Unpacking Urban Resilience: Environmental Management practices in 'Debre Birhan' city, North Shoa Zone, Amhara Regional State, Ethiopia.

A Thesis Submitted to the post-graduate Office of the Ethiopian institute of Architecture, Building Construction, and City Development, in Partial Fulfillment of the Requirements for the Award of a Master of Science Degree in Environmental Planning and Landscape Design

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April 2024

Addis Ababa, Ethiopia

EiABC, Addis Ababa University

Approval sheet

This is to certify that the thesis prepared by Tale Mekonnen entitled “Unpacking Urban Resilience: Sustainable Environmental Management Practices in 'Debre Birhan' city, North Shoa Zone, Amhara Regional State, Ethiopia’ and submitted in the partial fulfillment of the requirements for the Master of Science degree in Environmental Planning and Landscape Design complies with the regulations of the University and meets the accepted standards concerning originality and quality.

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Declaration

I, the undersigned, declare that this thesis is my own and original work and has not been presented for a degree in any other university and that all sources of material used for the thesis have been duly acknowledged, following the scientific guidelines of the University.

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Confirmation

The thesis can be submitted for examination with my approval as an Institute's supervisor.

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Abstract

Current research advocates that studies in cities of developing countries need special attention related to environmental management practices. Accordingly, this study aims to investigate the variables affecting environmental management practices and environmental management tools implemented based on household and key informants' opinions and perceptions of the experts on resilience thinking applied to environmental management practices of Debre Birhan City. Data were collected through questionnaires and expert interviews using KoboCollect and site observations. The results are analyzed using Pareto, Best Worst Method (BWM), and land use land cover change analysis using ArcGIS 10.8. The study used both random and purposive sampling techniques. Three hundred ninety-five (395) households and twenty-two (22) experts were contacted to collect data for the study. Accordingly, the result revealed eleven environmental, nine physical, ten social, and four institutional vital variables; Seven, five, four, and six environmental management tools for environmental, physical, social, and institutional factors were identified, respectively; and six resilience principles in the city. The BWM weight values rank waste management and expropration (0.5625) first, urban planning elements (0.3125) second, and lack of urban green and recreation (0.1250) third based on households.In contrast, experts ranked waste management and pollution (0.4838), lack of urban green and recreation (0.3225), and lack of urban planning elements (0.1935) ranked first, second, and third, respectively. Urban amenities and services (0.5932) and poor infrastructures (0.2373) are households' and experts' top physical variables, respectively. The city's most critical social variables are access-related and polluted industries. Promoting urban agriculture, improving road conditions, land use planning and zoning (compatibility), and collaboration among concerned institutions are the most implemented environmental management tools for environmental, physical, social, and institutional factors. Diversity and integration are the principles that are applied the most and least in environmental management practices. The study, therefore, recommends the enforced application of resilience principles as environmental management tools in environmental management policy documents to improve sustainability in the city.

Keywords: *Urban resilience; urban factors, Pareto Analysis; Environmental Management practices; Resilience-based management strategies;*

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Abbreviations/Acronyms

BWM	Best Worst Method
CRGE	Climate Resilient Green Economy
EA	Environmental Assessment
ECSPGs	Ethiopian Cities Sustainable Prosperity Goals
EEA	European Environmental Agency
EEPA	Ethiopian Environmental Protection Authority
EMS	Environmental Management System
EPE	Environmental Policy of Ethiopia
EU	European Union
FDRE	Federal Democratic Republic of Ethiopia
GDP	Gross Domestic Products
GTP	Growth and Transformation Plan
KMs	Kilometers
LDP	Local Development Plan
NDC	Nationally Determined Contribution
NGO	Nongovernmental Organizations
OECD	Organization for Economic Co-operation and Development
SDGs	Sustainable Development Goals
SP	Structure Plan

SSA	Sub-Saharan Africa
UEM	Urban Environmental Management
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
USAID	United States Agency for International Development

Acknowledgment

First and foremost, I would like to thank Dr. Mulugeta Maru, an assistant professor, for his constant assistance, direction, and mentoring while writing this thesis. His knowledge, support, and criticism helped determine the research and caliber of this procedure.

I would also like to express my deep appreciation to EiABC and Addis Ababa University for providing the facilities and other academic environments that made this research possible. We especially want to thank the environmental planning and landscape design chair for their help and encouragement during this study.

I also want to thank my family for their constant support, love, and tolerance throughout this challenging path. Their encouragement and faith in my skills have always given me courage and drive. I want to thank Ato Bedilu Wubshet, Mayor of Debre Birhan City, and Shefera Mekonnen for their cooperation and contribution to the research development.

Lastly, the EiABC postgraduate office, whose unflinching faith and encouragement have been my guiding light and inspiration for this thesis.

CHAPTER ONE: INTRODUCTION

1.1. Background of the study

The world is becoming increasingly urban, and the complex environmental, social, economic, and political concerns of the 21st century provide cities with ongoing challenges (UN-Habitat, 2022). Globally, cities and towns are becoming more congested and connected than ever (Henderson, 2010).

Urban resilience is now recognized as a critical concept for cities to alleviate urban pressures and risks caused by increasing urban concerns (Cao, 2023). Applying the resilience principle is critical to ensuring sustainable growth of urban areas. However, in the last decade, urban resilience has received attention in academic and political realms. The concept of resilience, which originated in ecology and system dynamics in particular, is currently applied in various domains, including disaster Management, adaptive Management, biodiversity Management, risk governance, spatial planning, and many more (Bahadur, Tanner and Pichon, 2016).

Planning for a resilient urban future involves addressing problems and developing solutions in an inclusive, place-based, integrated, risk-aware, and forward-looking approach (Chonko, 2018). Numerous international organizations have claimed that cities need to become more resilient to overcome environmental, social, physical, and institutional obstacles in management practices (Gencer, 2017).

Environmental considerations are important for current and future development cooperation when institutions make decisions that influence national, local, and sector-specific development policy, norms, plans, investments, and activities (Dalal-Clayton and Bass, 2009). International agreements such as the EU Urban Agenda, UN Habitat III, Sustainable Development Goals, UNFCC Paris Agreement, and Sendai Framework for Disaster Risk Reduction have also taken on the task of integrating the idea of Resilience into societies' fabric as an essential component of meeting their goals (ARUP, 2015 and Wang, Li and Li, 2021).

Urban Resilience necessitates a comprehensive assessment of a city's resources and hazards, including meaningful interaction with its most vulnerable residents (World

Bank, 2015). A city can improve its overall trajectory and the well-being of its residents by bolstering its fundamental structure and developing a deeper awareness of the risks that threaten its stability. This will allow it to succeed in facing both anticipated and unanticipated problems (Jabareen, 2013).

There are several contexts where the resilience concept has been used. Urban resilience, however, remains popular in academic discussions and policy discourse (Meerow and Newell, 2015; Weichselgartner & Kelman, 2015). Climate change, disaster management, resource management, economic and demographic difficulties, and other urban policy agendas can all be framed positively in urban resilience (Schofield and Twigg, 2019).

Cities in Sub-Saharan Africa (SSA) face various environmental, physical, and social challenges due to human-caused development (Gasparatos et al., 2020). Urban government structures are also a big challenge in these cities (Pattillo, Gupta & Carey, 2006). To address future sustainability challenges, governments in the region need to adopt resilience thinking, environmental policies, and treaties in their urban environmental management practices.

Ethiopia's growth and transformation plans, the First Growth and Transformation Plan (GTP I) and the Second Growth and Transformation Plan (GTP II), and Climate Resilient Green Economy (CRGE) initiative since 2011 and mainstreaming of CRGE, which spanned a 20-year time horizon, in GTP II, The Ten Year Development Plan and the recent Nationally Determined Contributions (NDCs), are strategies and means to achieve Resilience in urban areas of the country (Dagne et al., 2022).

Ethiopia is starting to experience a demographic and urban shift further into intermediary (medium-sized) cities (OECD & Institute, 2020). As rural transformation catalysts, these cities connect significant rural and urban communities to basic facilities and services and, therefore, require Resilience thinking in urban environmental Management practice to achieve sustainability. Ethiopia is adopting the Ethiopian Cities Sustainable Prosperity Goals (ECSPGs) framework, which intends to achieve SDG 11, emphasizing safe, resilient, and clean urban development (Baye 2021).

However, Ethiopian large, medium, and small-sized cities are more dynamic and fast-growing cities overwhelmed by many environmental and socio-economic problems (OECD & Institute, 2020). Therefore, well-managed intermediary cities can facilitate rural-urban transformation and contribute to structural transformation and development.

'Debre Birhan' city is one of the fastest-growing secondary cities, acting as a hub for a wide range of industries, factories, and infrastructures, with many environmental, physical, social, and institutional factors affecting environmental management practices (SymbioCity, 2020).

1.2. Research gaps

The research gap regarding inadequate environmental disclosure on urban environmental Management practices in SSA needs further study. The uncertain importance of environmental Management tools and Resilience in sustainable development integration, conceptual and methodological frameworks for data collection, and governance knowledge gaps must be better understood (Jabbarzadeh, Fahimnia & Sabouhi, 2017).

Conceptually, the absence of integrating environmental management tools and resilience concepts into urban environmental management practices results in various environmental, physical, social, and institutional problems. In particular, a lack of understanding in SSA cities about the problem-solving approach of environmental management theories and the combination of social-ecological resilience theories in mitigation measures.

Methodologically, data collecting and prioritization of elements in urban regions is conducted in a tiny portion of cities in industrial sites only by expert research. The isolation of residents from urban areas while collecting variables and implementing mitigating measures in cities caused troubles.

Other gaps include an incomplete indication of urban environmental Management practices, tradeoffs, and synergies to improve sustainability and Resilience through Environmental Management. Furthermore, it impacts sustainability and resilience in

inter- and intra-sectoral investigations and the impact of coordination, information sharing, vulnerability outsourcing, and vertical institutional integration (Fahimnia et al., 2019).

1.3. Problem statement

Urbanization is the most irreversible phenomenon (McGranahan & Satterthwaite, 2014) and is dominated by human-induced land use (Clement, Chi & Ho, 2015). It is a multifaceted socio-economic process that changes the built environment by transforming rural communities into urban ones with many problems (UN report, 2019). Problems associated with urbanization include high population density, poor infrastructure, lack of cheap housing, flooding, pollution, the development of slums, crime, traffic congestion, and poverty (Lumun and Edwe, 2019).

Urbanization also alters the biophysical structure of a landscape (Grimm et al., 2008), which impacts biodiversity within cities due to changing habitat quality and connectivity by increasing built environments (UNEP & UN-Habitat, 2005), as well as increased demands for food and resources (Elmqvist, Zipperer and Güneralp, 2015; Ke et al., 2018).

Urban areas usually face acute shocks and long-term pressures (UNDP, 2020). These include chronic pressures that gradually erode a community's fabric, such as frequent flooding, high unemployment, a lack of social safety nets, and unequal public transit systems, amplifying severe shocks' effects (Fahlberg et al., 2020).

In light of both the favorable and unfavorable social, economic, political, cultural, and environmental repercussions of urbanization (Mutuku, 2018), large agglomerations, a lack of institutional capacity, and improper urban planning are some obstacles to urban sustainability in developing countries (UN, 2012).

Environmental challenges, including land degradation and desertification, deforestation, soil erosion, wetland degradation, insect infestation, scarcity and pollution of surface and groundwater, biodiversity loss, extreme vulnerability to climate change, and the reduction of economically essential biological resources are

widely recognized problems in Sub-Saharan African (SSA) cities (Satterthwaite, 2017).

In order to curb the challenges above, the environmental Management practices in SSA countries have low internalization of ISO standards due to the low power of action of ISO Management standards and the role of orality, such as poorly formalized interactions between employees, in the implementation of ISO 14001 certifiable voluntary standard (Tene, Boiral and Heras-Saizarbitoria, 2020).

World Bank report (2017) indicated that the cities of SSA countries are crowded, disconnected, and expanded in an uncontrolled way. Ethiopia is one of the countries that experienced fast urbanization and investment in urban areas. However, urban infrastructure services are failing to contend with urbanization trends. Furthermore, the scarcity of formal land and housing development in urban areas results in chronic discrepancies between unhoused and under-housed (Alemayehu, 2019).

Nowadays, Ethiopia's intermediary (secondary and tertiary) cities contribute to a more inclusive urbanization process and create a balanced urban system on a national scale. They are improving urban inhabitants in terms of housing, infrastructure, transportation, and public service delivery and diversifying the national economic structure with various environmental, social, and institutional problems (OECD, 2020a).

The environmental issues in 'Debre Birhan' city include water pollution, land pollution, a lack of proper environmental impact assessment, inefficient waste management techniques (Choramo, 2021), and a lack of efficient greening (Zenebe et al., 2021). Problems associated with infrastructure include insufficient sanitation systems, traffic accidents, and inadequate drainage facilities. Incompatible land uses, horizontal urban growth, and access-related issues are all examples of social difficulties in the city. The lack of clear public information on the development practices, lack of participation, and public awareness among the residents are also institutional factors in 'Debre Birhan' city.

Therefore, this study explored the challenges of environmental management practices, how resilience principles were applied in various urban aspects, and finally, how to

make resilient urbanization for 'Debre Birhan' city in particular and in the country in general.

1.4. Objectives of the study

1.4.1. General Objective:

The study's general objective is to unpack urban resilience exemplified by the environmental management practices in Debre Birhan City, Ethiopia.

1.4.2. Specific objectives:

- To identify the factors affecting the environmental well-being of 'Debre-Birhan' city;
- To investigate the perception of residents and experts on the environmental management tools deployed in the city;
- To examine the extent to which the experts acknowledge Resilience principles and
- To provide Resilience-based environmental Management recommendations and implementation strategies applicable to the country's urban planning process.

1.5. Research questions

1. What factors affect the environmental well-being of Debre-Birhan city?
   - ✓ What are the environmental, physical, social, and institutional factors affecting the city's environmental management practices?
2. How do residents and experts perceive the environmental management tools implemented in the city to offset environmental management challenges?
3. What Resilience principles are acknowledged by experts in the city?
4. How can resilience principles be integrated into environmental Management tools to develop Resilience-based planning strategies and recommendations for the city of 'Debre Birhan' and the country?

1.6. Scope of the study

Both space and theme delimit the research's scope.

1.6.1. Spatial Scope

The research area is geographically located in the North Shoa zone, notably 'Debre Birhan' city of Amhara Regional State, in Ethiopia.

1.6.2. Thematic Scope

Thematic focuses on the spatial and institutional factors, environmental management tools implemented, and resilience thinking in practice. Specifically, the following variables are addressed.

Environmental variables included solid and liquid waste management, water and land pollution, lack of green and open spaces (parks, forests, gardens, buffer zones, playgrounds, squares, and plazas), loss of urban agriculture, and surface flooding. The paper focuses on the physical variables, including road conditions, drainage facilities, and sanitation systems. The **Social variables** constitute access to educational services, access to health services, uncontrolled land cover change, condition of land use compatibility, informal settlements, transportation conditions, traffic accidents and congestion, urban sprawl, and urban expansion. On the other hand, the **Institutional variables** encompass shared planning, objective setting, alignment, and disclosure of tasks.

The thematic scope concerning resilience thinking is attached to **Diversity,** which covers ecological diversity, urban land use, road network conditions, Management techniques/methods, and locational diversity of organizations and service centers. The next issue is **Redundancy**: multiple nodes (primary & and secondary), multiple green and open spaces, multiple forests, multiple road hierarchies, and road condition and conservation areas. The third component is **Modularity,** which deals with **the** connectivity of street road networks and nodes, green belts, and greenways. The fourth resilience principle covered is **integration, which is** explained by stakeholder involvement/public participation/ and collaboration during decision-making. The fifth resilience attribute is **Interdependence,** which includes integrated road networks and green infrastructures. The last component is **robustness, which refers to the sustainability of urban transportation networks (roads, bridges, etc.) and the** sustainability of urban form.

1.7. Significance of the study

This investigated and suggested the best resilience frameworks, policies, management mechanisms, and implementation strategies for decision-makers and government bodies. Furthermore, this study was used to improve urban areas' livability and implement the site's finest systems.

1.8. Research limitations

This study has faced several limitations. These include very limited preceding research on the topic, household understanding of the variables prioritization and limitation of similar countries' experience on the issues, lack of an updated base map the city, time consumed for expert interviews due to continuous meetings, and lack of willingness to answer the questionnaires by some experts and households.

1.9. Organization of the paper

Chapter One: include an introduction, problem statement, objectives, and research questions, and define the spatial and thematic scope of the study. **Chapter Two** offered an overview of the research topic's theoretical, conceptual and contextual literature. The best studies from other countries were reviewed in this chapter to perform a theoretical and contextual analysis of the study and highlight the lessons that will be drawn from them. **Chapter Three:** This chapter primarily focused on the methodologies for gathering, analyzing, interpreting, and discussing data to do the research. **Chapter Four** presents the paper's findings and discussion, as well as provides details and analysis of the findings from observation, interviews, data collected from government and private offices, and a literature review. **Chapter Five** focuses on the environmental management strategies to offset environmental management problems. **Chapter Six**: Finally, this chapter includes the conclusion and recommendations of the paper.

CHAPTER TWO: LITERATURE REVIEW

2.1. Definitions of terms and concepts

Resilience is a dynamic concept (Rutter, 2012), and it is the ability to adapt or cope successfully in the face of a threat or disaster and recover from it (European Commission, 2012). Most definitions of Resilience entail dealing with pressure, stress, or a degree of resistance to environmental risk (Bowes and Jaffee, 2013).

Urban Resilience: is the ability of urban or city dwellers to withstand social, health, environmental, disaster, and climate-related risks and prepare for future impacts (UN-Habitat, 2022).

Environmental Management is a required field that provides a thorough introduction and resource for apprentices and practitioners, introducing principles, practice, and critical policy issues (Nel & kotze, 2016). It also brings together the common threads that run through the different application fields, such as the precautionary principle, the "polluter pays" principle, a multidisciplinary and proactive approach, the pursuit of sustainable development, evaluation of risks, hazards, and impacts, and environmental stewardship (Sadeleer, 2020).

Urban Environmental Management (UEM) tools address environmental Management system compliance, accomplish environmental objectives and outcomes, and serve as a resource for policymakers to promote a better awareness and understanding of the variety of tools accessible to the government and our stakeholders (Doorasamy, 2015).

2.2. Theoretical Review

2.2.1. Theories of Resilience

Resilience thinking emerged from the discovery and the insight that biological systems have numerous basins of attraction, and it has evolved into a method for comprehending complex adaptive systems and acts as a foundation for multidisciplinary and transdisciplinary research with a focus on social-ecological

systems (Levin et al., 2013). The three types of resilience theories are engineering, ecological, and social-ecological.

- **Ecological Resilience**

Resilience is quickly becoming a buzzword in ecology, conservation, Management, and policy, maybe because it offers the potential to avoid thresholds and undesirable changes in the condition of a system (Walker & Salt, 2012).

Holling (1973) proposed Resilience as a concept concerning the environment, or more specifically, concerning ecosystems, as a way to understand the ability of ecosystems to absorb change or, more specifically, how to persist in developing in the original state under disturbances and changing conditions or states (Desjardins et al., 2015).

Ecological Resilience is also used in applied ecology to describe an ecosystem's capacity to return its core structure, processes, and functioning (or to remain primarily intact) in the face of natural and human-made shocks and stresses, disruptions, or invasive species (Pope, Allen and Angeler, 2014; Seidl et al., 2016).

Ecological resilience refers to an ecosystem's stability and ability to tolerate disruption and restore itself without collapsing into a qualitatively different state through controlled mechanisms (Gunderson and Holling, 2002). According to Brand (2005), ecological Resilience has two components:

- The time it takes for an ecosystem to recover from a disruption and return to equilibrium (capacity of a system for recovery and response).
- A system's ability to absorb disturbance and reorganize while enduring change while retaining the same function, structure, identity, and feedback (the capability of a system to resist change).

Ecosystems serve as natural shock absorbers. Ecosystems and ecosystem services can mitigate natural disasters. An ecological adaptive system is defined by the ecological entities participating, their properties, and the biophysical laws governing their interaction (Schlüter et al., 2019). In this era of rapid change, effective ecosystem Management necessitates understanding an ecosystem's response to these stressors and

disturbances and understanding an ecosystem's response not only to these stressors and disturbances but also to management action (Germino et al., 2016).

- **Engineering Resilience**

Engineering Resilience focuses on restoring a system's structural and functional characteristics to its pre-disturbance state after a disturbance (Hollnagel, 2013). The recovery time is the measurement unit, so rapid return times indicate solid engineering Resilience (Angeler and Allen, 2016). This Definition ignores the possibility of different states for the same system since it presumes a single equilibrium defines systems equilibrium.

Engineering Resilience in a management setting makes the naive assumption that an ecosystem always recovers from a degraded condition to a prior or more desired one and that the only relevant metric is return time (Pillay and Morel, 2020). So, Resilience engineering aims to create systems that can adapt when they fail (Hollnagel, Woods & Leveson, 2006).

- **Social-ecological Resilience**

Social-ecological Resilience is the capacity to adapt to or transform in the face of change in interconnected systems, which is the biological (epidemiological ecosystem) and social (social and economic conditions of life in the society), mostly unexpected change, in ways that continue to support human wellbeing (Chapin et al., 2010; Biggs, Schlüter and Schoon, 2015).

Socio-ecological systems are complex adaptive systems (Preiser et al., 2018), that show how intricately entwined society and ecology are (Harrington et al., 2010). The interconnections or interactions between human societies and ecosystems are a major source of a system of systems' Resilience (Francis and Bekera, 2014). Social, political, and environmental changes are among the contributing variables.

In social-ecological Resilience, humans are part of the natural world, rely on ecological systems for survival, and continually impact the ecosystems in which they live, from the local to the global scale. Resilience is a feature of these interconnected social-

ecological systems (Resilience Alliance, 2010). Resilience devotion is mainly about understanding how periods of slow change interact with periods of fast change in linked social-ecological systems confronted with actual uncertainty and what this means for people and the earth (Folke, 2016).

2.2.2. Theories of environmental management

Environmental management refers to managing contemporary human society with the environment and its consequences (Sulphey & Safeer, 2017). Thus, environmental management is a means of justifying environmental protection measures using institutional or corporate frameworks to regulate environmental repercussions due to irresponsible human meddling (Barrow, 2004). According to Sadghi (2019), environmental management can be carried out through case, ecosystem, regional, and problem-solving approaches.

- **Case Approach**

Unconditionally, problems could require certain or case-based solutions (Xu et al., 2010). Environmental management also uses a variety of approaches to solve the diverse problems that arise on the earth (LotusArise, 2021). Therefore, the case approach is a part of an environmental management system created in reaction to a specific instance or circumstance (Sadghi, 2019).

According to the study conducted by Humphreys, McIvor & Chan (2003), the case approach is essentially utilized to handle challenges that have been identified and specifically defined based on specific goals or conditions.

- **Ecosystem approach**

The ecosystem approach, centered on biological interactions between organisms and their environments, implies a direct connection between ecosystem services that sustain human well-being and the condition of natural resource systems (Malaco, 2023). Therefore, it puts human beings and their practices of utilizing natural resources at the center of decision-making (Moore et al., 2017). The ecosystems may include natural and abnormal.

