	8.00	6.00	7.00				
	var. index			1.28	0.00	2.00	1.50	1.75		**1.31**	**5.22**	**6.82**
	savings and insurance	19	97	1	0	3	3	1	5		2.00	
		20	98	0	0	2	2	1				
	var. sum			1.63	0.00	5.00	5.00	2.00				
	var. index			0.81	0.00	2.50	2.50	1.00		**1.36**	**2.61**	**3.55**
	budget and subsidy	21	99	1	1	2	2	1	6		3.00	
		22	100	1	0	2	2	1				
		23	101	1	0	2	1	1				
	var. sum			3.00	1.00	6.00	5.00	3.00			**23.00**	
	var. index			1.00	0.33	2.00	1.67	1.00		**1.20**	**3.91**	**4.70**
											30.00	
	∑(xi*wi)											**56.71**
	∑(xi*wi)/∑wi											**1.89**
INSTITUTIONAL	*internal institutions and development plan*	1	102	4	1	5	3	1	1		5.00	
		2	103	2	1	2	4	2				
		3	104	3	0	2	2	1				
		4	105	3	0	4	2	2				
		5	106	3	0	3	3	2				
	var. sum			15.38	2.00	16.00	14.00	8.00				
	var. index			3.08	0.40	3.20	2.80	1.60		**2.22**	**5.36**	**11.87**
	effectiveness of internal institutions	6	107	2	0	1	2	1	2		3.00	
		7	108	2	0	2	3	1				
		8	109	3	1	1	1	1				
	var. sum			6.50	1.00	4.00	6.00	3.00				
	var. index			2.17	0.33	1.33	2.00	1.00		**1.37**	**3.21**	**4.39**
	external institutions and networks	9	110	2	0	3	2	1	3		2.00	
		10	111	2	0	3	2	1				

Dimension	Variable	Dim. Qn. no.	All Qn. No.	Respondent 1 BCC	Respondent 2 MHC	Respondent 3 DoDMA	Respondent 4 MoLHUD	Respondent 5 EAD	No. of Variables	Variable index (x_i)	Var. weight (w_i)	x_i*w_i
	var. sum			4.25	0.00	6.00	4.00	2.00				
	var. index			2.13	0.00	3.00	2.00	1.00		**1.63**	**2.14**	**3.48**
	institutional collaboration and coordination	11	112	3	4	3	1	2	4		4.00	
		12	113	2	0	3	0	3				
		13	114	1	0	2	2	1				
		14	115	3	4	3	5	1				
	var. sum			9.25	8.00	11.00	8.00	7.00			14.00	
	var. index			2.31	2.00	2.75	2.00	1.75		**2.16**	**4.29**	**9.27**
											15.00	
	∑(xi*wi)											**29.01**
	∑(xi*wi)/∑wi											**1.93**
	Overall FRI											**1.97**
	Percent											**49.19**