Applying the ecosystem approach to upholding the conventions of three goals: fair and equal distribution of benefits resulting from using natural resources, sustainable usage, and conservation (Enright & Boteler, 2020).

- **Regional approach**

According to the report conducted by LotusArise (2021), the regional approach is based on ecological zones or bio-physical units such as watersheds, river basins, coastal zones, command area development, areas covered by water development plans, islands, managed protected areas, etc.

The regional approach, also known as the eco-regional approach, essentially functions by honoring the natural systems in the environment (Moradi & Rahmati, 2023). Hence, within the context of biophysical concerns, eco-regions are regarded as systems with well-defined boundaries (Kotchen & Young, 2007). As a result, the regional approach emphasizes the region's unique qualities and occasionally incorporates global elements.

- **Problem-Solving approach**

Unlike the other approaches, problem-solving defines and prioritizes problems, generates alternate or possible solutions, selects potential solutions, and then implements the preferred solution (Keeney, 2013). Basically, the problem-solving approach which centers on environmental issues and generally involves investigation (Ulutas & Köksalan, 2017).

Therefore, this environmental management approach starts with a problem-framing basis (Pontius & McIntosh, 2019). This framework is about what makes for good problem-solving. To identify problem-framing, the cognitive psychology or perception of humans provides information on problems or issues (Leiblein & Macher, 2009; Pal & Poyen, 2017). Furthermore, the problem-solving approach is designed to assist participants in coming up with a solution or several answers for a given issue (Koc & Arslan 2017).

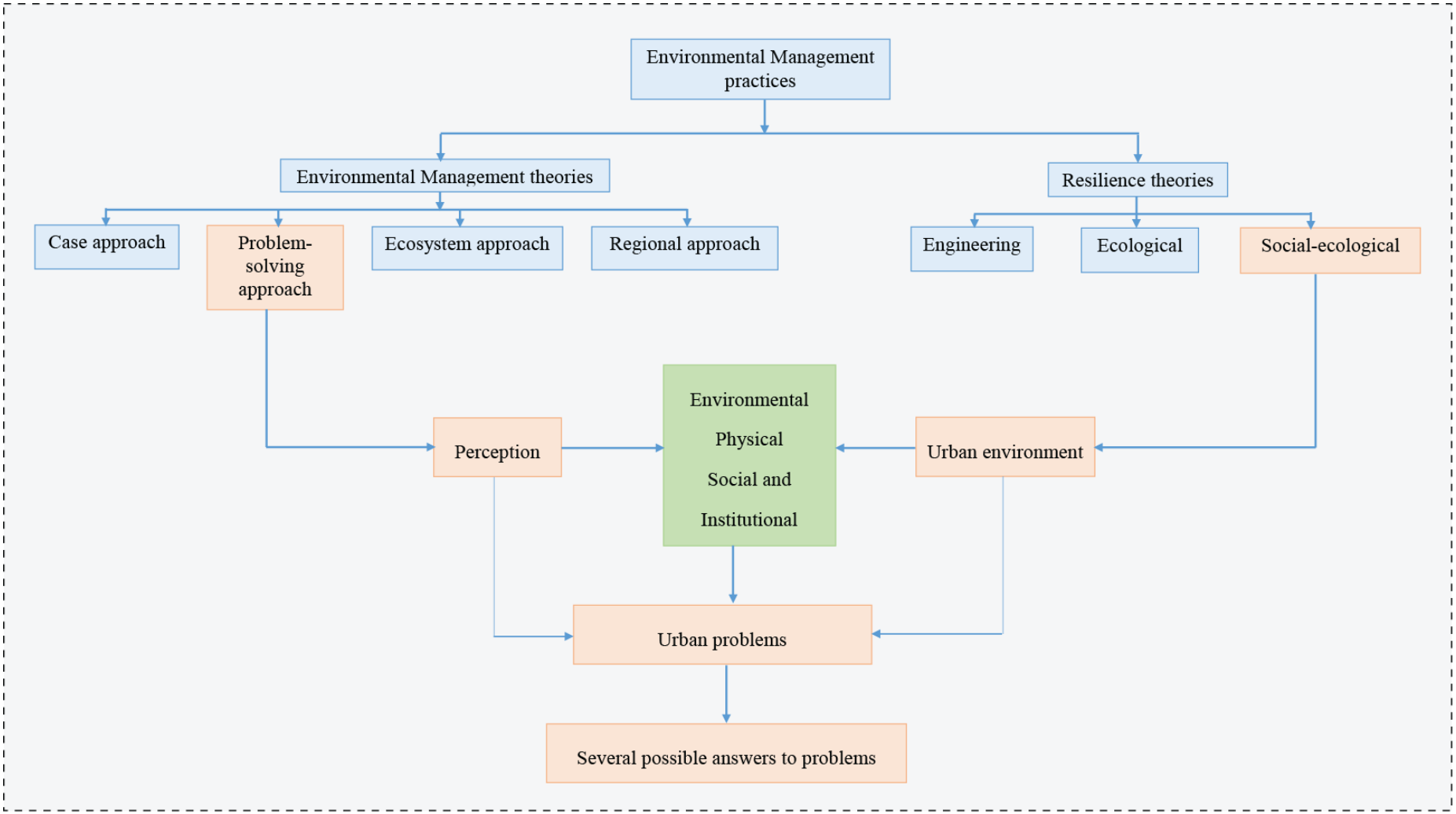

Figure 2:1 Theoretical framework of the study.

2.3. Conceptual Review

2.3.1. Variables affecting urban environmental Management practices

Cities are economic, social, and service development engines (Colenbrander, 2016; Mourshed, Bucchiarone and Khandokar, 2016). However, urban environmental difficulties have become a persistent global issue due to the adverse environmental consequences of rapid urbanization (Komeily and Srinivasan, 2015), unwise use of resources (EEA, 2015; van der Voet et al., 2009), and pollution (Ameen, Mourshed and Li, 2015).

Cities are expanding in population (OECD, 2020a) and geographical or land coverage (Seto et al., 2011) and have become the primary determinant of environmental quality at the local, regional, and global levels. Changes in land use and cover, energy demand and associated greenhouse gas emissions, water consumption and availability, waste generation and control mechanisms, pollution, sanitation, and infrastructure are all urban development variables that are making it more difficult to manage urban environments (Ramalingam and Clarke, 2012).

Besides that, local and global factors such as natural disasters, poor governance (Gök and Nausheen, 2021), lack of public awareness (Kamaruddin, Ahmad and Alwee, 2016; Rahmani, Wafa and Mazloum Yar, 2021) and insufficient knowledge (Keles et al., 2023) can aggravate the environmental management situation.

- **Environmental and physical variables**

The most common environmental challenges that need to be addressed as a priority in cities in developing countries are water, and soil pollution; flooding; desertification; a lack of a waste management system; untreated and contaminated areas; and inefficient infrastructure, ecosystem destruction, topography and a reduction in green spaces (Imuraa et al., 2005). The most environmental and physical variables are listed in Table 2:1.

Table 2:1 Significant environmental and physical variables affecting urban environmental management practices

1. Environmental variables	References	2. Physical variables	References
Waste management problem • Solid waste management • Liquid waste management	Victoire et al. (2020) & Abubakar et al. (2022) Aneesa, Arathi & Geetha (2021)	Lack of toilet	(Burgess, 2016)
Lack of green and open spaces • Lack of forests • Lack of gardens • Lack of playgrounds • Lack of parks • Lack of squares • Lack of plazas • Lack of buffer zones	Ferreira et al. (2023) Clarke et al. (2019) & Schwarz et al. (2016) Katsavounidou (2021) González et al. (2023) & Loughran (2020) Maslovskaya (2019) Kelbaugh (2014) Petrova et al. (2022) & Al Mamun & Kim (2020)	Road related problems • Lack of road connectivity • Narrow width roads • Lack of road hierarchy • Lack of road amenities • Surface deterioration of roads • Narrow sidewalks for wheelchairs • Poor road lighting systems	Saikia & Kar (2023) Makori & Kitosi (2023) Valença, Moura & Morais (2021) Gaigne et al. (2017) Kuleno & Lera (2020) Hatzakis, Alčiauskaitė & König (2024) Perkins et al. (2015)
Pollution • Water pollution • Land pollution	Singh, Andaluri & Pandey (2022), Vallero & Vallero (2019)	Lack of efficient waste collection bins	Rossit, D. G., & Nesmachnow, S. (2022) Leeabai et al. (2019)
Loss of agricultural fields	Muchelo (2017)	Pollution of river banks	Mondal & Tripathy (2020)
Surface flooding	Cea & Costabile (2022)	Poor drainage systems	Francisco et al. (2023)
Water and wind erosion	Tuo et al., (2023) & Yang et al. (2023)		

- **Social and institutional variables**

Social factors challenge environmental Management systems and impact sustainable development in an urbanizing world (Friel et al., 2011; Mahzun et al., 2020). Severe structural issues of city administrations make it impossible to anticipate and plan urban development (Linares, 2003). Poor public participation in policy-making processes and lack of collaboration in horizontal institutional structures impact the successful execution of urban environmental Management practices (Ganeshu, Fernando & Keraminiyage, 2023).

Lack of coordination between local government and communities and multilevel government sectors also affects the sustainability of environmental management in urban areas (Dawkins et al., 2019). The social and institutional variables are further discussed in Table 2:2.

Table 2:2 Significant social and institutional variables affecting urban environmental management practices.

1. Social variables	References	2. Institutional variables	References
Spatial access related problems • Access to educational services • Access to health services • Access to playgrounds • Access to religious services • Access to urban agricultural fields	Podawca & Pawłat-Zawrzykraj (2018) Dumedah et al. (2023) Czalczynska-Podolska (2014) Kozma et al. (2023) Meenar (2017)	Lack of community participation in decision making processes	Zanudin, Ngah & Misnan (2019)
Existence of polluted industries	Wu (2020)	Poor management systems	Cities Alliance (2017)
Transportation	Nikiforov (2020) & Mbuzi (2020)	Lack of environmental impact assessment	Ho, Nor-Hisham & Zhao (2020)
Traffic accidents	Cabrera-Arnau, Curiel & Bishop (2020)		
traffic congestion	Mbuzi (2020) & Choudhary et al. (2022)	Lack of public awareness	Odoom et al. (2024)
Compatibility issues • Land use incompatibility • Locational incompatibility	Ifediora (2019) (Grodach, C., & Martin, D.)	Lack of environmental education	Nyika & Mwema (2021)
Land cover change	González-Jaramillo, V. H., & Novelli, A. (2022)	Lack of collaboration	Rubado, M. E. G. H. A. N. (2019)
Informal settlements	Fard (2018)		
Urban expansion & sprawling	Jarah et al. (2019) & Bhatta (2010)		

2.3.2. Environmental Management tools

Environmental Management is a response to human actions for in light of the terrible human influence on natural ecosystems today (UNDP, 2011). Therefore, environmental Management aids in the ability of the environment to recover on its own from human misuse and abuse (McGregor, 2021).

On the other hand, environmental Management integrates policy, social, and scientific aspects (Aponte, 2021). It focuses on finding solutions to the practical issues that people have while interacting with nature, utilizing resources, and producing waste (Ekins et al., 2020). With similar idea, environmental Management is intimately related to issues such as determining fair and equitable resource allocation, guaranteeing sustainable economic growth, and protecting the environment for future generations (Abraham, 2013).

Environmental management tools are methods for evaluating the environmental aspects and potential consequences related to outcomes (Balkau, 2005), and it is also a system in a set of procedures and practices that enable it to mitigate its environmental impacts and improve its operational efficiency (Routray & Jayant, 2006).

Today, any city development strategy includes urban environmental Management approaches and action plans in its practice (Fioretti et al., 2020). These urban Management strategies contain mitigating tools related to environmental issues in physical, social and institutional dimensions (European Investment Bank, 2018; Srinivas, 2015; World Health Organization, 2022). Managing urban environment is closely linked to governance for long term sustainability (Fan, Shen & Wang, 2022).

Appropriate institutional setting is required for urban environmental Management practices to be improved (Shimomura & Matsumoto, 2010). The Management functions used to address environmental problems in cities, including tools of intervention, mechanisms of coordination and decision-making, as well as current restrictions and initiatives that have an impact on Management efforts for environmental issues in cities, are the key elements to guide institutional setting for environmental Management practices in urban areas (Langa, 2021).

The summarized environmental management tools implemented to mitigate environmental, physical, social and institutional problems in urban areas are listed in Annex II.

2.3.3. Relevance of integrating Resilience thinking into environmental Management of cities

Two recent major ideas for planning and policy-making are urban Resilience and sustainability (Elmqvist, 2014). Both ideas share certain commonalities as well as variances concerning their respective goals, guiding principles, dimensions, and indicators (Steurer & Hametner, 2013). Within the global context, Resilience thinking is regarded as a useful instrument for reducing negative consequences related to environmental, social, political, and financial stress (Daniel, 2020).

Resilience thinking is also a paradigm that is helpful to the goals and objectives of sustainable development because it examines how complex social-environmental systems can be handled in the face of disturbances (Pisano, 2012; Walker & Salt, 2006; Xu & Marinova, 2013).

The UN Sustainable Development Goals, particularly those related to sustainable cities and communities and climate action, and the UN Sendai Framework for Disaster Risk Reduction, highlight the relevance of Resilience thinking (OECD, 2018). Long-term sustainability initiatives need to bring Resilience and system changes together (World Economic Forum, 2022).

Resilience thinking tries to identify a system's characteristics that must be maintained or improved to achieve sustainability by embracing human and environmental systems as complex entities constantly adjusting through cycles of change (Walker & Salt , 2012; World Economic Forum , 2023).

In the context of current urban development, Resilience consists of important guiding principles that are integrated into disaster risk reduction, environmental Resilience, social Resilience, land use planning, urban ecosystems, urban upgrading, and other urban project cycle (Jha, Miner & Stanton-Geddes, 2013). These Resilience principles, which can focus on the system or its governance (Quinlan et al., 2016), are certain

processes or techniques and behaviors that either help policies or practices increase a city's Resilience or make it more resilient (Berbés-Blázquez et al., 2016).

The design of new solutions, evaluation of current circumstances, proposed options & plans, and exploration of stakeholder views can all be done using Resilience principles (Wardekker, 2018). However, putting Resilience ideas into practice is not a standalone task. It should be integrated into a broader process of resilience assessment that takes into consideration the context, urban systems and components, and imagined past, present, and future. Such assessments may include various sets of Resilience principles, analysis of findings, environmental planning and integrated urban planning (Wilk, 2016).

2.3.4. Resilience-based urban environmental Management Practices review

Evaluation of Resilience-based policy relies upon the use of frameworks and criteria that examine resilience behaviors in social-ecological systems (Folke et al., 2002). Consequently, Walker & Salt (2006) specifies nine resilience features, including diversity, modularity, variability, acknowledging slow variables, tight feedbacks, social capital, innovation, overlap in governance, and ecosystem services in any social-ecological systems. Schouten et al. (2012) further examines these qualities to support and facilitate the development of rural and urban policy.

Diversity, redundancy and modularity are principles identified in the literature that have the most frequent correlations with the Resilience of social-ecological systems, and these systems may be improved in their ability to handle shocks and stresses by strengthening these attributes (Biggs, Schlüter & Schoon, 2015; Martin-Breen & Anderies, 2011). Building Resilience also calls for a sustained commitment as well as an integrated strategy to increase the capabilities of components in social-ecological systems (Hung et al., 2016; Que et al., 2022).

The concept of diversity is explained by three interconnected factors. These are namely: variety (the number of different elements present), balance (the number of representative elements or relative abundances) and disparity (how different the

elements or components from one another functionally) with respect to diversity in a particular function (Kotschy, 2013; Kotschy et al., 2015).

Redundancy is a deliberate repetition or multiplicity of system parts to boost a system's reliability, and Resilience of individual system components guarantees that redundant components can resume functioning after the occurrence of disturbances. Since it entails having extra capacity and backup systems, it is the measurement of additional components or alternative pathways enabling system Resilience (Kharrazi, Rovenskaya & Fath, 2016).

Contrarily, modularity is a system characteristic that evaluates the extent to which a network's strongly interconnected nodes can be divided into distinct communities or clusters (Biggs et al., 2012). So, modularity ensures that residual functionality is maintained when system components fail (Jackson & Ferris, 2013).

Robustness, connected to strength and toughness, is the ability to function effectively or sustain across a variety of potential circumstances (Munoz, Billsberry & Ambrosini, 2022). Therefore, it is the continuance of particular system characteristics in light of irregular circumstances, uncertainties, and disturbances (Greiving , 2018).

Interdependence as a resilience principle includes the mutual dependence of integrated systems or green infrastructures (Trogal et al., 2019). Ecological and multi-complex physical infrastructures interdependencies increase the resiliency of cities as a system (Markolf et al. , 2018).

To promote social-ecological Resilience, participation through active engagement of all pertinent stakeholders is regarded as essential (Aldunce et al., 2016). Public participation aids in establishing the relationships and trust necessary to raise the reliability of information and authority while making decisions (Gote & Wende, 2022).

Table 2:3. Description of Resilience principles and characteristics with different dimensions in this study.

Resilience principles	Characteristics/dimensions to be achieved
Diversity	Ecological diversity, functional land use, Management techniques, urban greening, road networks and service centers.
Redundancy	Multiple nodes (primary & secondary), urban parks, urban waste Management systems, green buffering, flood control and protection, urban agriculture, open spaces.
Modularity	Densely connected nodes, road network, public services, and sanitation facilities.
Robustness	Sustainability of urban form and urban transportation networks
Interdependence	Integrated road networks, integrated green infrastructures
Integration	Public participation and collaboration during decision-making process.

Source: Author's computation based on the above sources.

Theoretically Resilience thinking is fostering and understanding of complex, adaptive, dynamic and interaction in social-ecological system across scales (Biggs, Schlüter & Schoon, 2015). Resilience in specific concept describes the attributes of such systems as adaptability, transformability, maintaining and normative approach towards sustainability (O'Connell et al., 2015).

The concept of Resilience thinking is a measurable and descriptive way of thinking applied in the context of urban planning and environmental Management for urban sustainability (Cañizares, Copeland & Doorn, 2021). Urban planners, policy makers, environmentalists and urban designers began to consider Resilience in environmental Management practices of urban areas (Sharifi et al., 2017).

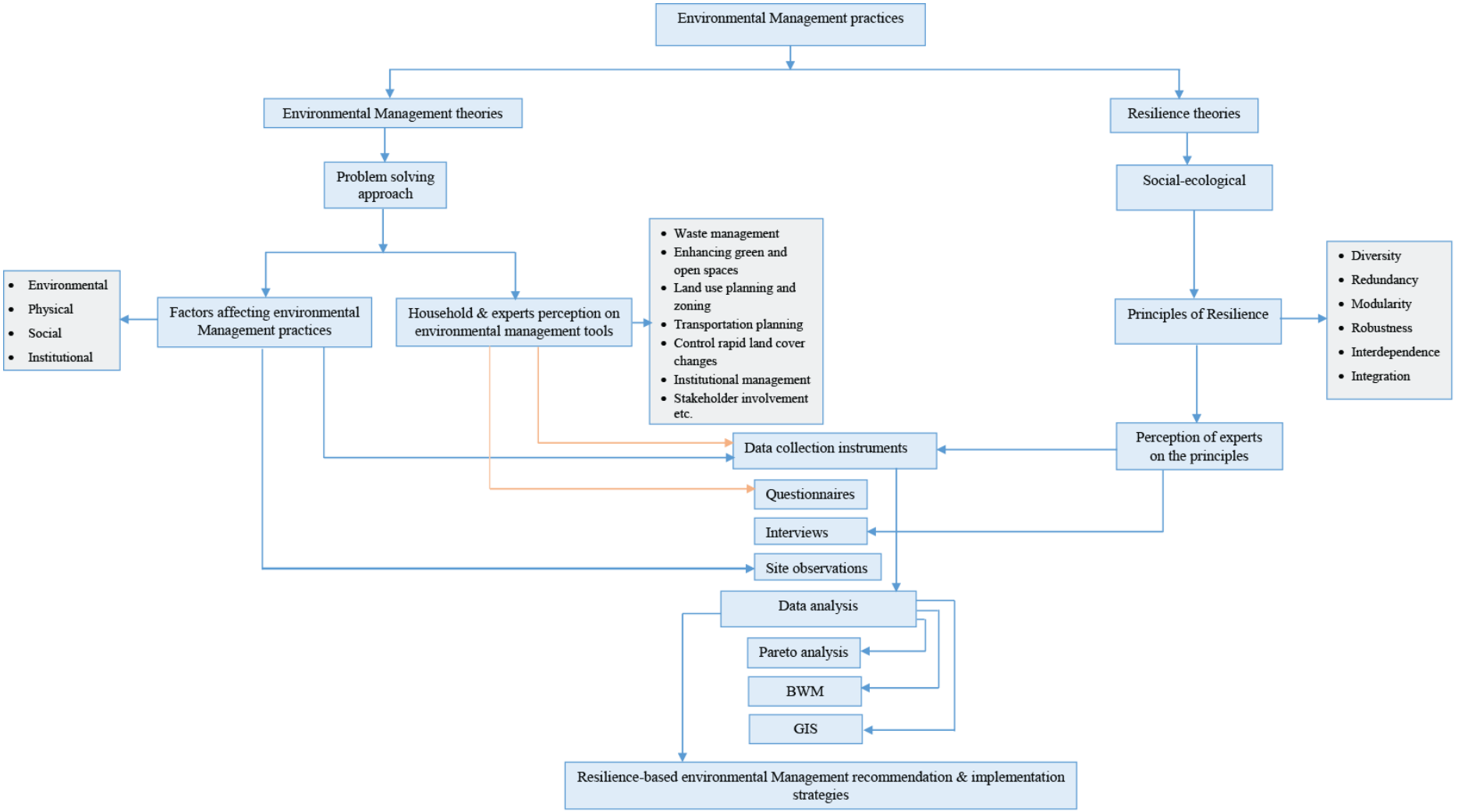

Figure 2:2 Conceptual framework of the study.

2.4. Contextual Review

2.4.1. Implementation of urban environmental Management practices in Ethiopia from a resilience perspective

Ethiopia is making progress in aligning its urban development policy arenas, and adopted its initial blueprint for national development for a year (Dagne et al., 2022). Based on the same source, the Green Legacy Initiative, the Ten-Year Development Plan, GTP I and GTP II) shows the development plan experience and resilience indicators.

Integrating environmental concerns into national development frameworks, enhancing decentralization for environmental Management, encouraging civil society and improving environmental monitoring and assessment are key areas for policy action to improve the growth quality and modify international and industrial country policies (DFID et al., 2002).

Ethiopia has made and implemented environmental Management policies and promotes striving to live in a good environment in its current constitution (Dejenie & Kakiso, 2023). The same source further remarks that the articles in the constitution used as a reference when formulating policies, and implementing practices. In light of this, article 44 (1) of the Federal Democratic Republic of Ethiopia (FDRE) Constitution of 1995 states that everyone has a right to a clean and healthy environment to improve the living standard and sustainable development (Dejenie & Kakiso, 2023).

Environmental policy developed in 1997 Ethiopia contains sector and cross-sector components make up the environmental Management document, including human settlements, the urban environment, and environmental health (EEPA, 2004). This source also mentions that the policy includes components that stress the significance of including socio-ecological dimensions in development projects and programs.

The Environmental Policy of Ethiopia (EPE) is a comprehensive document that outlines strategies for ten distinct environmental sectors, including soil and agriculture, forests and woodlands, biodiversity, water, energy, minerals, human settlement, industrial waste, climate change, and cultural heritage (FDRE, 1997). The same source also identifies cross-sectoral issues need to be reflected for effective implementation

including; land use, community participation, land tenure, environmental economics and impact assessment.

The CRGE is essential recently implemented initiatives in Ethiopia. According to FDRE (2011), the CRGE is a component of the GTP and was created with the goal of becoming middle-income by 2025. The same source explains that CRGE makes a concerted effort to integrate addressing the negative effects of climate change with achieving sustainable economic growth.

Ethiopian local government representatives are modifying and putting into practice Local Agenda 21 in all areas to support both short and long-term sustainable developments, including secondary cities, and these initiatives serve as resilience roadmaps. However, poor implementation of sustainable environmental management practices and low level of applying resilience principles are the major gaps in their management practices.

CHAPTER THREE: RESEARCH METHODS AND MATERIALS

3.1. Description of the study area

Debre Birhan is a city in central Ethiopia and is located in the North Shewa Zone of the Amhara Region, about 130 kilometers northeast of Addis Ababa on the paved highway to Dessie, with latitude and longitude of 9°41′ N 39°32′ E and an elevation of 2,840 meters. It was an early capital of Ethiopia and later, along with 'Ankober' and 'Angolalla', one of the capitals of the kingdom of Shewa (Chisholm, 1911).

Today, Debre Birhan city is the administrative center of the North Shewa Zone of the Amhara Region, and it has nine Kebeles and sixteen newly added rural areas with a total population of 202,227.

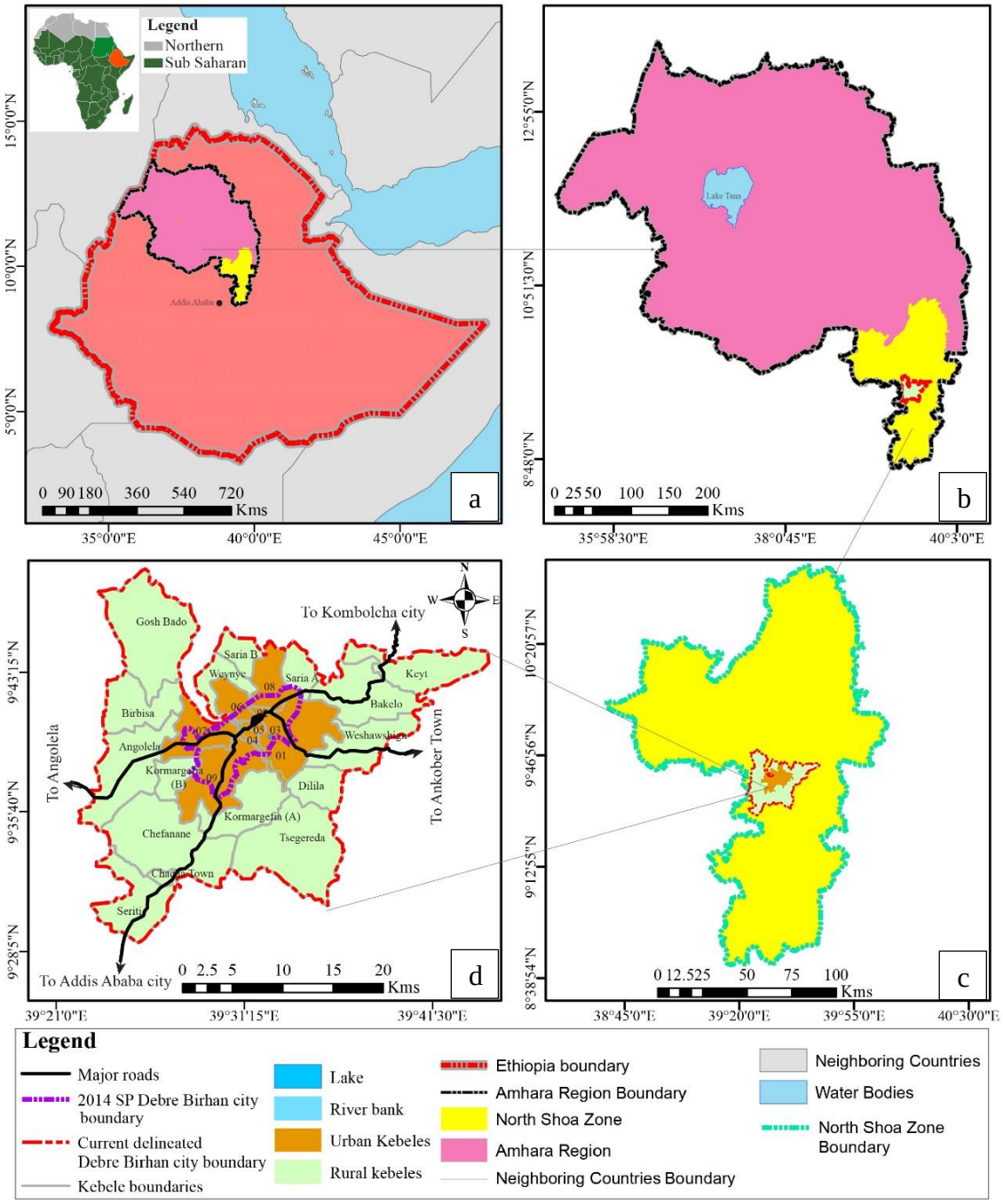

Figure 3:1. Location map of Ethiopia (a), Amhara region (b), North Shoa zone(c) and Debre Birhan city (d).

Source: Author's Computation from Google Earth Pro using ArcGIS 10.8 based on urban expansion study of Debre Birhan city in 2014 & 2022.

3.2. Research methods

3.2.1. Research design

This research is mainly used exploratory research design to investigate mostly qualitative data. Thus, it was used to collect data such as: the current development practices, existing urban conditions and problems such as solid and liquid waste Management, drainage, sanitation, river bank condition, road surface condition and connectivity in 'Debre Birhan city'.

Surveys, questionnaires, documents from the city and observations are research methods to address mainly the first objective. This method is also used to investigate environmental Management tools from interviews, administrative offices, online research, literature research, reports, magazines, books and case study research.

This study also used descriptive and explanatory research methods in integrated way with exploratory research design for mixed design approach. Comparative and correlative survey was used to describe the environmental, physical, social and institutional variables. Explanatory method was also used to explain why the study area face challenge to be resilient and how resilience principles will be applied.

3.2.2. Data types and their sources

Multiple sources of data were used in this study to better understand concerns of urban Resilience and development strategies, as well as to answer research questions through analysis. The primary data were collected from local residents of 'Debre Birhan' city, urban and engineering consulting offices in the city, non-government organizations and local government offices.

Major sources for the primary data are the local government offices of the city including water supply and sewage service, land administration and Management office, urban infrastructure office, sanitation and beautification office, environmental protection office, agriculture office and the city's mayor office. Photographs from selected field observations were also used as the sources of data.

Secondary data like aerial photograph were obtained from Google Earth pro, spatial information from base map and land use of the city; websites, the various policy documents, urban development plans, strategy documents, published and unpublished document, project documents, works of literature and reports ere the other data sources.

3.2.3. Sampling design

Households

Applying formula is one method of calculating sample size (Singh & Masuku, 2014). Hence, researchers applied the equations to produce a representative sample for the proportions of a large sample. Yamane (1967) provides a simplified formula to determine sample sizes from a given population (Singh & Masuku, 2014). According to Birhan Health and Demographic Surveillance System (2019) survey the number of households in 'Debre Birhan city' was 18,933 with totaling 77,766 individuals (Bekele et al., 2022).

This study were used a simplified formula of Yamane (1967) to determine the required sample size at 95% confidence level and 5% margin of error based on this sampling unit. The Yamane formula is expressed as;

$$n = \frac{N}{1 + N(e)^2}$$

Where n = Desired sample size

N = Total number of households lived (i.e., 18,933)

e = Precision of sampling error (it could be 0.10, 0.05 or 0.01 usually 0.05)

$$n = \frac{18{,}933}{1 + 18{,}933(0.05)^2} = 391.72$$

Hence, the total sample households determined for this study were 395.

Institutional and experts sampling technique

Purposive sampling technique: a method where specific or informative individuals or events are purposefully chosen to offer crucial information that cannot be found through other options (Tongco, 2008). In order to address certain problems or concerns, institutions are specifically chosen based on their areas of competence, and specialists are chosen based on their experience and specialized knowledge in a particular field or problem (Taherdoost, 2021). Expert samples typically comprise minimum participants at least 12 to reach data saturation in qualitative research (Fugard & Potts, 2015).

Therefore, this study used purposive sampling technique for institutional and key informants for specific cases. Accordingly, twenty two experts from eight local government offices of 'Debre Birhan' city were selected.

3.2.4. Methods of data collection

Primary data collection methods

Site observation: an investigation to describe qualitative data and support findings from the site. It was applied to investigate environmental, physical and social problems as well as practical actions and Management practices in the city at various locations. Recording, capturing photographs using camera, recording geographic position from mobile GPS (GPS essentials app) tracking for selected spot points or issues were used during site observation to support the research findings.

The sites visited included residential and commercial areas, public areas (nodes), industrial areas, urban agriculture sites, dominant urban expansion and informal settlement sites and inner city (Figure 3:2). This method were applied to investigate current drainage condition, river bank condition, waste Management systems, road condition (accessibility, surface material and other amenities), public spaces, and vegetation covers using existing base map of 'Debre Birhan' city.

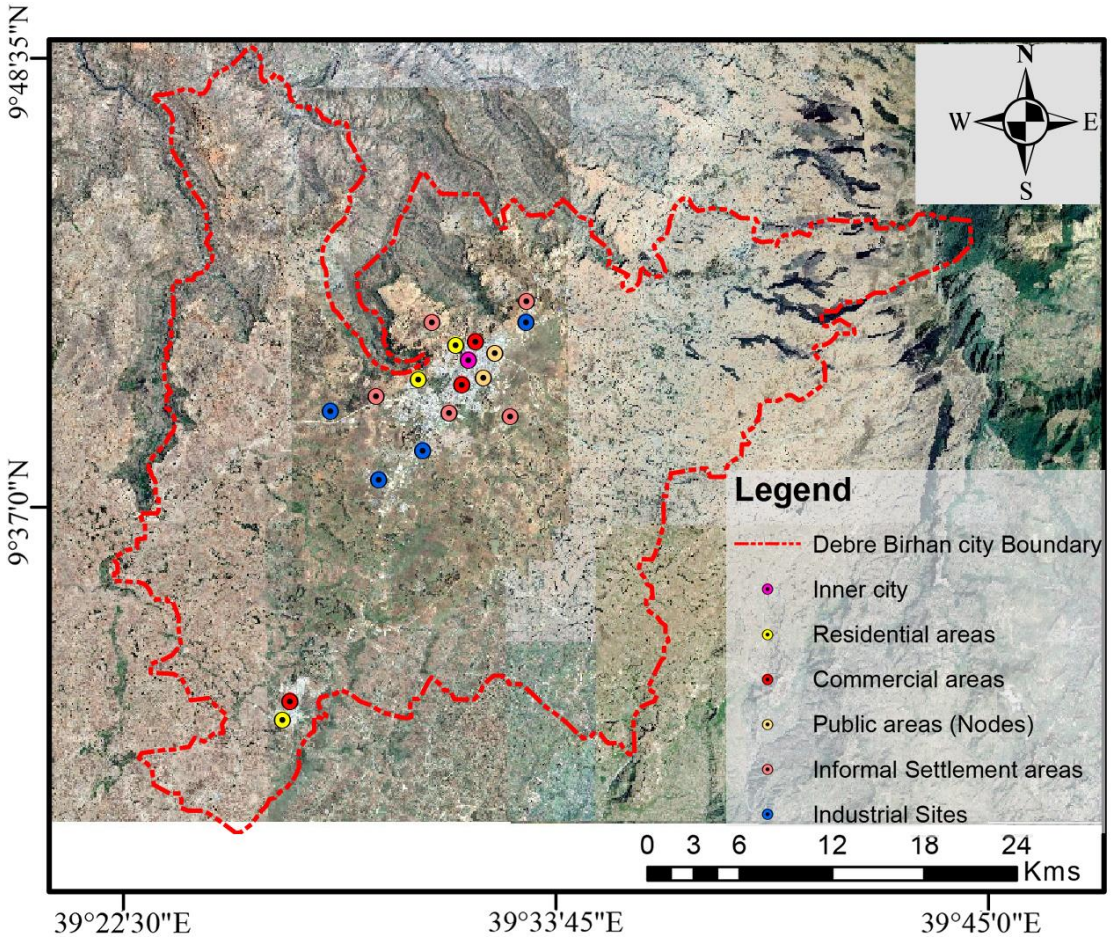

Figure 3:2 Sample location points for observations in Debre Birhan city.

Questionnaires:

Closed-ended questions allows to easily group, compare, or rank environmental Management variables or problems in urban areas (Baburajan, Silva & Pereira , 2020). In current digital world, there are different types of web-based data collection tools to utilize these closed-ended questions (Cooper et al., 2006). These data collection tools helps to save money, time and increases accuracy and quick to analyze (Chaudhuri et al., 2022; Dray, Dunsch & Holmlund, 2016).

Kobo Collect/Toolbox as the research instrument

This study used closed-ended questions on environmental, physical social and institutional variables with a predefined range of possible answers and Likert Scale measurements or ranks from nine items ranging from 1 to 9 (where, 1= none, 2= somewhat between none and moderate, 3= moderate, 4= somewhat between moderate

and high than, 5= high, 6= somewhat between high and very high, 7= very high, 8= somewhat between very high and absolute important, 9= absolutely important).

The questionnaires created and compiled in Kobo Toolbox then deployed into KoboCollect based on predetermined criteria. Finally, the environmental Management variables outputs was downloaded from Kobo Toolbox in the form of Microsoft Excel for further analysis.

Expert interviews:

Interviews with experts and key informants are qualitative conversations with individuals (usually ranges from 15 to 35) who are knowledgeable about the local community (USAID, 1996). Expert interviews are conducted to gather data from a variety of persons who have firsthand knowledge of the community, such as community leaders, professionals, or residents (Chazdon & Lott, 2010). These local specialists can shed light on the nature of issues and make ideas for solutions to their specific knowledge and understanding.

Therefore, multiple interviews to assess structured and unstructured information conversation to get relevant data from different professionals. These experts usually from government officials, project staffs, relative consultants, outsiders and NGOs.

Accordingly, for purposely selected staffs, this research used closed-ended questions that were developed after gathering major information with open-ended questionnaires from the city Mayor and other staffs.

Table 3:1 List of local government institutions and number of professionals who participated as expert's interview.

Mix of local government offices	Professions of the participants	Frequency /Number of participants/
Solid waste Management office	Environmentalist	1
Sanitation and beautification office	Environmentalist & sociologist	2
Environmental protection office	Environmentalist, sociologist & geologist	4
Agriculture office	Environmentalist & economist	2
Urban infrastructure office	Environmentalist, architect & urban planer	3
Land administration and Management	Urban planner, architect & geologist	3
Urban development and Housing office	Urban planner & economist	5
Water and Sewerage service	Environmentalist & geologist	2
Total		**22**

The mix of these professionals were ideal for environmental Management projects for the city. These professionals for key informant interviews are: environmentalists (7), architects (2), urban planners (6), sociologists (2), geologists (3) and economists (2). The purpose selection of environmentalists about 32% and Urban planners (27%) due to high connection with land use planning and environmental protection in the city, though they are working in different institutions mentioned on Table 3:1.

Secondary data collection methods

The secondary data types were collected using various data collection techniques. It involved the review of both published and unpublished documents.

The published literature search review: include environmental Management tools, and urban resilience characteristic and principles and review of documents from different sources. Whereas the **unpublished documents search review:** includes reports of different offices, previous studies and thesis.

3.2.5. Method of data analysis

3.2.5.1.Pareto analysis

Pareto analysis, as stated by Vilfredo Pareto around 1895, is statistical approach that applied in decision-making to identify the small number of tasks that have the greatest overall impact (Goodman, 2007). The Pareto principle applies the idea of figuring out which of the top 80% of the issues are reasons or causes for the remaining 20% of issues (Juran, 2019). For this study, the purpose is to identifying and prioritizing the vital problems that have critical impact on the environmental Management practices of 'Debre Birhan' city. An 80% cumulative percentage was used as the criterion for choosing the most important variables.

A Pareto chart is also a graphical tool used to illustrate analytical results by displaying the variables' relative importance that is easy to interpret (Alkiayat, 2021). It has both bars and lines. The bars show the individual values in descending order of height from left to right, while the curve line shows the sample's cumulative proportion. To show the crucial few variables that require the greatest attention when applying the 80/20 rule, an 80% cut-off line was also provided.

Therefore, the most relevant variables in the Pareto chart are those with a cumulative percentage of under 80% (the left side of the intersection point of an 80% cut-off line and the curve line).

Recently, Pareto analysis was applied to identify vital environmental sustainability indicators due to large number of variable in the city, particularly in manufacturing sectors (Gani et al., 2021). Similarly, this study used Pareto analysis to identify the most important environmental, physical, social and institutional variables affecting environmental management practices in 'Debre Birhan' city, secondary city of Ethiopia.

3.2.5.2. The application of Improved Best Worst Method

The Best Worst Method (BWM) is a relatively new decision-making tool created by Rezaei (2015) for multi-criteria decision-making problems (Liang et al., 2021). The BWM requires the pairwise comparisons known as reference, or 2n-3 pairwise comparisons (Rezaei, 2015).

Consequently, pairwise comparisons using two vectors and BWM were utilized to calculate the weights of the criteria that required fewer comparisons and more consistent comparisons (Moslem et al., 2020). Based on Rezaei (2016), decision maker, an expert, or a group of specialists first determine which criteria are best (most desirable, most important, etc.) and worst (least desirable, least important, etc.). Subsequently, the criteria that yields the best results is contrasted with the others, and the latter with the former. Next, by creating a maxmin issue, the weight of each criterion is ascertained. The comparison or criteria ranges from 3 to 9. The criteria greater than nine in numbers need thematic grouping.

$$AB = (mbaBB, aB(m_b + 1), aB(m_b + 2), \ldots, , aBn) \ldots\ldots\ldots \text{(eq. 1)}$$

$$AW = (a1W, a2W, \ldots, a(n-3)W, a(n-2)W, mwanW) \ldots \text{(eq. 2)}$$

$$minmaxj \left\{ \left| \frac{wB}{mb \cdot wj} - aBj \right|, \left| \frac{wj}{mw \cdot wW} - ajW \right| \right\} \ldots\ldots\ldots\ldots\ldots\ldots \text{(eq. 3)}$$

$$\text{Min } \xi = wB + wW + \sum_{j=1}^{n-(mb+mw)} wj = 1,\ wB,\ W, \geq 0 \forall j \ldots\ldots\ldots\ldots \text{(eq. 4)}$$

$mb>1$ $mb>1$ and/or $mw>1$

But, should be $mb=mw=1$, for Improved Best Worst Method (BWM-I)

$w*B1=wB/mb$ *and* $w*W1=wW/mw$.

Weight (w) = $wB/2$ and $wW/2$

Where AjB= represents the preferences of the best criterion

AjW= represents the preferences over the worst criterion

Min ξ= Minimum possible consistency index

Using the Improved Best Worst Method (BWM-I), decision-makers can select as many best/worst criteria as there are in the real issue (Pamučar et al., 2020). This results in a reduction of the total number of comparisons in the model from 2n - 3 (in the traditional BWM) to 2n - 5 (in the BWM-I). At last a consistency ratio is calculated for BWM-I to check the reliability of the comparisons. These values are ranging from 0 to 1, and a value closer to 0 is indicates higher consistency (Liang, Brunelli & Rezaei, 2020).

Consistency ratio of BWM calculated using the following formula.

$$CR = \frac{\xi}{\max \xi}$$

Where CR= Consistency Ratio

ξ= the optimal objective value of model

$\max \xi$= the maximum possible consistency index

In some cases, Pareto analysis is used to optimize the variables into 80% of the total variables or factors for further MCDM process (Anysz et al., 2021). The scale responses of the vital indicators, identified from Pareto chart, are need pairwise comparison based analysis method. Therefore, the Likert scale responses are further analyzed using BWM of analysis for prioritizing the vital indicators.

The consistency ratio (CR) results are interpreted as follows: values less than 0.2 indicate very high consistency; values between 0.2 and 0.4 indicate strong consistency; values between 0.5 and 0.7 indicate moderate consistency; and values between 0.7 and 1 indicate low consistency between each households and experts BWM comparison matrixes.

3.2.5.3. SPSS-based Dimension reduction: Principal component analysis

The results of the Pareto analysis are the beginning of applying BWM. However, suppose the number of variables extracted from the Pareto analysis is above nine. In that case, it cannot be applied directly in the BWM, which requires further stratification, grouping, ranking, or aggregation into at least three criteria with a

minimum of three sub-criteria. The BWM is suitable for decision criteria from 3-9 (Rezaei, 2016). Hence, the aggregation calls for applying dimension reduction of the factor analysis, such as principal component analysis (PCA) extraction methods, to identify the groups and rank them accordingly (Kardıyen & Hasan Örkcü, 2006).

Muzamhindo, Kong, & Famba, (2017) explained that the PCA procedure establishes a performance scale for ranking by extracting first the principal components and establishing a relative scale of weights for each component.

3.2.5.4. Geospatial Analytic Method: GIS-based spatial analysis

Geospatial analysis remote sensing and thematic mapping (i.e., satellite imaging of land use/ land cover change) for social variables in the city. Qualitative data (spatial related data) were analyzed and mapped using ArcGIS 10.8.

Several phases are involved in creating a map of the city's land use/land cover change for this study:

- **Defining time frame**: into three consecutive decades from 2003 to 2023 in 10 years interval of time.
- **Data collection from satellite imagery**: satellite images from Landsat of 2003, 2013 and 2023 of the city.
- **Preprocessing of data**: dereferencing and masking Landsat images.
- **Image classification**: unsupervised classification method which is algorithm grouping pixels into clusters based on spectral similarities and classify images into different land cover classes (urban and built-up areas, forests, agricultural/ crop lands, vegetation, grasslands and barren lands).
- **Accuracy assuagements**: compare the classification results with the truth data on the ground.
- **Change detection**: comparing classified images from selected time frames using vector analysis.
- **Mapping and interpretation:** using ArcGIS 10.8 software and finally calculating the different classified vectors into table format.

Factors affecting sustainable environmental management practices

The factors affecting the sustainable environmental management practices in terms of environmental, physical, social and institutional variables in a city level. These four factors also categorized in to sub factors based on their themes for Pareto and BWM prioritization as shown in Figure 3:3.

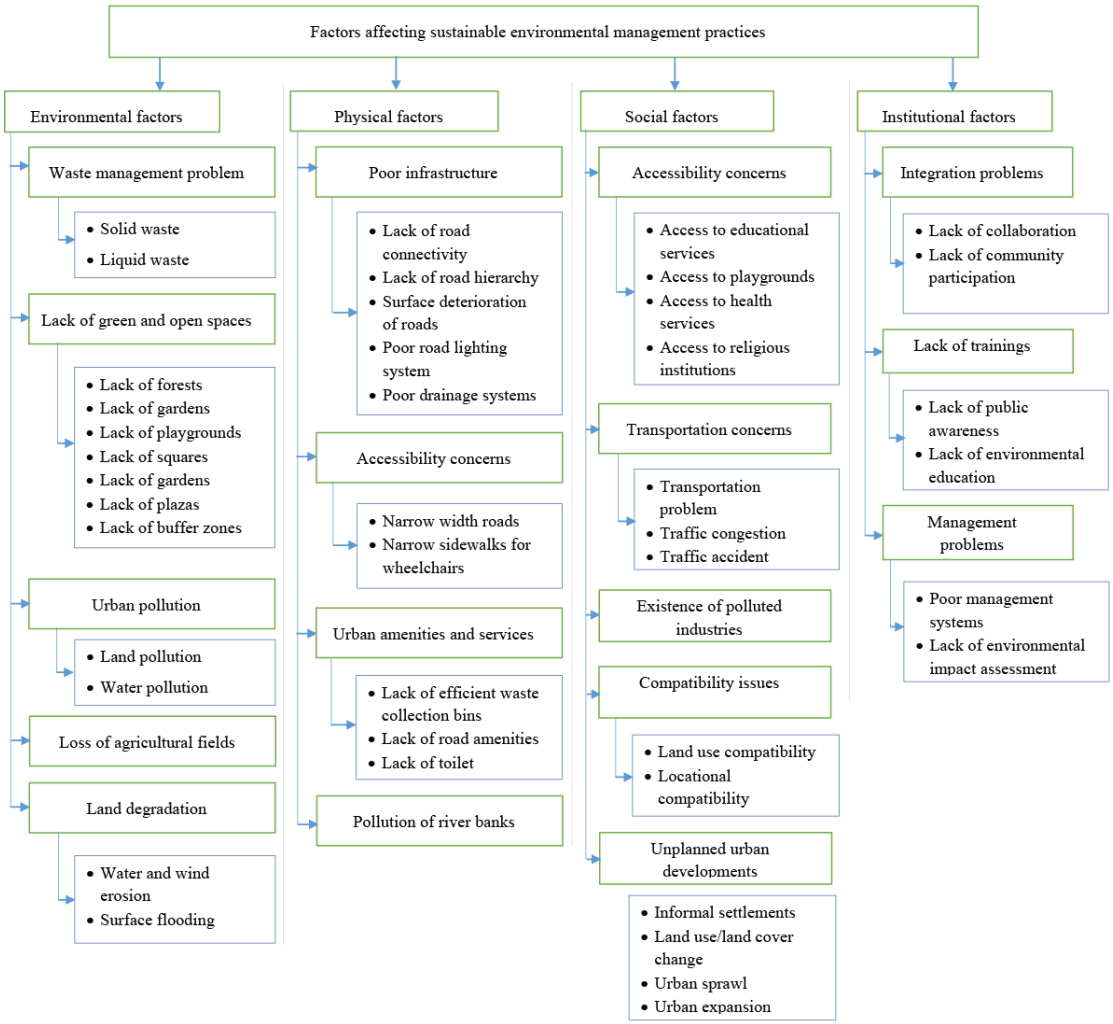

Figure 3:3 Classification of factors affecting sustainable environmental management practices of urban areas.

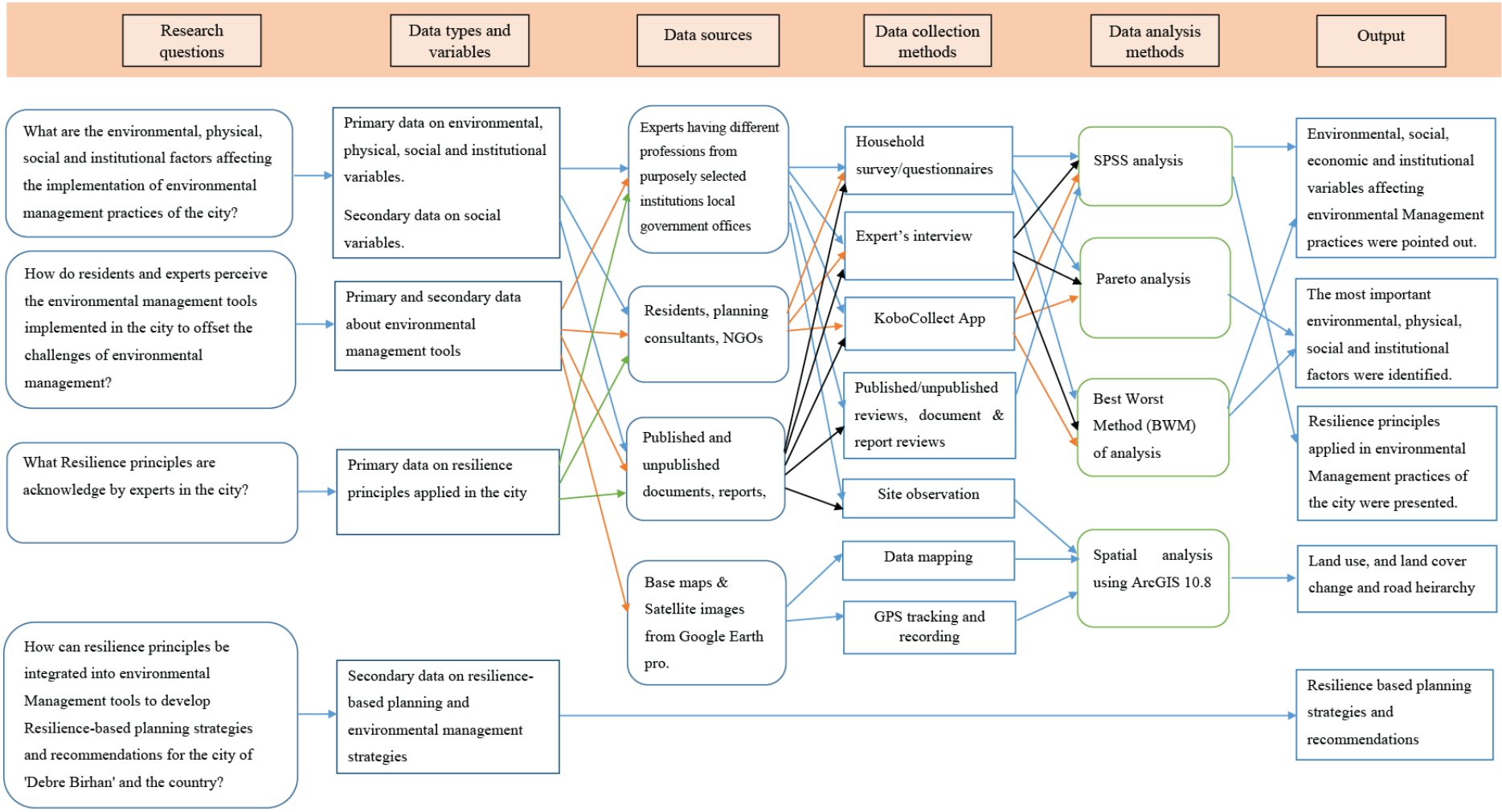

Figure 3:4 Methodological framework of the study.

3.2.6. Method of data presentation

Data presentation entails presenting a data in a clear and succinct manner to explain the research findings (Cleland & Dixon, 2019). Therefore, utilizing a variety of data presentation approaches in a research to make the results easier to read. Different types of data are usually presented in terms of textual or descriptive, tabular, diagrammatic or graphic and maps using appropriate software's (In & Lee, 2017).

Accordingly, this study were used a mix of presentation techniques based on the data gathered and analyzed. Texts in paragraph form, tables, diagrams, graphs, figures and maps were used to present the results.

CHAPTER FOUR: RESULTS AND DISCUSSIONS

4.1. Results

This chapter presents the factors affecting the implementation of environmental management practices, the environmental management tools implemented and the expert opinions on Resilience thinking so far applied to the environmental Management practices of 'Debre Birhan' city.

4.1.1. Factors affecting the implementation environmental Management practices in 'Debre Birhan' city

This section of the paper analyzes environmental, physical, social and institutional challenges in 'Debre Birhan' city, and the variables are presented as follows.

4.1.1.1. Environmental variables and their validation

Views from households

The identified environmental challenges are based on the perception of sampled household and key informant respondents and the variables considered are relied on the literature review section of this paper (Table 2:1). Fourteen environmental variables are presented as follows.

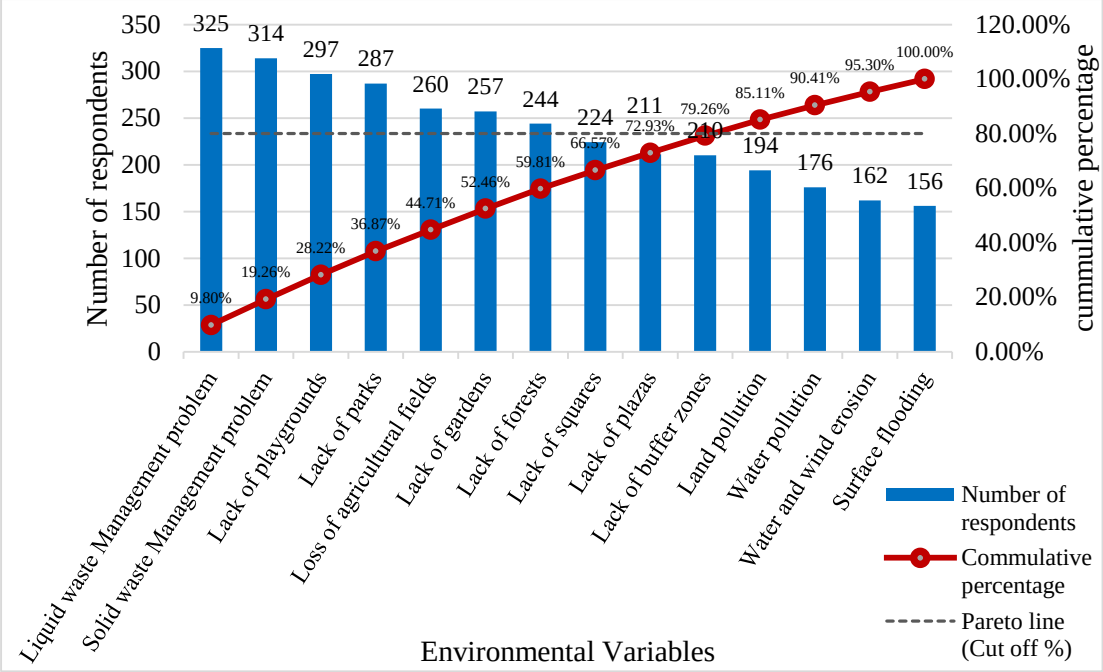

Figure 4:1 Pareto chart of environmental variables based on the responses from households in Debre Birhan city.
Source: Author's computation (2023).

Based on Pareto 80/20 principle, **ten environmental variables** including liquid waste Management problem, solid waste Management problem, lack of playgrounds, lack of urban parks, loss of agricultural fields, lack of gardens, lack of forests, lack of squares, lack of plazas and lack of buffer zones are considered as vital and also causes for the four least important (surface flooding, water and wind erosion, water pollution and water pollution) factors in the city as shown Figure 4:1.

The ten vital variables (obtained from Pareto analysis) are the vital criteria's for the second approach of Best Worst Method (BWM). These most important variables are also assigned to best-to-others and others-to-best pairwise comparison vectors for the analysis of BWM. However, variables greater than nine in numbers must be grouped based on their themes to reduce between three and nine indicators.

Table 4:1 Principal components and associated ranking of the environmental variables.

No	Rotated Component Matrix[a]				
	Environmental variables	Component			Rank
		a	b	c	
1	Solid waste Management problem	0.234	0.111	**0.835**	2
2	Liquid waste Management problem	0.143	0.15	**0.852**	1
3	Lack of buffer zones	0.386	**0.682**	0.076	7
4	Lack of forests	**0.690**	0.351	-0.061	8
5	Lack of urban parks	**0.545**	0.470	0.206	9
6	Lack of playgrounds	**0.778**	0.043	0.318	4
7	Lack of gardens	**0.763**	0.141	0.226	6
8	Lack of squares	0.432	**0.690**	0.031	5
9	Lack of plazas	**0.591**	0.254	0.162	10
10	Loss of urban agriculture	-0.004	0.822	0.21	3

Source: Author's computation (2023).

Based on Table 4:1 above, the variables fall under three components, and the bold numbers indicate the highest value for the items (used for ranking the variables) in each component. The composite score is used in ranking and dimension reduction of the variables to fit the BWM.

Table 4:2 The best-to-others and others-to-worst pairwise comparison of environmental vectors by the household respondents.

No	Main and sub-vital environmental indicators	Best to Others Preferences	Others to Worst Preferences	Weights	Ksi* value
1	**Urban waste management and land expropriation (EN-1)**				
	• Solid waste	**6**	**1**	0.031335	
	• Liquid waste management.	**9**	**1**	0.040269	0.0604
	• Loss of urban agriculture	**1**	**7**	0.261751	
2	**Urban Green and Recreation (EN-2)**				
	• Lack of forests	**2**	**5**	0.09604	
	• Lack of Urban Public Squares	**1**	**9**	0.172311	0.059
	• Lack of playgrounds	**9**	**1**	0.016934	
	• Lack of gardens	**4**	**5**	0.048003	
3	**Urban planning elements (EN-3)**				
	• Lack of buffer zones	**5**	**1**	0.041669	
	• Urban parks	**1**	**2**	0.187513	0.0625
	• Lack of plazas	**2**	**4**	0.104174	

Source: Author's computation (2023).

For the household's best-to-others and others-to-worst average scale responses, further BWM steps were taken to calculate the relative weight and consistency ratio for each grouped vital indicators shown on Table 4:2. Following that, each main element is

ranked according to its relative weight. Higher reliability of the households' opinions is implied by a lower consistency ratio number, and vice versa.

Table 4:3 Average weight and relative ranking of main environmental variables by the household respondents.

No	Environmental variables	Weights	Relative rank
1	Urban waste management and land expropriation (EN-1)	0.5625	1
2	Urban Green and Recreation (EN-2)	0.1250	3
3	Urban planning elements (EN-3)	0.3125	2
	Average consistency ratio (CR)	= (0.059+0.0625+0.0604)/3=0.061	

Source: Author's computation (2023).

It is evident from Table 4:3 that EN-3 is ranked first, followed by EN-2 and EN-1. This finding reveals that waste management and encroachment to agricultural fields are the significant environmental factors the households perceive to affect the city's and its inhabitants' well-being. Moreover, the Table also shows the consistency ratio value of 0.061, showing that the pairwise comparisons and judgments in ranking the variables are within the acceptable level of the consistency limits. The average consistency ratio of the environmental variables indicates highly consistent among them.

Views from experts

Furthermore, the fourteen environmental variables were analyzed based on the opinion of experts as follows.

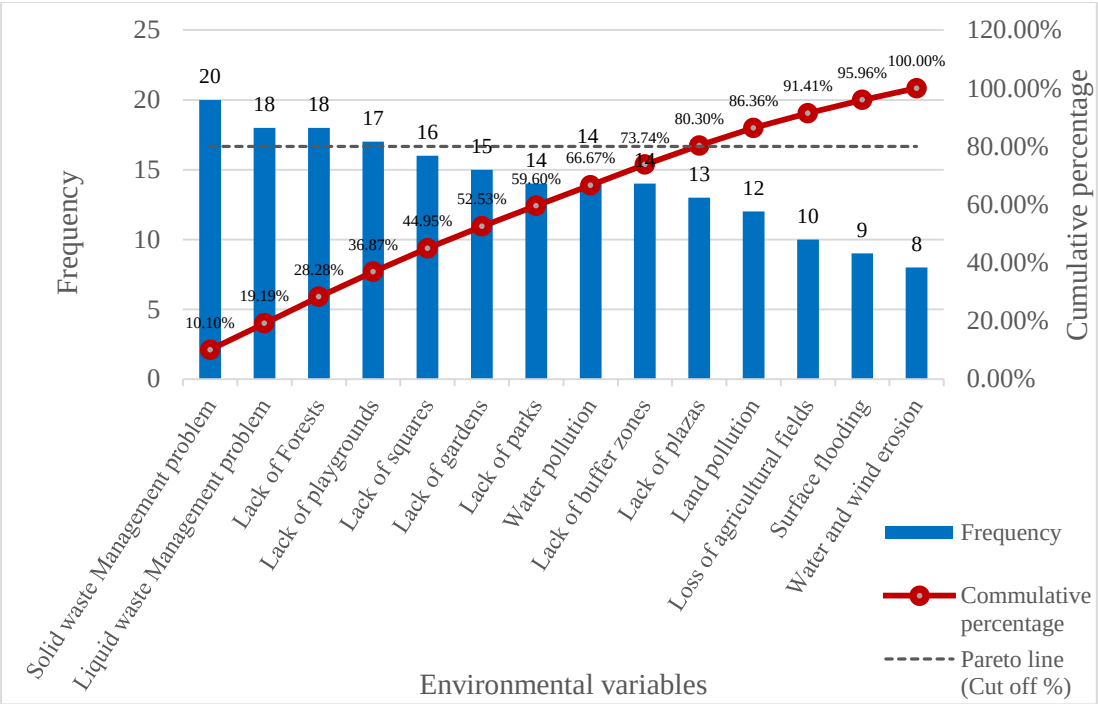

Figure 4:2 Pareto chart of environmental variables based on the responses from experts in Debre Birhan city.
Source: Author's computation (2023).

Solid and liquid waste management problems, lack of forests, lack of playgrounds, lack of squares, lack of gardens, lack of parks, water pollution, lack of buffer zones and lack of plazas are the most prioritized environmental variables, and causes for land pollution, loss of agricultural fields, surface flooding, and water and wind erosion in the city based on the Pareto 80/20 proportion as shown in Figure 4:2.

The Pareto analysis result also grouped waste management problem, lack of green and open spaces and water pollution based their themes to reduce the pairwise comparison elements for BWM of analysis.

Table 4:4 The best-to-others and others-to-worst pairwise comparison environmental vectors given by the key informant respondents.

No	Main and sub-vital environmental indicators	Best to Others Preferences	Others to Worst Preferences	Weights
1	**Urban waste management and pollution (EN-1)**			
	• Solid waste	**1**	**8**	0.303907
	• Liquid waste management.	**2**	**7**	0.202607
	• Water pollution	**6**	**1**	0.033767
2	**Urban Green and Recreation (EN-2)**			
	• Lack of forests	**4**	**5**	0.101302
	• Lack of Urban Public Squares	**5**	**4**	0.081042
	• Lack of playgrounds	**4**	**6**	0.101302
	• Lack of gardens	**7**	**4**	0.057887
3	**Urban planning elements (EN-3)**			
	• Lack of buffer zones	**5**	**1**	0.050651
	• Urban parks	**1**	**2**	0.067535
	• Lack of plazas	**2**	**4**	0.101314

Source: by the author (2023)

Table 4:4 shows the best-to-others and others-to-worst environmental vectors with average values assigned by the key informants for the main variables identified using Pareto analysis on the scale values of 1 to 9.

Table 4:5 Average weight and relative ranking of main environmental variables by the key informant respondents.

No	Environmental variables	Weights	Relative rank
1	Urban waste management and pollution (EN-1)	0.4838	1
2	Urban Green and Recreation (EN-2)	0.3225	2
3	Urban planning elements (EN-3)	0.1935	3
	Average consistency ratio (CR)	0.101	

Source: by the author (2023)

Based on Table 4:5, waste management problem and pollution (0.4838) is the most prioritized, lack of urban green and recraetion (0.3225) the second and urban planning elements (0.1935) the third environmental variables in the city.

In general, the households and experts result show waste management problems are the first prioritized problem. Whereas, loss of agricultural fields and lack of green and open spaces are the second and third for households, and lack of green and open spaces and water pollution for experts respectively.

Validation of BWM results from the field observation

The prioritized environmental variables from household and experts perception needs validation with real problems related to waste management and limited green and open spaces on the ground. Accordingly, waste management problems and lack of green spaces seen during site observation as follows.

Solid waste Management problem

Solid waste management problems were observed on streets, river sides, drainage lines and open spaces of the city (Figure 4:3).

Figure 4:3 Solid waste Management problem in Debre Birhan city: solid waste on streets (a), on open spaces (b), in open drainage lines(c), and along river bank sides (d).
Source: Author's computation (2023).

Solid waste dumped by the communities in city center (Figure 4:3a-d) indicate poor Management procedures, polluting the area and causing flood.

Liquid waste Management problem

The key informants asserted that the main reason for the liquid waste management in the city is poor drainage and sanitation systems, along with untreated water discharges from the city's industries.

Figure 4:4 Liquid waste Management problems: liquid waste on land (a), on drainage lines (b, discharged from industries (c), and leachates from substandard dump sites (d).
Source: computed by the authors (2024).

Poor drainage and sanitation systems like liquid waste on open drainage lines in front of residents (Figure 4:4b), waste on open spaces in the city (Figure 4:4a), waste from industries (Figure 4:4c) and leachates from substandard dump sites (Figure 4:4d) were proved as the liquid waste management problem in 'Debre Birhan' city.

Low green and open space coverage

The existing reserved forests as well as the green and open spaces in the city is insufficient and low area coverage compared to the other built-up areas and the total land area of the city. Green and open spaces limitation is existed in the center and sub centers of the city (Figure 4:5).

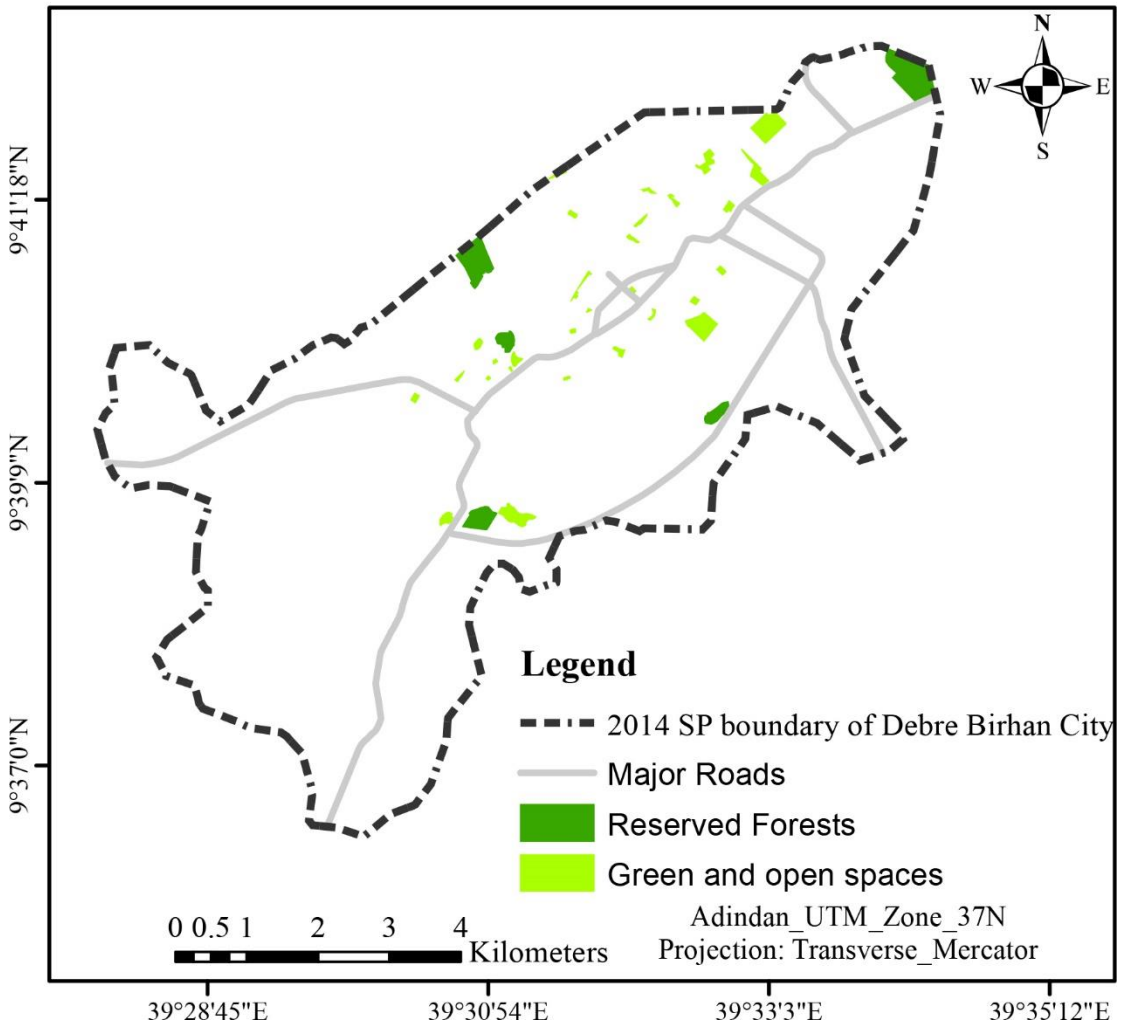

Figure 4:5 Reserved forests, and green and open spaces cover map of Debre Birhan city based on 2014 proposed SP boundary.
Source: computed by the authors (2023).

4.1.1.2. Physical variables

View from households

In this section, the physical factors indicated on Table 2:1 of the literature review were analyzed in terms of household and key informant perceptions. Accordingly, eleven physical predefined variables were analyzed and presented as follows.

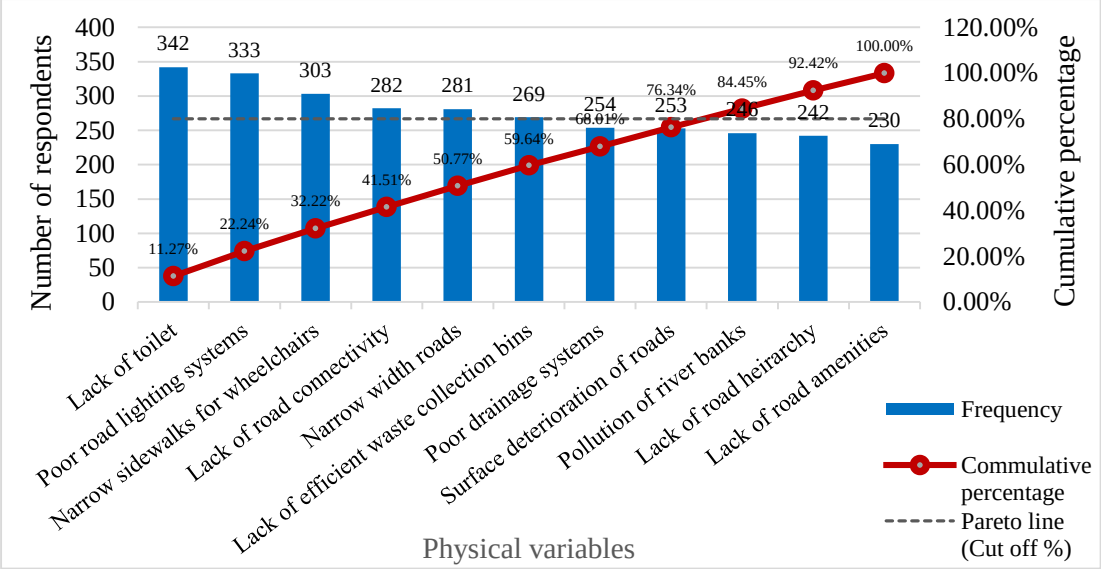

Figure 4:6 Pareto chart of physical variables from household responses in Debre Birhan city. Source: Author's computation (2023).

Based on Figure 4:6, eight vital physical variables are identified for from households. These eight prioritized physical variables are causes the remaining three factors affecting environmental management practices of the city. These eight physical indicators are grouped into three sub indicators (poor infrastructures (PH-1), accessibility concerns (PH-2) and urban amenities and services (PH-3)) as shown in Table 4:6.

Table 4:6 The best-to-others and others-to-worst pairwise comparison physical vectors given by the household respondents.

No	Main and sub-vital Physical indicators	Best to Others Preferences	Others to Worst Preferences	Weights
1	**Poor Infrastructures (PH-1)**			
	• Lack of road connectivity	**5**	**4**	0.079696
	• Surface deterioration of roads	**7**	**2**	0.056926
	• Poor drainage systems	**8**	**1**	0.033207
	• Poor road lighting systems	**2**	**7**	0.199241
2	**Accessibility Concerns (PH-2)**			
	• Narrow width roads	**4**	**5**	0.09962
	• Narrow sidewalks for wheelchairs	**3**	**6**	0.132827
3	**Urban amenities and services (PH-3)**			
	• Lack of efficient waste collection bins	**6**	**3**	0.066414
	• Lack of toilet	**1**	**8**	0.332068

Source: author's computation (2023)

Table 4:6 shows the main and sub-vital physical vectors and their best-to-others and others-to-worst average preferences given by the household for further BWM analysis of the variables in the city.

Table 4:7 Average weight and relative ranking of main physical variables given by the household respondents.

No	Physical variables	Weights	Relative rank
1	Poor Infrastructures (PH-1)	0.1695	3
2	Accessibility Concerns (PH-2)	0.2373	2
3	Urban amenities and services (PH-3)	0.5932	1
	Average consistency ratio (CR)	0.066	

Source: by the author (2023)

Based on Table 4:7, urban amenities and services (0.5932), accessibility concerns (0.2373), and poor infrastructures (0.1695) are the three prioritized physical variables respectively. The average consistency ratio (0.066) of the BWM results show very high reliability among the household respondents.

Views from experts

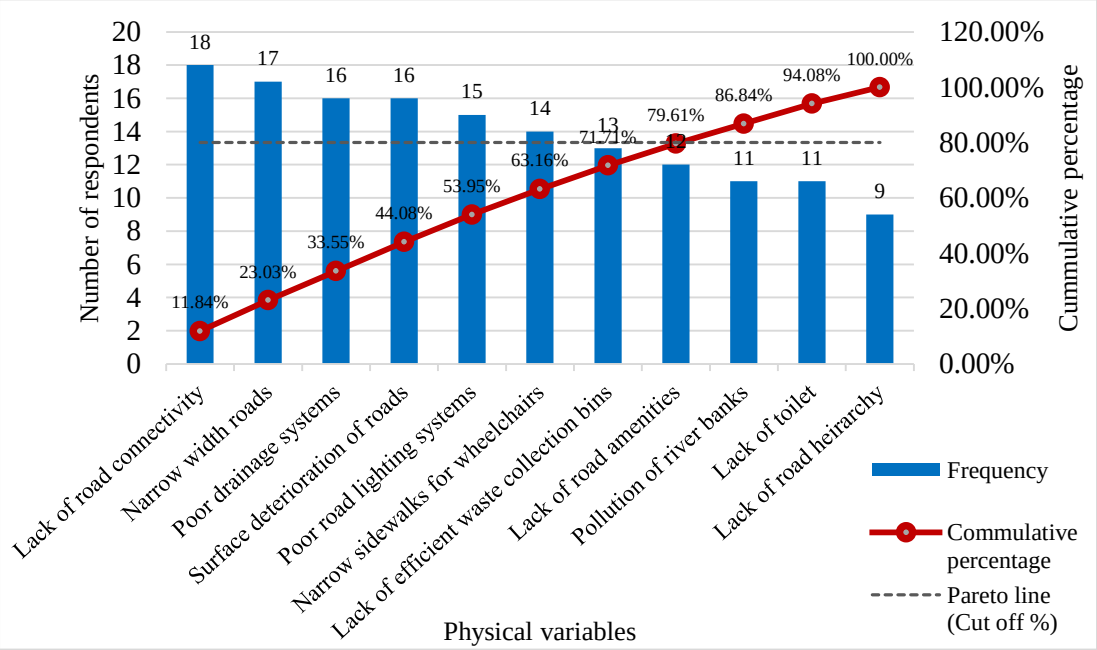

Figure 4:7 Pareto chart of physical variables from experts in Debre Birhan city.
Source: Author's computation (2023).

The Pareto chart shown in Figure 4:7 indicates eight vital physical variables from Pareto analysis of expert responses. These eight prioritized physical variables are also causes for the remaining three least important physical variables.

Table 4:8 The best-to-others and others-to-worst pairwise comparison physical vectors given by the experts.

No	Main and sub-vital Physical indicators	Best to Others Preferences	Others to Worst Preferences	Weights
1	**Poor Infrastructures (PH-1)**			
	• Lack of road connectivity	**1**	**6**	0.079696
	• Surface deterioration of roads	**4**	**4**	0.056926
	• Poor drainage systems	**4**	**5**	0.033207
	• Poor road lighting systems	**6**	**1**	0.199241
2	**Accessibility Concerns (PH-2)**			
	• Narrow width roads	**3**	**5**	0.09962
	• Narrow sidewalks for wheelchairs	**5**	**2**	0.132827
3	**Urban amenities and services (PH-3)**			
	• Lack of efficient waste collection bins	**7**	**3**	0.066414
	• Lack of road amenities	**8**	**2**	0.332068

Source: Author's computation (2023).

Table 4:8 shows the vital physical vectors and their best-to-others and others-to-worst average preferences given by the experts for further BWM analysis of the variables in the city.

Table 4:9 Average weight and relative ranking of main physical variables given by the experts.

No	Physical variables	Weights	Relative rank
1	Poor Infrastructures (PH-1)	0.5	1
2	Accessibility Concerns (PH-2)	0.3333	2
3	Urban amenities and services (PH-3)	0.1667	3
	Average consistency ratio (CR)	0.100	

Source: computed by the author (2023)

Table 4:9 indicates poor infrastructures (0.5), the top, accessibility concerns (0.3333) second, and urban amenities and services (0.1667) ranked in third level. These prioritized physical variables were the leading causes of limited accessibility issues and traffic accidents in the city. The consistency ratio (0.100) shows moderately reliable in the comparison of the physical variables from experts view.

Validation of physical problems with site observation

Road-related issues are perceived by experts and households, according to the BWM findings. Narrow-width width roads and problems with road connectivity are thus presented based on field observations.

Lack of road connectivity

The secondary data on road related issues reveals lack of road connectivity and affects mobility in 'Debre Birhan' city.

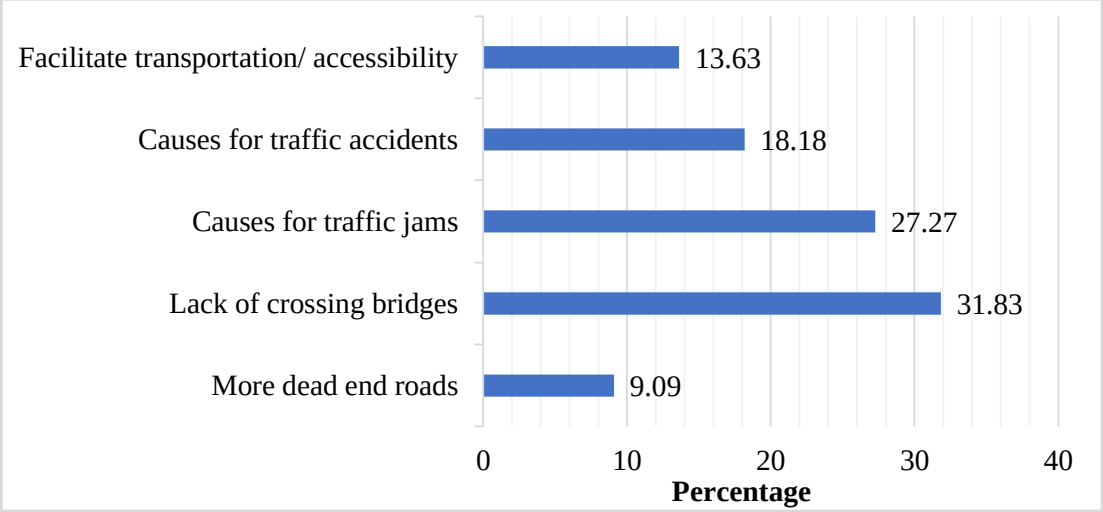

Figure 4:8 Condition of road network related to connectivity in Debre Birhan city.
Source: computed by the author (2023)

Figure 4:8 illustrates the condition of road network conditions related to connectivity in 'Debre Birhan' city. Based on the Figure, 31.83% of the respondents shows lack of crossing bridges on river banks and high way roads.

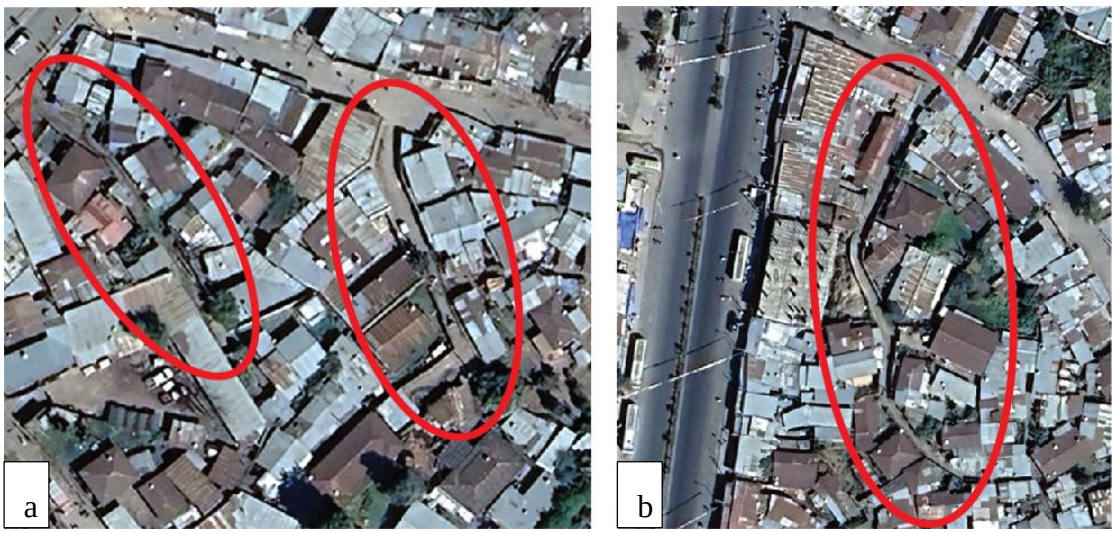

Figure 4:9 Connectivity issues in Debre Birhan city: dead end roads (a) and limits vehicular accessibility issues (b).
Source: computed by the author (2023)

Figure 4:9 indicates lack of road connectivity in the city. The Figure shows the accessibility issues (Figure 4:9a) and dead end roads (Figure 4:9b).

Narrow width roads

According to key sources from the Urban Infrastructure Office, narrow roadways that are less than four meters wide cause problems since they restrict accessibility inside the city. The majority of these roads exist in the city centers and creates vehicle accessibility issues.

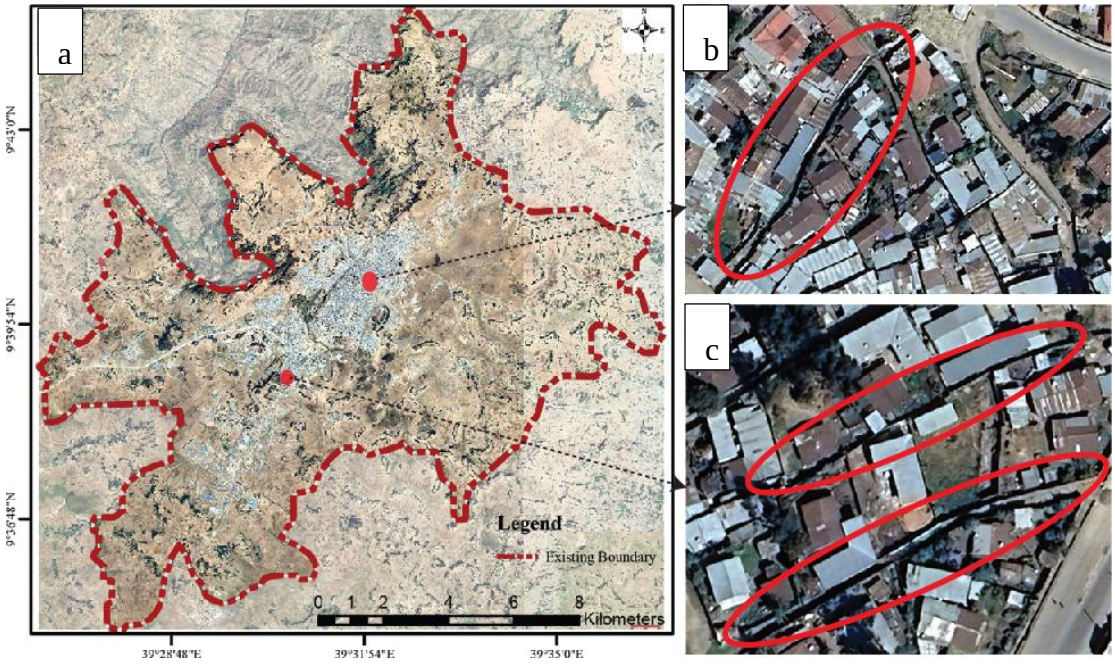

Figure 4:10 Aerial photo Debre Birhan city (a), narrow width roads less than 4 meters in the center (b) and sub center of the city (c).
Source: computed by the author (2023)

Figure 4:10 demonstrates narrow street widths of less than 4 meters, which limit vehicular accessibility in the city centers (Figure 4:10b) and sub centers (Figure 4:10c) marked in red shapes.

Types and condition of drainage systems

The drainage systems include open, closed and earthen drainage lines are provided in 'Debre Birhan' city.

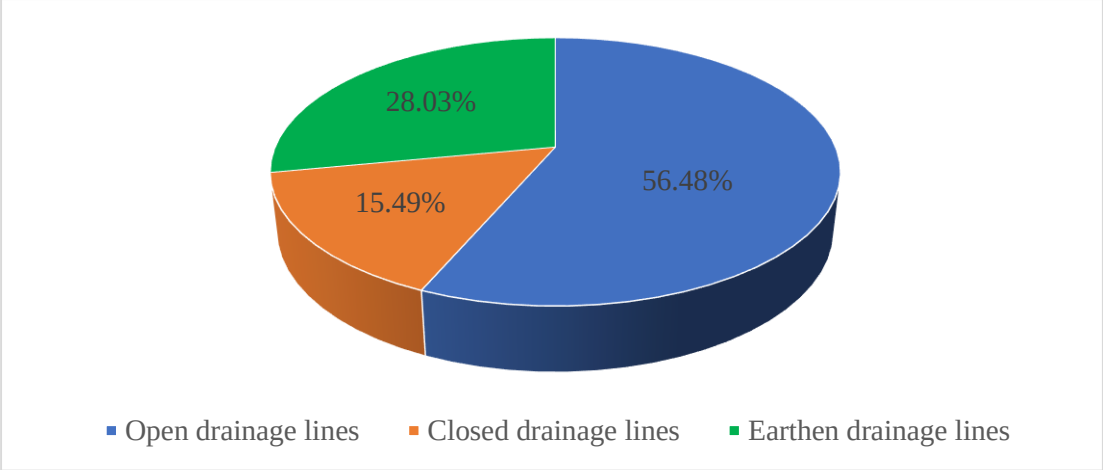

Figure 4:11 Type of drainage systems in the city.

Figure 4:11 shows the distribution three different drainage lines that facilitate the flow of rainwater or deter its mobility in the city.

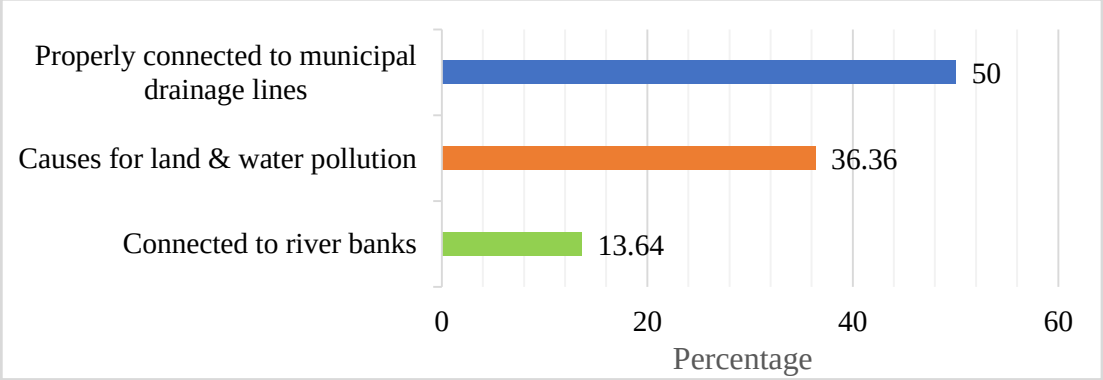

Figure 4:12 The condition of drainage systems in the city by experts.

Based on Figure 4:12, half of the drainage lines are properly connected to municipal drainage lines and one-third of them are causes for land and water pollution. The rest are connected to drain to rivers and its banks.

Figure 4:13 Drainage systems in Debre Birhan city: open drainage caused flooding (a), open drainage filled solid waste (b), open drainage creating land pollution (c) and closed drainage line (d).
Source: author (2023)

Sanitation problems

Experts indicated that inadequate sanitation systems in the city is a major challenge. They also assert that most provided drainage systems are not serving to drain storm and waste water, rather become a sanitation problem. However, the condition of some sanitation systems are provided with proper sanitation facilities and proper storm water drainage lines. In addition, the city limited toilets and adequate facilities.

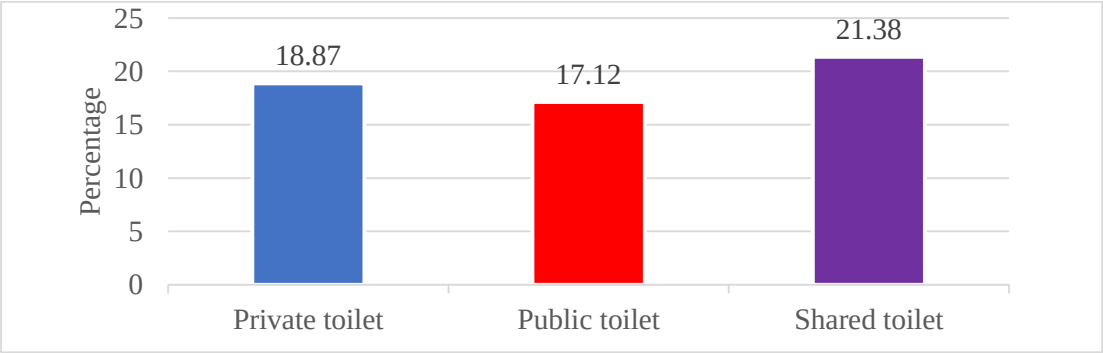

Figure 4:14 Condition of sanitation in Debre Birhan city.

Based on Figure 4:14, most of the sanitation systems of the city are shared toilet (21.38%) and private toilet (18.87%). Limited number of public toilets in the city were also causes for open defecation.

Road condition

Experts perceive that, surface material types of roads affected the accessibility in the city. Generally, the existing roads surface material are asphalt, cobbles stone, gravel and earthen. Surface deteriorated asphalt and cobbled stone roads in the city are poor. Gravel and earthen roads are also very poor in 'Debre Birhan city.

Figure 4:15 Existing road types and conditions in Debre Birhan city: surface deteriorated asphalt road (a), surface deteriorated gravel road (b), asphalt roads and walkway (c) and cobblestone road (d). Source: author's computation (2023).

Figure 4:15 depicts the road conditions in 'Debre Birhan' city. It contains the city's main road (a), which has surface deterioration and is difficult for vehicles to access and a narrow and deteriorated gravel road (b) only accessible by foot, better asphalt roads

with pedestrian walkways and closed drainage systems (c) and cobblestone road having good surface with open drainage lines (d).

Lack of road hierarchy

Principal Arterial Streets (PAS), Sub Arterial Streets (SAS), Collector Streets (CS), and Local Streets (LS) are the expected road hierarchies. The proposed Structure Plan (SP) manual indicate that these roads networked appropriately to facilitate accessibility and traffic flow in a city (Figure 4:16). The road hierarchies in the city, however, are not well considered as indicated in the existing road network as shown in Figure 4:17.

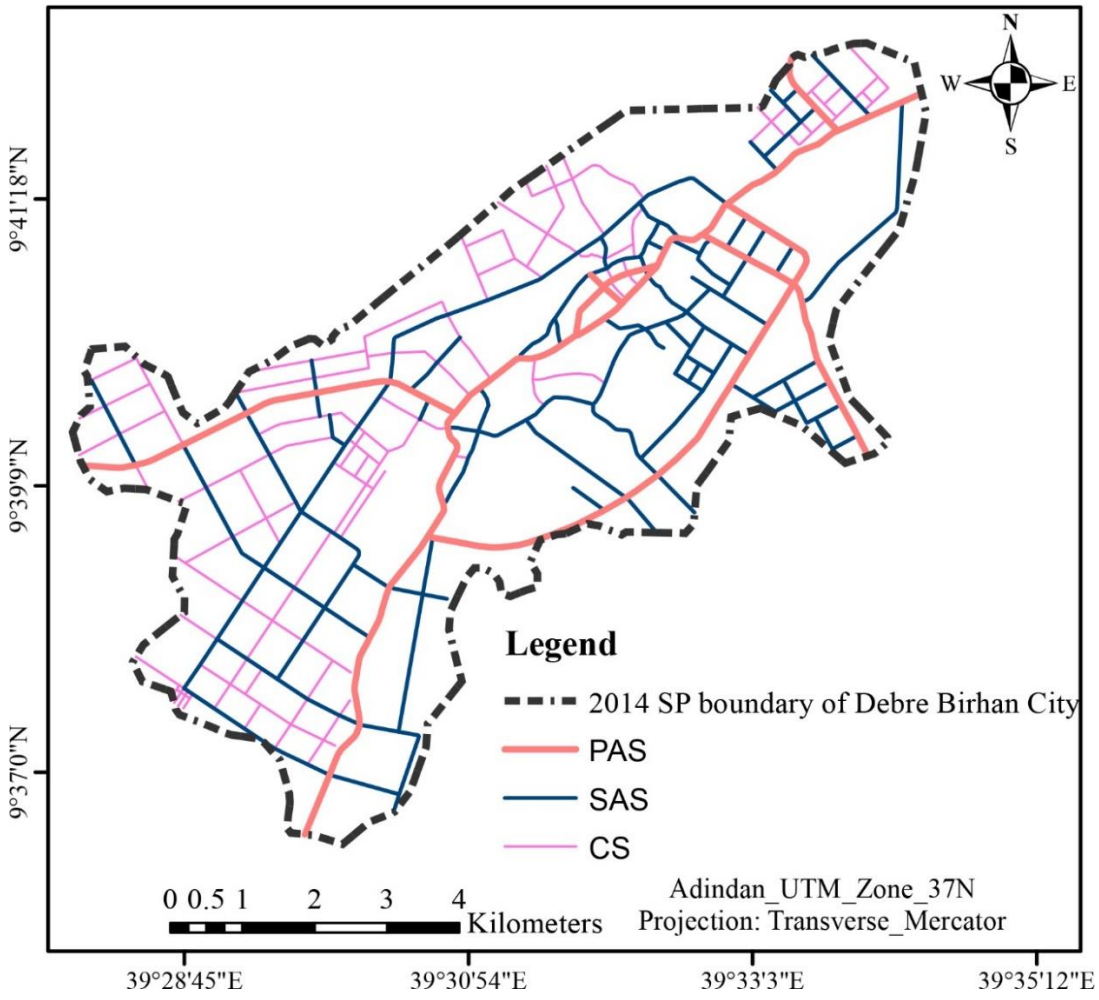

Figure 4:16 Road heirarchies in the 2014 proposed SP of Debre Birhan city.

Figure 4:16 shows the road hierarchies of 'Debre Birhan' city based on the 2014 proposed SP map.

Table 4:10 Allocated land for different road hierarchies proposal of the 2014 SP of the Debre Birhan city.

Road hierarchy	Width (m)	Length (m)	Area (ha)	Percentage from total area of the existing city (14,744 ha)
PAS	40	20,100	80.4	0.55%
	30	13,300	39.9	0.27%
SAS	25	41,760	104.4	0.71%
	20	27,800	5.56	0.04%
CS	15	99,240	148.86	1.00%
Total			**429.16**	**2.57%**

Source: land Management office of the city.

As shown Table 4:10, the proposals of road hierarchies in SP shows only PAS, SAS and CS. These, roads covers 2.57% of the existing total area of the city. The city is majorly covered with CS having 1%.

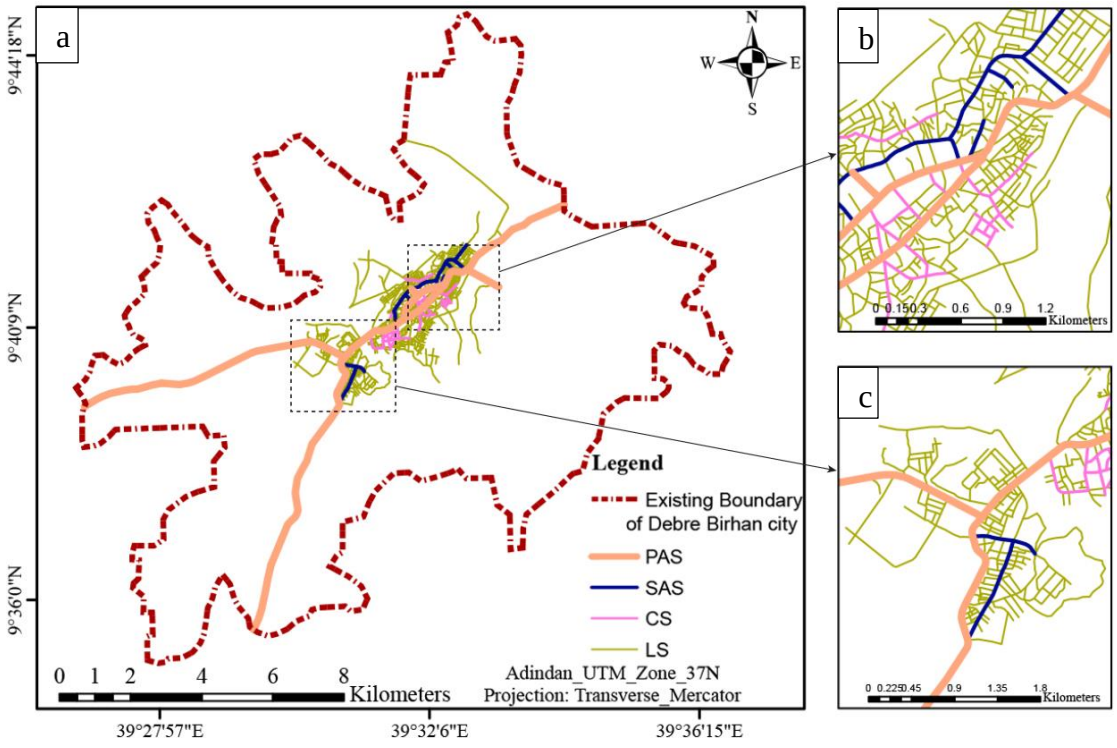

Figure 4:17 Existing road heirarchies of Debre Birhhan city (a): in the center (b) and sub centers (c).

Figure 4:17 shows improper road hierarchies in the center and sub center of 'Debre Birhan' city. Most of the roads covered with local streets (LS) and much of them are directly connected to PAS and SAS roads. This causes for bad transportation and mobility accesses in the city.

4.1.1.3. Social variables

Views from households

This section of the paper analyzed the social variables indicated on Table 2:2 based on the perception household and experts in 'Debre Birhan' city.

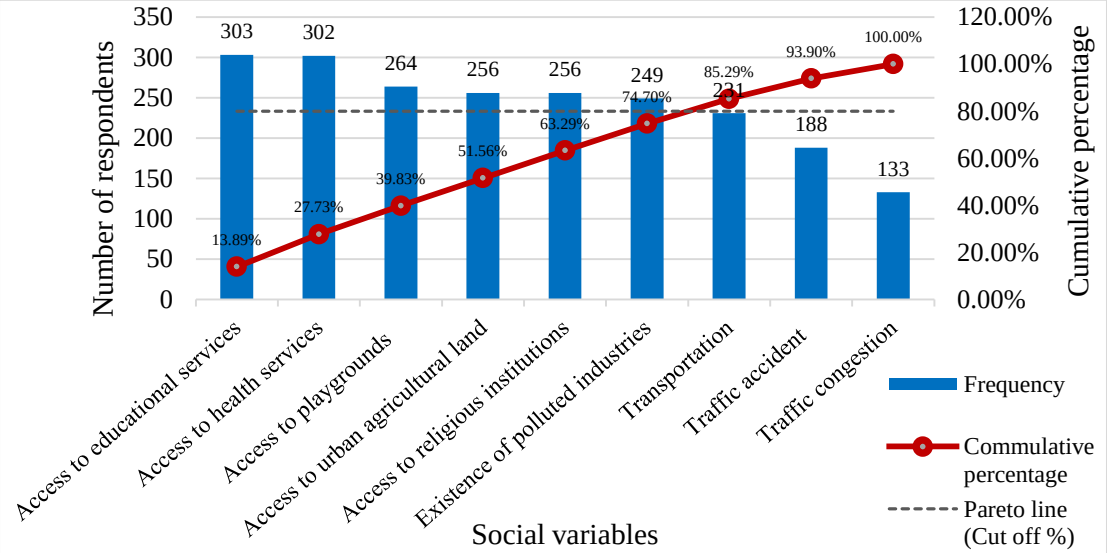

Figure 4:18 Pareto chart of social variables based on households in Debre Birhan city. Source: Author's computation (2023).

Access to educational services, access to health services, access to playgrounds, access to urban agricultural land, access to religious institutions and existence of polluted industries are identified as vital social variables and causes for transportation, traffic accidents and traffic congestion (Figure 4:18) by using Pareto analysis for BWM of analysis technique. Therefore, these variables are considered for best-to-others and others-to-worst comparison matrix.

Table 4:11 The best-to-others and others-to-worst pairwise comparison social vectors given by the household respondents.

Vital social indicators	Best to Others Preferences	Others to Worst Preferences
Access to educational services	5	2
Access to health services	5	2
Access to playgrounds	1	5
Access to urban agricultural land	2	3
Access to religious institutions	6	1
Existence of polluted industries	3	5

Source: computed by the author (2023)

Table 4:11 shows the best-to-others and others-to-worst variables and the average preferences given by the household respondents from Likert scale values.

Table 4:12 Average weight and relative ranking of main social variables given by the household respondents.

Social variables	Weights	Relative rank
Access to playgrounds	0.3665	1
Access to urban agricultural land	0.2356	2
Existence of polluted industries	0.1571	3
Access to health services	0.0942	4
Access to educational services	0.0942	4
Access to religious institutions	0.0524	6
Average consistency ratio (CR)	**0.105**	

Source: author's computation (2023).

Based on Table 4:12, access to playgrounds (0.3665), access to urban agricultural land (0.2356) and existence of polluted industries (0.1571) are the top three prioritized vital social variable in the city.

Views from experts

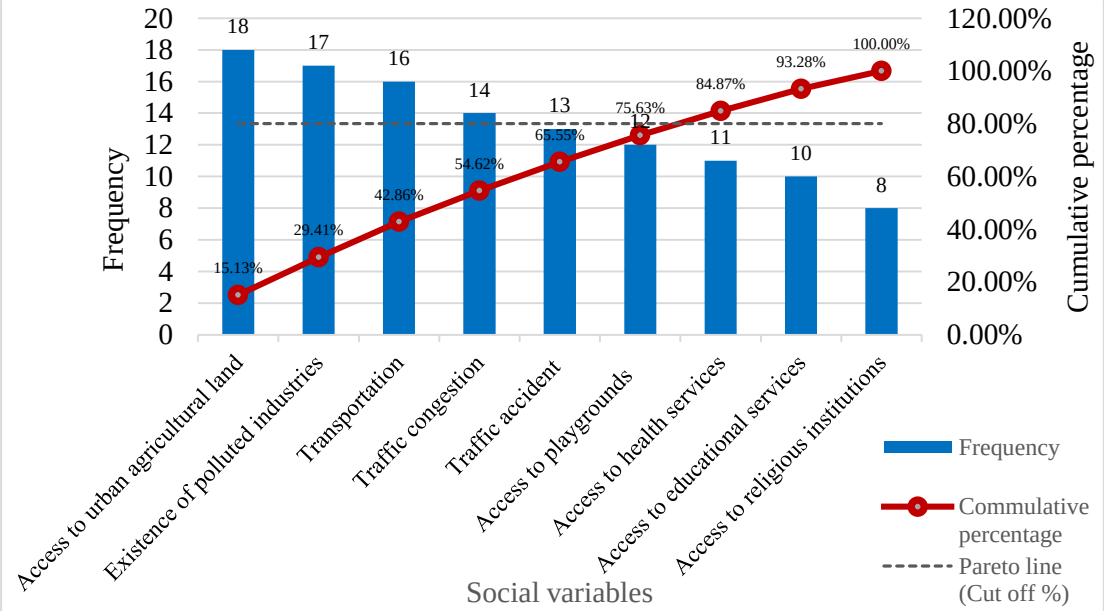

Figure 4:19 Pareto chart of social variables based on responses from selected experts in Debre Birhan city.
Source: Author's computation (2023).

Based on Figure 4:19, access to urban agricultural land, existence of polluted industries, transportation, traffic congestion, traffic accidents and access to playgrounds are the most important variables and causes for access to health services, access to educational services and access to religious institutions from expert responses. These vital indicators were considered for best-to-others and others-to-worst comparison matrix in BWM of analysis.

Table 4:13 The best-to-others and others-to-worst pairwise comparison social vectors given by the key informant respondents.

Vital social indicators	Best to Others Preferences	Others to Worst Preferences
Access to urban agricultural land	5	2
Existence of polluted industries	5	2
Transportation	1	5
Traffic congestion	2	3
Traffic accidents	6	1
Access to playgrounds	3	5

Source: author's computation (2023)

Table 4:13 shows the social variables and their average preferences given by the experts using scale preferences from 1 to 9.

Table 4:14 Average weight and relative ranking of main social variables given by the key informant respondents.

Social variables	Weights	Relative rank
Access to urban agricultural land	0.3793	1
Existence of polluted industries	0.2212	2
Transportation	0.1475	3
Traffic congestion	0.1106	4
Traffic accidents	0.0885	5
Access to playgrounds	0.0527	6
Average consistency ratio (CR)	**0.0632**	

Source: author's computation (2023)

Based on Table 4:14, access to urban agriculture (0.3793), existence of polluted industries (0.2212) and transportation (0.1475) are the top three prioritized social variables with respectively.

In addition to the above variables land use compatibility issue, locational incompatibilities, informal settlements, land cover change, uncontrolled expansion and urban sprawl are another social variables considered in this study. Thus, the results from expert's response are presented in Figure 4:20

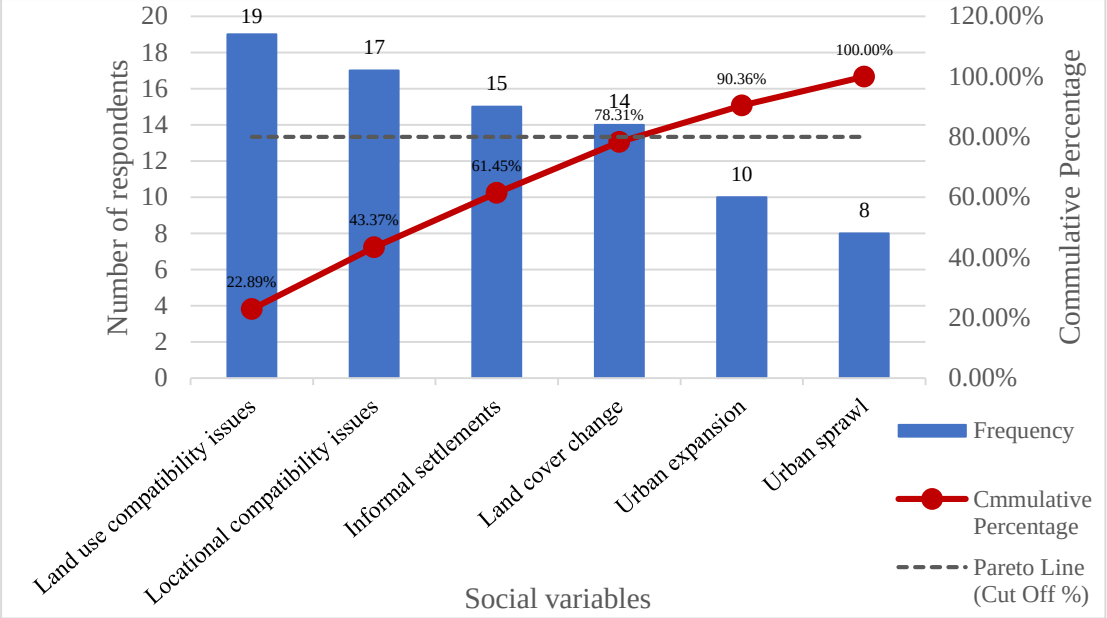

Figure 4:20 Pareto chart of social variables from key informant responses.
Source: author (2023)

Figure 4:20 depicts that land use incompatibility, locational incompatibilities, informal settlements and land cover change are the most important social variables based on the key informant responses using Pareto analysis. These four variables are considered for BWM.

Table 4:15 Average weight and relative ranking of main social variables given by the key informant respondents.

Social variables	Weights	Relative rank
Land use compatibility issues	0.5496	1
Locational compatibility issues	0.2137	2
Land cover change	0.1603	3
Informal settlements	0.0763	4
Average consistency ratio (CR)	**0.0916**	

Source: author (2023).

Table 4:15 depicts land use and locational compatibility issues are the most prioritized social variables in 'Debre Birhan' city.

Land use compatibility issues

Land use incompatibility in the city claimed as a social urban problem by sampled key informants from land administration and Management offices. These land use incompatibilities presented in the city are polluting industries with settlements, polluting industries with commercial, polluting industries with urban agriculture, river banks with polluting industries and urban agriculture with river banks.

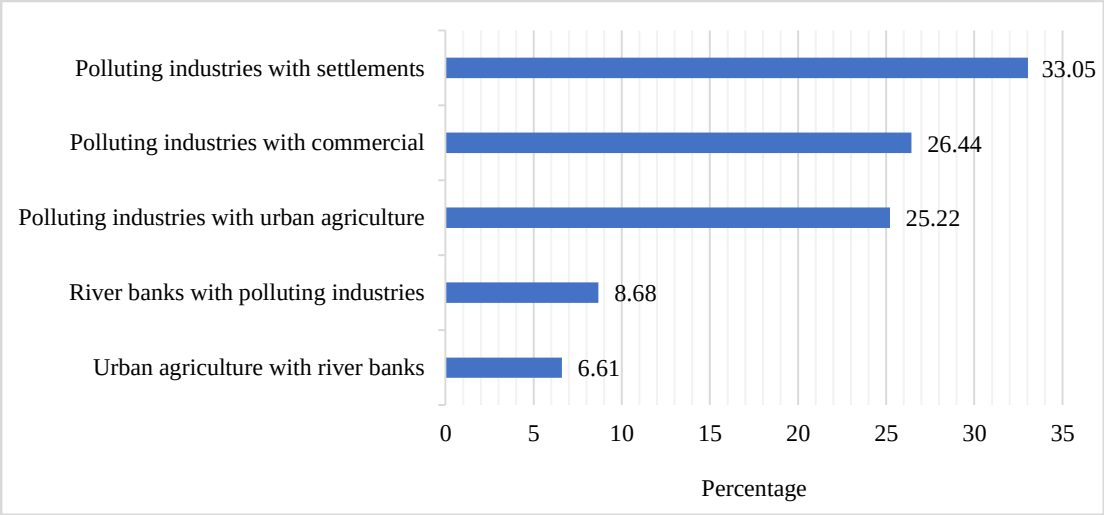

Figure 4:21 Level of land use compatibility issues in Debre Birhan city.
Source: Author (2023).

Figure 4:21 illustrates the level of major land use compatibility issues in the city. Based on the Figure, the level of polluting industries with settlements is very high with the value of 33.05%.

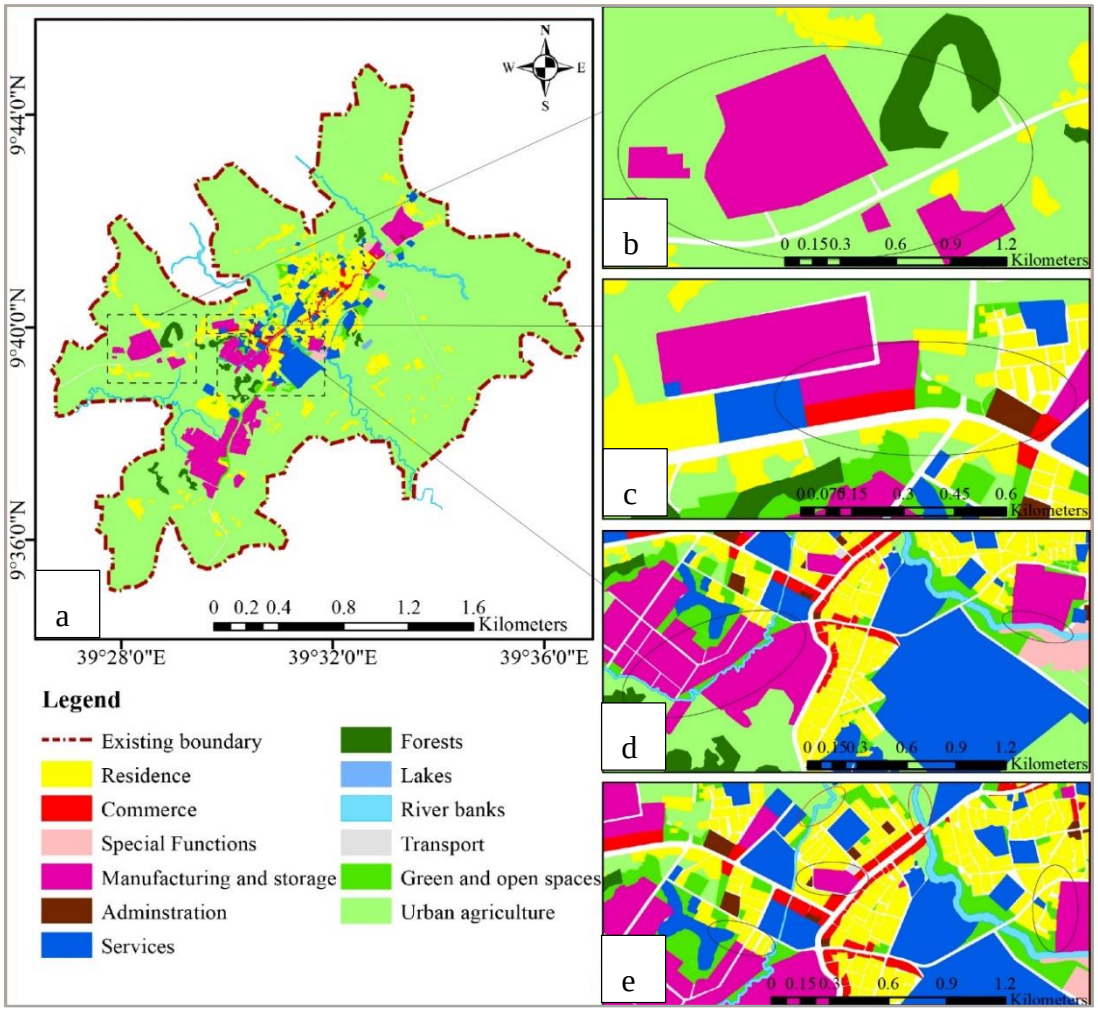

Figure 4:22 Existing land use map of Debre Birhan city (a), industries with urban agriculture (b), industries with commercial (c), industries with river banks (d), industries with settlements (e).
Source: produced by the author based on 2014 base map of the city and Google earth pro using Arc GIS 10.8, 2023.

Figure 4:22 describes the major incompatibilities existed in 'Debre Birhan' city. Land use incompatibilities of polluting industries: with urban agriculture (b) in the periphery of the city, with commercial settlements at the sub center of the city (c), with river banks (d) and with settlemnts (e).

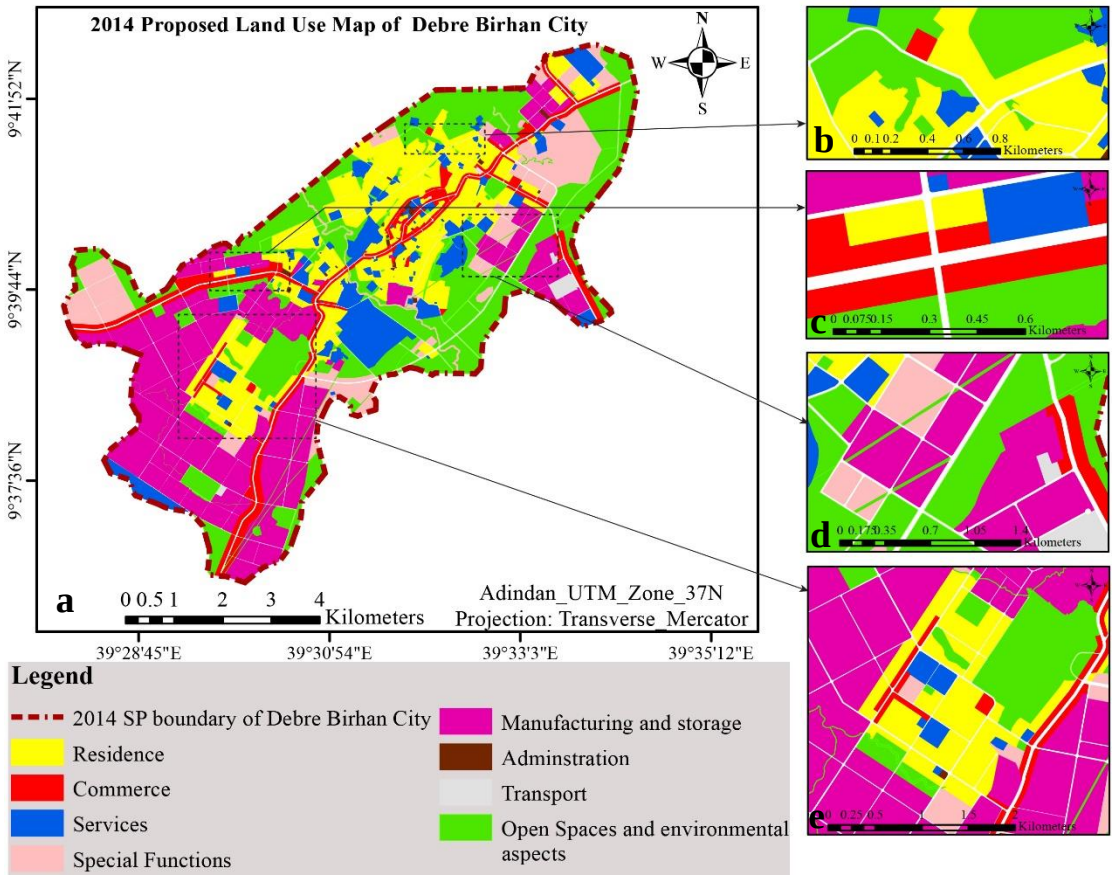

Figure 4:23 The 2014 proposed SP of Debre Birhan city (a), locational incompatibilities of commercial and social services (b), industries with commercial and settlements (c, d & e).
Source: by the author based on 2014 base map of the city.

Figure 4:23 shows the land use incompatibilities; polluting industries with commercial and settlements on the 2014 SP of 'Debre Birhan' city (c, d & e).

Causes for locational compatibility issues

Key informants from the Environmental Protection Office also claimed that compatibility problems were caused by the locations of polluting industries. Accordingly, the majority of the polluting industries' locations are determined by the city's structure plan, which places them close to regions used for urban agriculture and some polluting industries are conveniently accessible for transit.

A driving factor for the incompatibility is the problem of land use due to lack of enough experienced professionals related to land use planning.

Table 4:16 Locational incompatibility issues in Debre Birhan city

Locational compatibility attributes	Responses weight in percent
Industries	
Considering Accessibility/transportation	36.36
Separated from settlements	27.28
Considering river streams and sensitive lands	18.18
Causes for land and water pollution	18.18
Social services	
Considering proximity to settlements	38.46
Considering mobility and transportation	61.54
Settlement	
Settlement development in relatively gentle slope	72.73
Settlement development in steep slope	27.27
Commercial	
Considering proximity to settlements	31.82
Only center of the city	50
At the sub centers of the city	18.18

Source: author (2023)

Based on Table 4:16, development of industries were without considering river streams and sensitive lands, and land and water pollution in 'Debre Birhan' city. Commercial hubs at the sub centers of the city are limited and causes incompatibility.

Land cover change

According to key informants, uncontrolled urban growth and changes in land use and cover in 'Debre Birhan' city lead to several environmental issues, such as the loss of agricultural lands and increased flooding. Over three decades, the city's land cover have changed, with more built-up regions and fewer green spaces and agricultural land in the years 2003, 2013 and 2023.

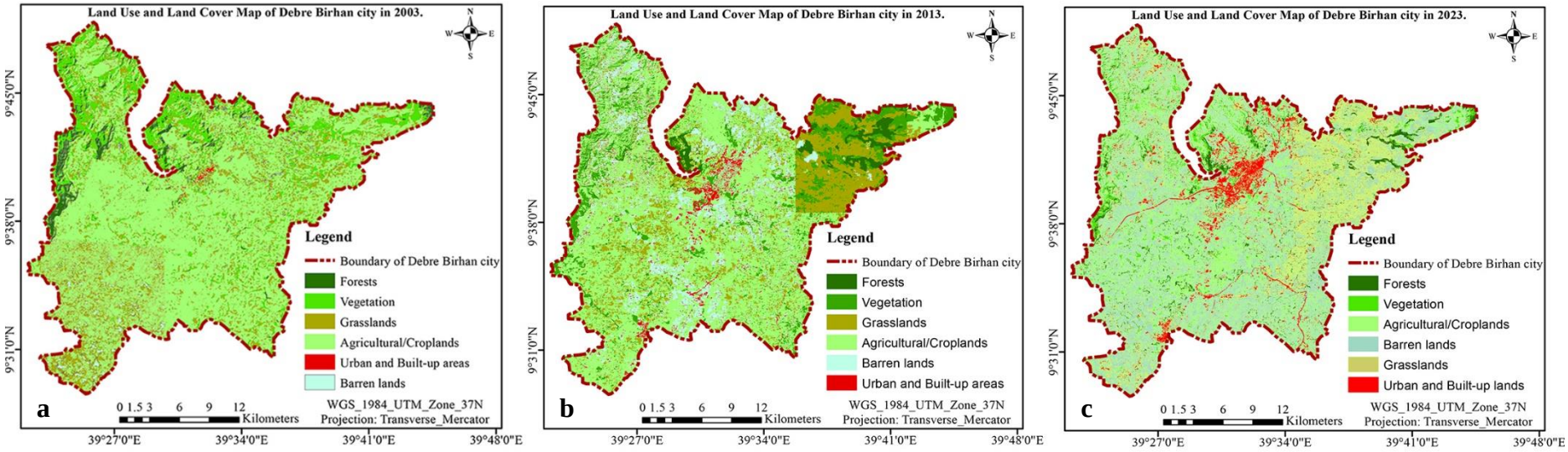

Figure 4:24 Land cover changes: land use cover of 2003 (a), land use cover of 2013 (b) and land use cover of 2023 (c).

Source: author (2023).

Figure 4:24 indicates the land cover of the city between 2003-2013 and 2013 to 2023 with ten years interval of time. Based on the Figure, the level of built-up areas in the city is increasing.

Table 4:17 Land cover change of Debre Birhan city using geospatial techniques.

Land cover categories	**Years**						**Area changed (%) 2003-2023**
	2003		**2013**		**2023**		
	Area (ha)	**Area (%)**	**Area (ha)**	**Area (%)**	**Area (ha)**	**Area (%)**	
Urban & built-up areas	127	0.00	411	0.01	2,326	0.03	+0.03
Forests	3,396	0.05	3,203	0.05	3,372	0.05	0.00
Vegetation	9,232	0.13	9,203	0.13	5,692	0.08	-0.05
Agricultural/ croplands	44,042	0.62	36,753	0.52	26,181	0.37	-0.25
Grasslands	11,404	0.16	12,673	0.18	23,509	0.33	+0.17
Barren lands	2,629	0.04	5,763	0.08	9,661	0.14	+0.10

Source: author (2023)

Table 4:17 illustrates the land cover change of the city from 2003 to 2023 shown Figure 4:24. Based on Table 4:17, urban & built-up areas, grasslands, and barren lands increased with the value 0.03%, 0.17% and 0.1% respectively, while vegetation and agricultural lands are decreased.

4.1.1.4. Institutional variables

This part of the study covers the current institutional arrangements as well as the vertical and horizontal structures or collaborations in decision-making processes in 'Debre Birhan' city. These variables are analyzed from the data collected from households and experts of the city.

Views from households

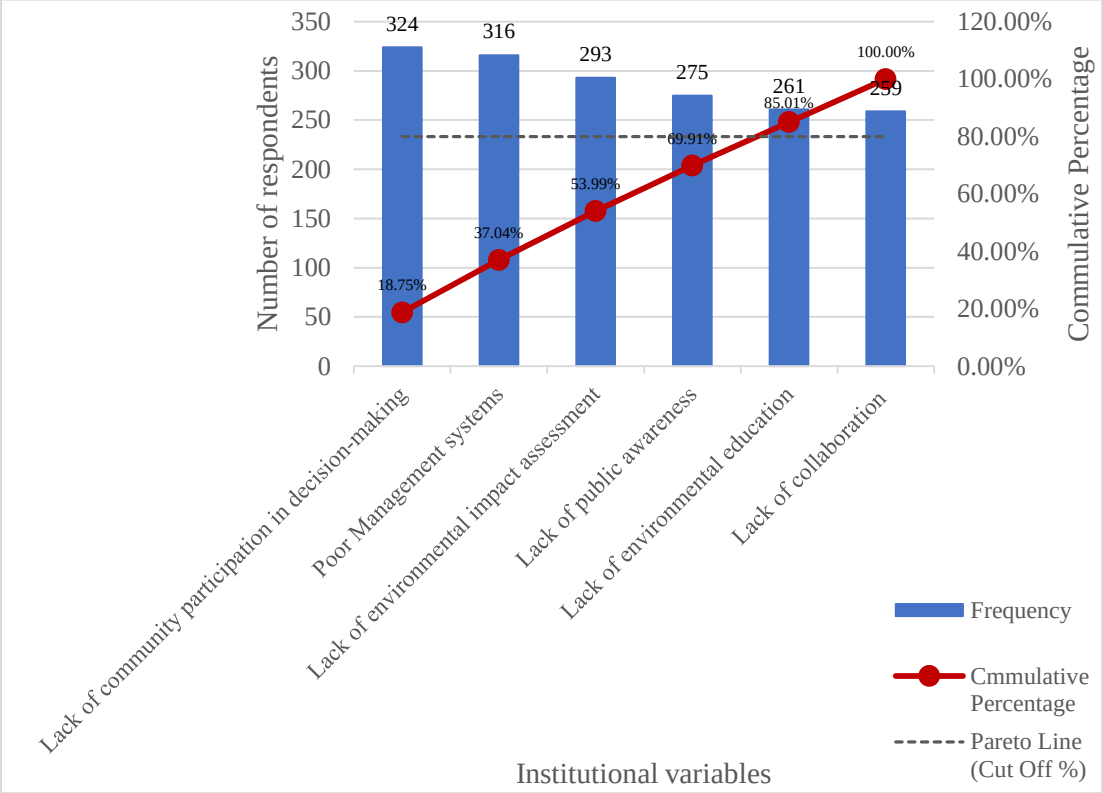

Figure 4:25 Pareto chart of institutional variables from households perception.
Source: Author's computation (2023).

Figure 4:25 indicates the Pareto chart of institutional variables affecting the Management practices of the city based on household responses. Accordingly, lack of community participation, poor Management systems, lack of environmental impact assessment and lack of public awareness are the most important factors, and causes for lack of environmental education and collaboration as shown in the Figure.

Table 4:18 Average weight and relative ranking of main institutional variables given by household respondents.

Institutional variables	Weights	Relative rank
Lack of community participation in decision-making	0.538	1
Lack of environmental impact assessment	0.231	2
Poor Management systems	0.154	3
Lack of public awareness	0.077	4
Average consistency ratio (CR)	**0.077**	

Source: author (2023).

Lack of community participation in decision-making (0.538) the most prioritized problem and lack of public awareness (0.077) and the least problem based on BWM of analysis from households responses as shown Table 4:18.

Views from experts

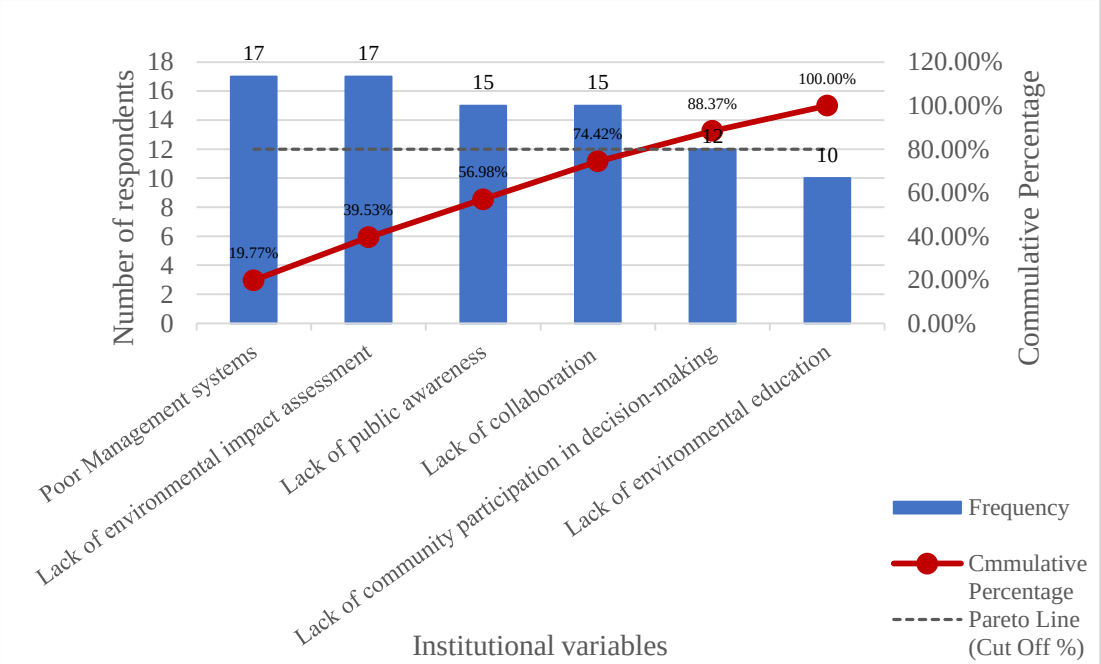

Figure 4:26 Pareto chart of institutional variables based on responses from experts.
Source: author (2023)

Figure 4:26 shows the most vital institutional variables based on experts perception. These are poor management systems, lack of environmental impact assessment, lack of public awareness and lack of collaboration.

Table 4:19 Average weight and relative ranking of main institutional variables given by the key informant respondents.

Institutional variables	Weights	Relative rank
Poor Management systems	0.648	1
Lack of environmental impact assessment	0.191	2
Lack of collaboration	0.085	3
Lack of public awareness	0.076	4
Average consistency ratio (CR)	**0.114**	

Source: author (2023).

Table 4:19 puts poor Management systems (0.648) as the most important factors, which the same with Pareto analysis, in the city. Whereas, lack of public awareness (0.076) is the least important variable as shown in Table 4:19.

4.1.2. The environmental management tools implemented to offset the challenges in the city

This portion of the paper outlines the city's mitigation measures implemented based on the perception of households and key informants. The variables considered are based on the literature review section of the paper (Annex IV).

4.1.2.1. Environmental management plan implemented for environmental factors

This section of the paper illustrates the environmental Management tools implemented to mitigate environmental problems in the city based on the perception of the households and experts.

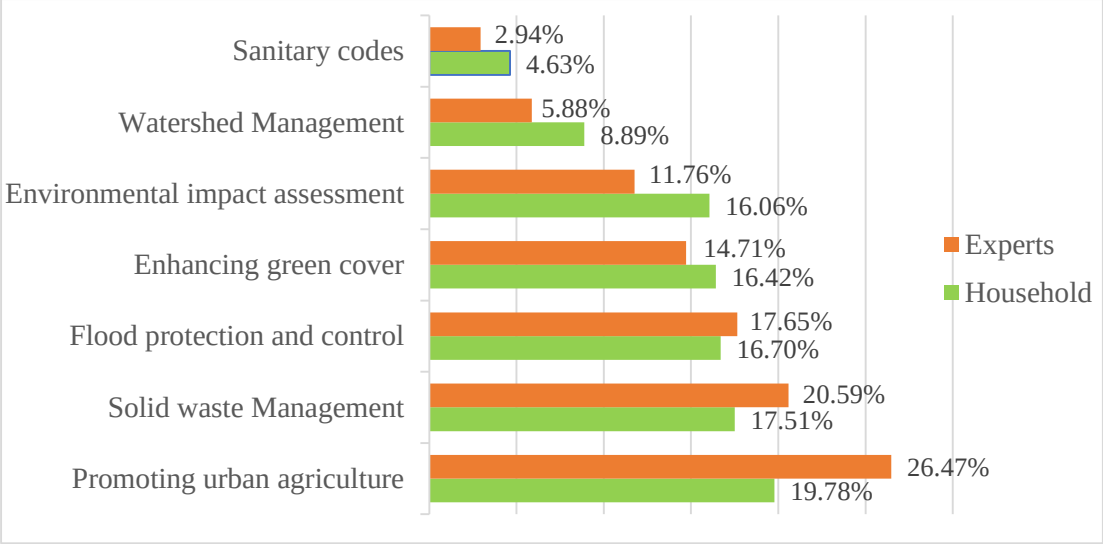

Figure 4:27 Level of environmental management tools implemented in the city based on households and experts perception.
Source: author (2023).

The top three implemented environmental Management tools are promoting urban agriculture (19.78%), solid waste Management (17.51%), and flood protection & control (16.70%) based on households perception (Figure 4:27). The least two implemented mitigation measures for environmental factors are sanitary codes (4.63%) and watershed management (8.89%) respectively as shown in Figure 4:27.

Whereas, enhancing green cover, promoting urban agriculture and solid waste management were the most three implemented environmental management tools based on the experts perception with respective values of 26.47%, 20.59% and 17.65% (Figure 4:27). The least implemented environmental management tools are sanitary codes (2.954%) and watershed management (5.88%) as similar rankings with percentage value differences.

Solid waste Management mechanisms implemented by the city

'Debre Birhan' city was implemented solid waste management mechanisms through solid waste management office. These mechanisms are prioritized by the experts as follows.

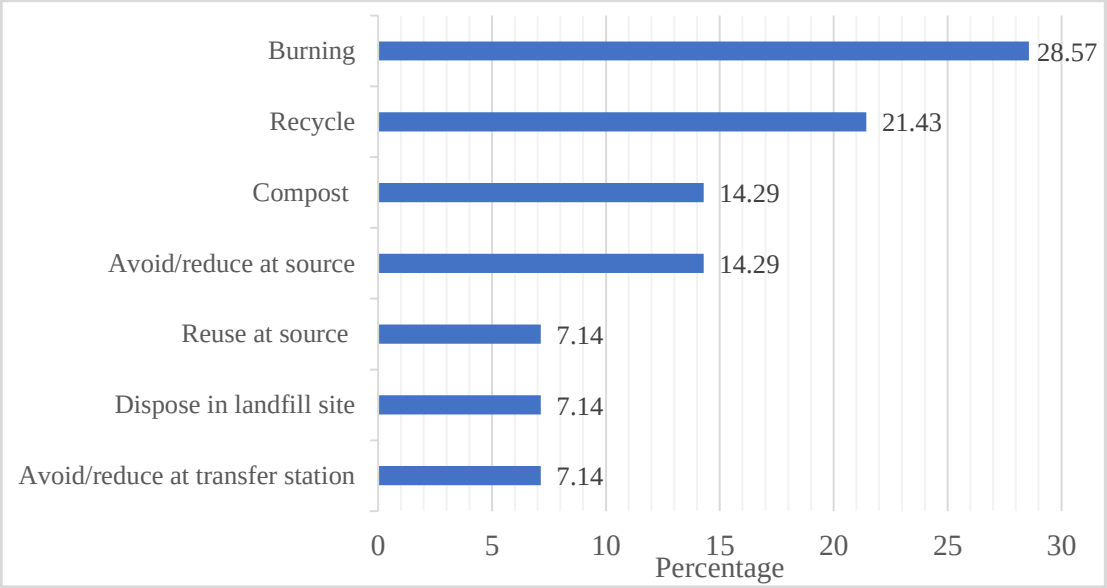

Figure 4:28 Proportion of implemented solid waste Management mechanisms as sampled experts perception.
Source: author (2023).

The bar graph on Figure 4:28 outlines solid waste Management techniques so far applied in the city. Burning is the first and recycling is the second, with values of 28.57% and 21.43%, respectively. The Figure also put reuse at source, avoid/reduced at transfer station, and dispose in landfill site, all with the same value of 7.14%. As a result, environmentally unfriendly solid waste management techniques (open burning) applied in the city.

Figure 4:29 Solid waste Management mechanisms used in Debre Birhan city: open burned trashes (a), temporary dumping sites (b, c and d).
Source: author (2023).

The photographs on Figure 4:29 reveals solid waste Management mechanisms practiced in the city. Open spaces are sites used for open burning of solid wastes in the city (a), streets are served as a temporary dumping sites (b, c & d).

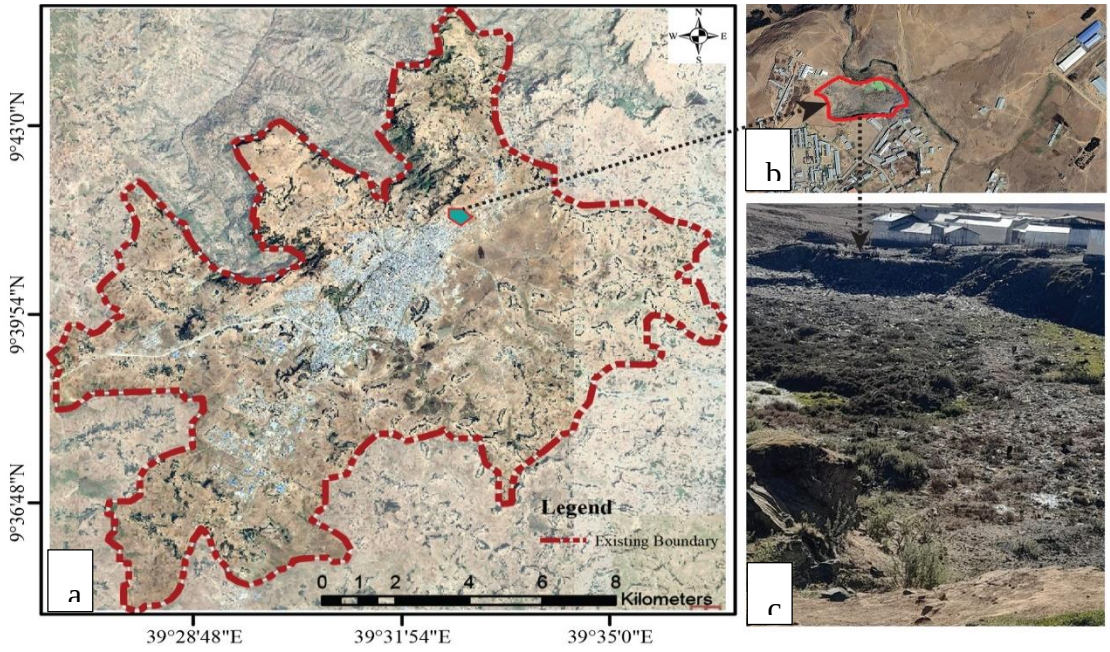

Figure 4:30 Land fill site in Debre Birhan city: Debre Birhan city (a), location of landfill site (b) and picture of landfill site (c).
Source: Author's computation (2023).

Figure 4:30 indicates the location of solid waste landfill site at the north east periphery of the city. Based on Figure 4:30c, the landfill site of the city is without any design considerations and causes for land, air and water pollution.

Enhancing green cover

Based on Debre Birhan city land Management office, the current green coverage of the city is 7.56%.

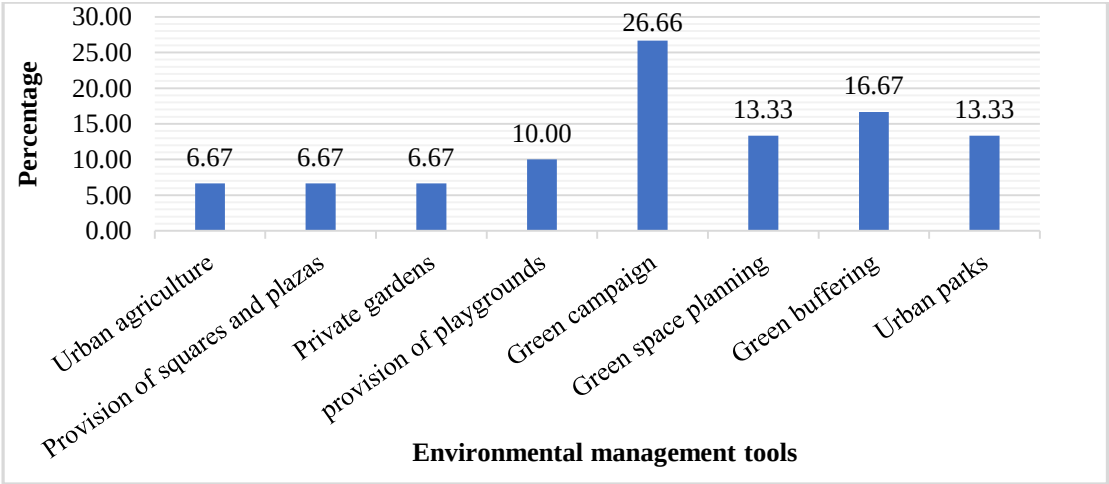

Figure 4:31 Environmental management tools implemented to improve green related management tools in the city.

Figure 4:31 indicates the mitigation measures implemented to improve green and open spaces in the city. Accordingly, green campaign is the most implemented Management tools with the value of 26.66% while urban agriculture, provision of squares and private gardens are the least applied tools with equal value of 6.67%.

Flood protection and control

The environmental management tools implemented to protect and control flooding in the city are summarized as follows.

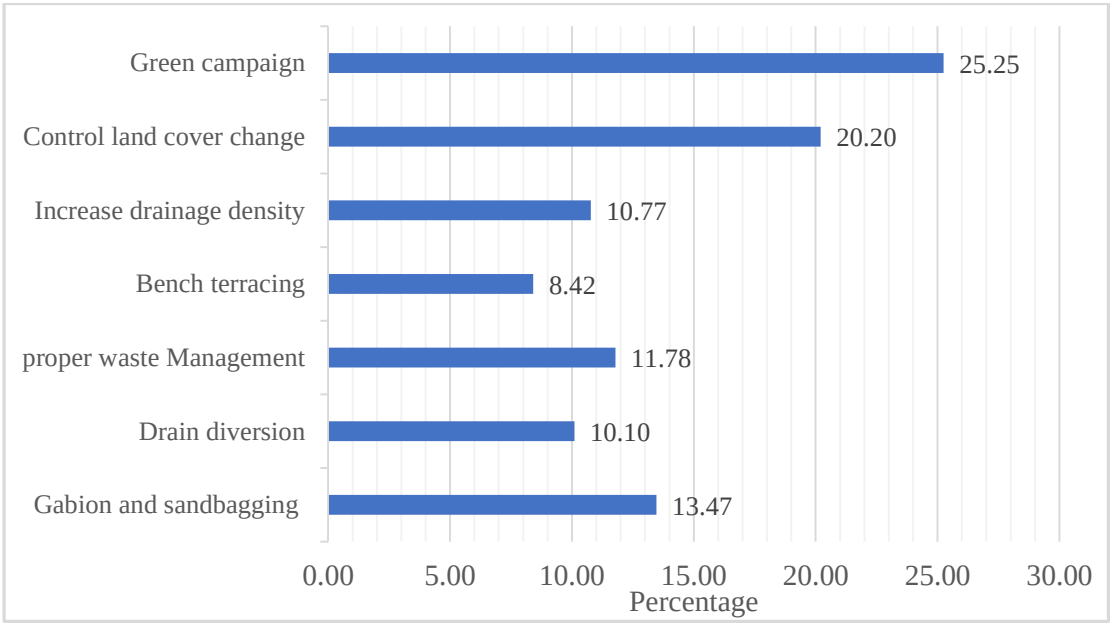

Figure 4:32 Mitigation measures implemented to control and protect flooding.
Source: computed by the author (2023).

Based on Figure 4:32, green campaign and control land cover change are the two most implemented mechanisms to control and protect flooding with the value of 25.25% and 20.2% respectively.

Based on the city asset Management office, 8.1 hectares of land are conserved in the city. It was mostly done by, 6.2 km length meshed stone-based gabion structure constructed to protect water and soil erosion, and 4.7 km length of retaining wall along the river banks also implemented to control surface flooding in the city.

Figure 4:33 Flood control and protection mechanisms implemented in Debre Birhan city: meshed gravel gabion (a) and masonry retaining wall (b).
Source: computed by the author (2023).

Figure 4:33 depicts the environmental Management methods put in place to preserve soil and river systems from erosion. The city practiced meshed stone-based gabion wall to control steeped land affected by surface flooding as shown in Figure 4:33a. Based on Figure 4:33b, the river system is protected from flooding by a masonry wall system that wraps around bridge retaining walls.

4.1.2.2. Environmental management tools implemented for physical factors

Environmental management tools implemented in the city based on household and expert perceptions are presented as follows.

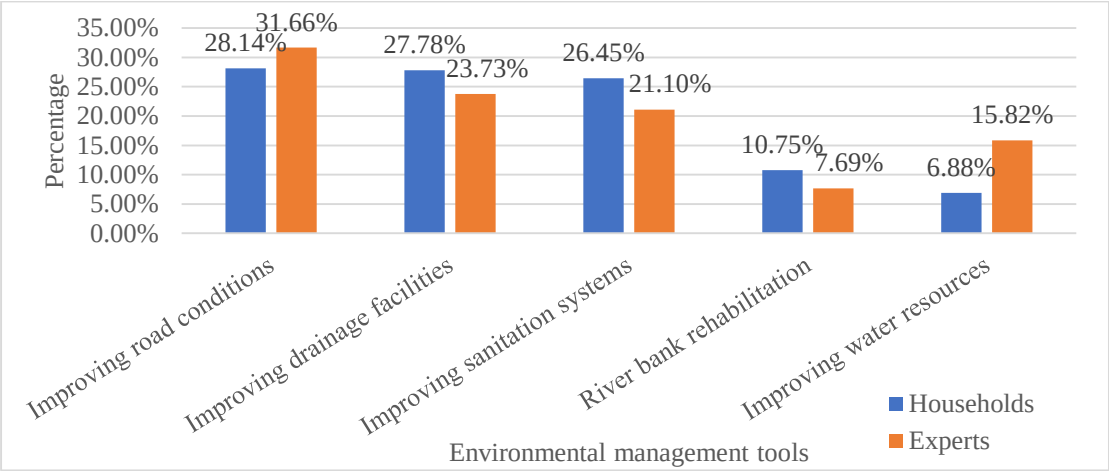

Figure 4:34 Environmental management tools implemented in the city.
Source: Author (2023).

Figure 4:34 illustrates the environmental management tools implemented by the city based on the household perception. Improving road conditions and drainage facilities identified as the top variables (28.14%) and improving water resources the least implemented variable (6.88%) in 'Debre Birhan' city. Whereas, improving road conditions is the top implemented tools with the value of 31.66% and river bank rehabilitation the least implemented environmental management tools (7.69%) from experts perception.

Improving road conditions

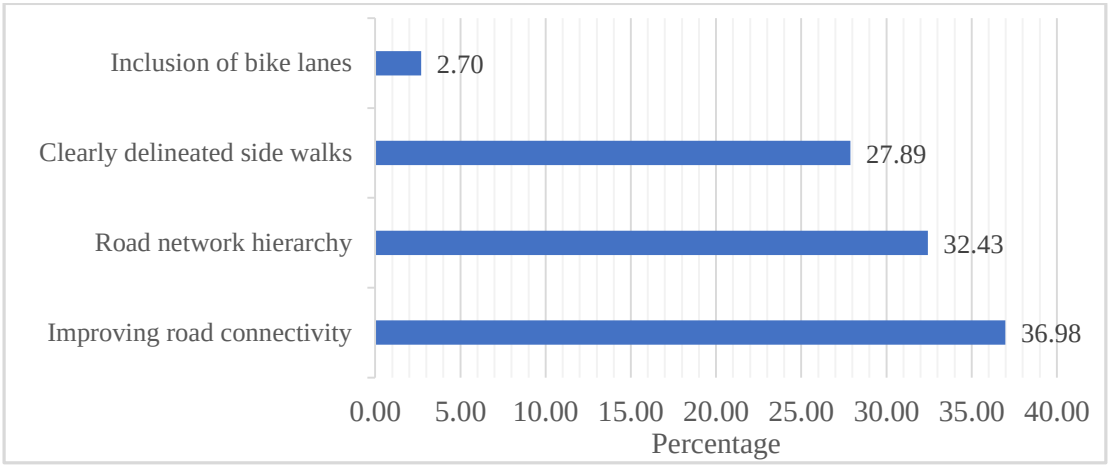

Figure 4:35 Mitigation measures implemented to improve road conditions.
Source: Author (2023).

Figure 4:35 indicates connectivity is the most implemented measurement tools to improve road conditions in the city with the value of 37%. However, sustainability and smart city concept in cities advises the rest least implemented physical variables.

Improving drainage facilities

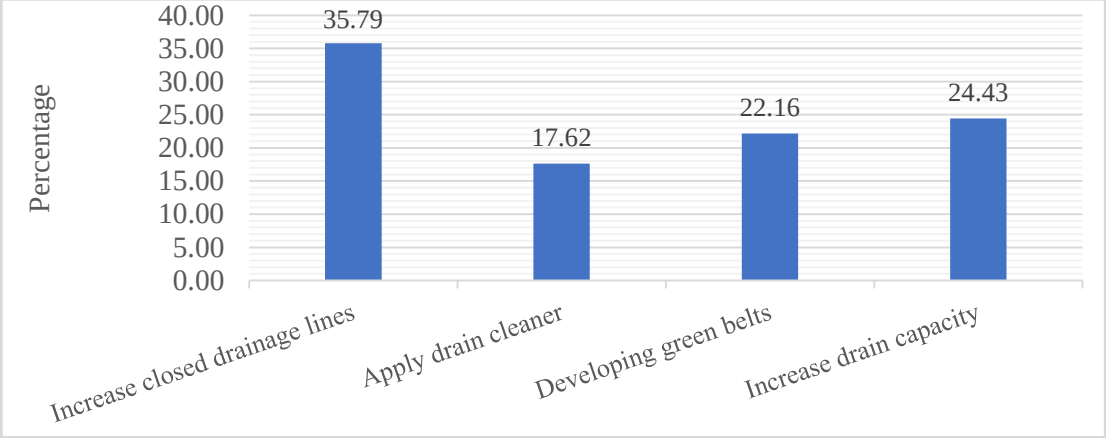

Figure 4:36 Mitigation measures implemented to improve drainage facilities.
Source: computed by the author (2023).

Based on Figure 4:36, increase closed drainage lines is the most implemented mitigation measures to improve drainage facilities in the city with the value of 36%. Therefore, drainages of the city is affected by clogging with little implementation of drain cleaner and green belts.

Improving sanitation systems

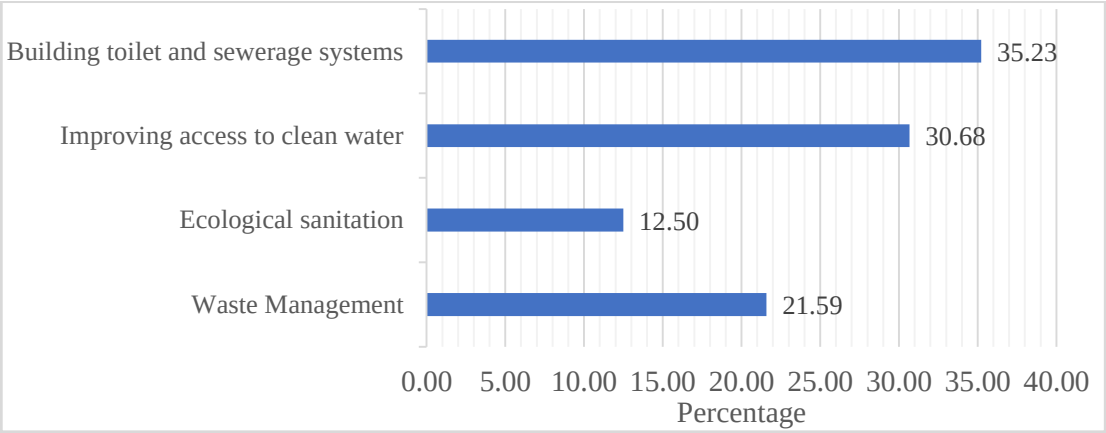

Figure 4:37 Environmental management tools implemented to improve sanitation systems.
Source: Author (2023).

Figure 4:37 puts building toilet and sewerage systems, and improving access to clean water the two most implemented mitigation measures with the value of 35% and 31% respectively. This implies low understanding of residents and professionals on waste management and sanitation systems and also little advantage of ecological sanitation concept in the city.

4.1.2.3. Environmental management tools implemented for social factors

The environmental management tools implemented for social factors based on household and expert perceptions are analyzed as follows.

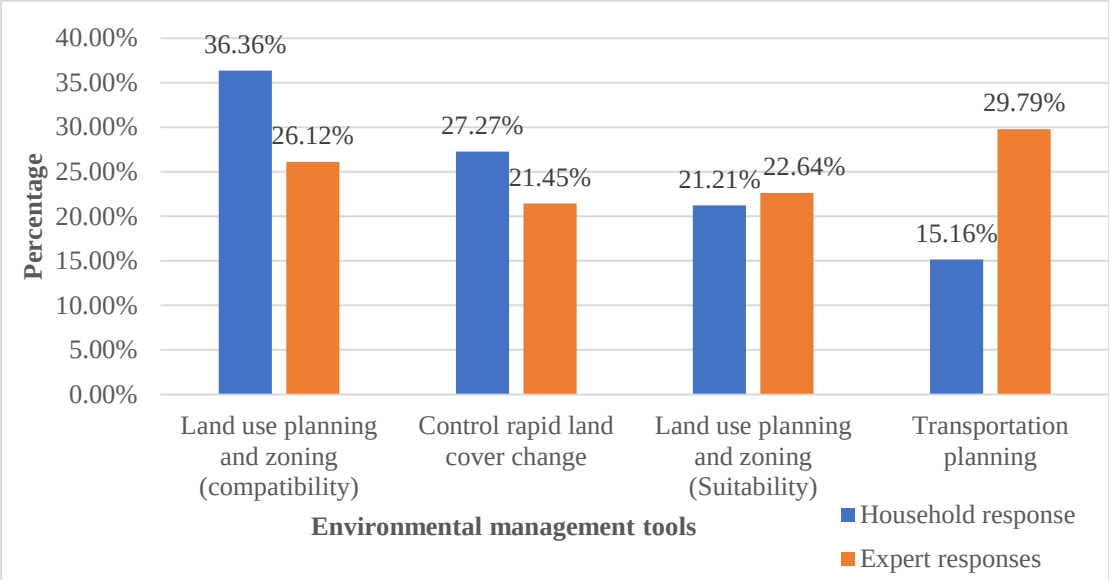

Figure 4:38 Environmental management tools implemented in the city.
Source: author's computation (2023).

Based on Figure 4:38, land use planning & zoning related to compatibility (36.36%), and control rapid land cover change (27.27%) are the most and transportation planning (15.16%) the least implemented management tools based on household responses. Whereas, transportation planning (29.79%) is the most implemented environmental management tools from expert responses. The disparity in results indicates a gap in expert and household awareness and knowledge of mitigating methods.

Land use planning and zoning (compatibility)

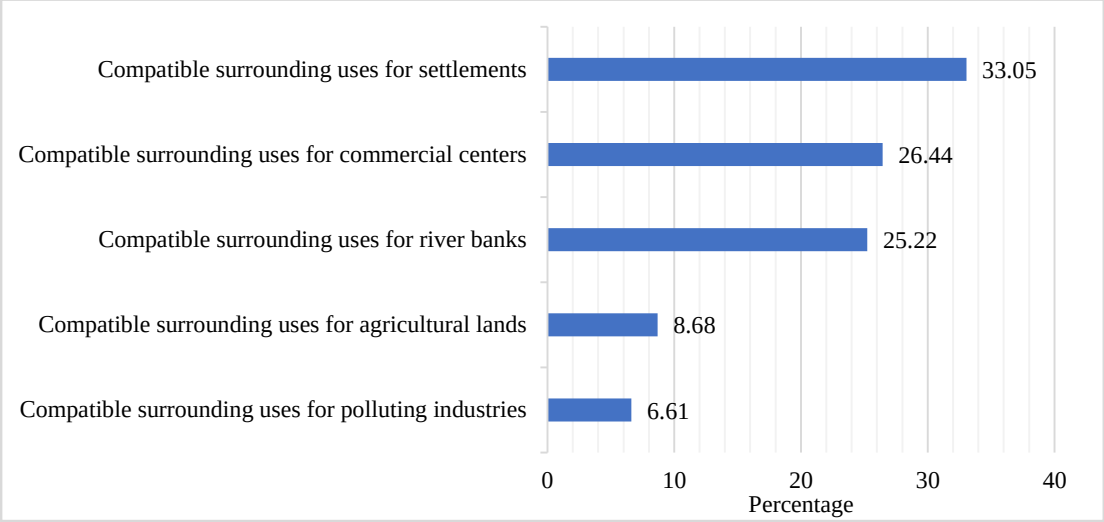

Figure 4:39 Mitigation measures implemented to land use planning & zoning (compatibility).
Source: Author's computation (2023).

Based on Figure 4:39, compatible surrounding uses for settlements, compatible surrounding uses for commercial centers and compatible surrounding uses for river banks are the three most implemented tools with respective value of 33%, 26% and 25%. As an industrial city, compatibility issues related to industries (6.61%) and agricultural lands (8.68%) receive little attention in development management techniques.

Land use planning and zoning (Suitability)

This section of the paper analyzes the suitability related to land uses and zonings implemented in 'Debre Birhan' city.

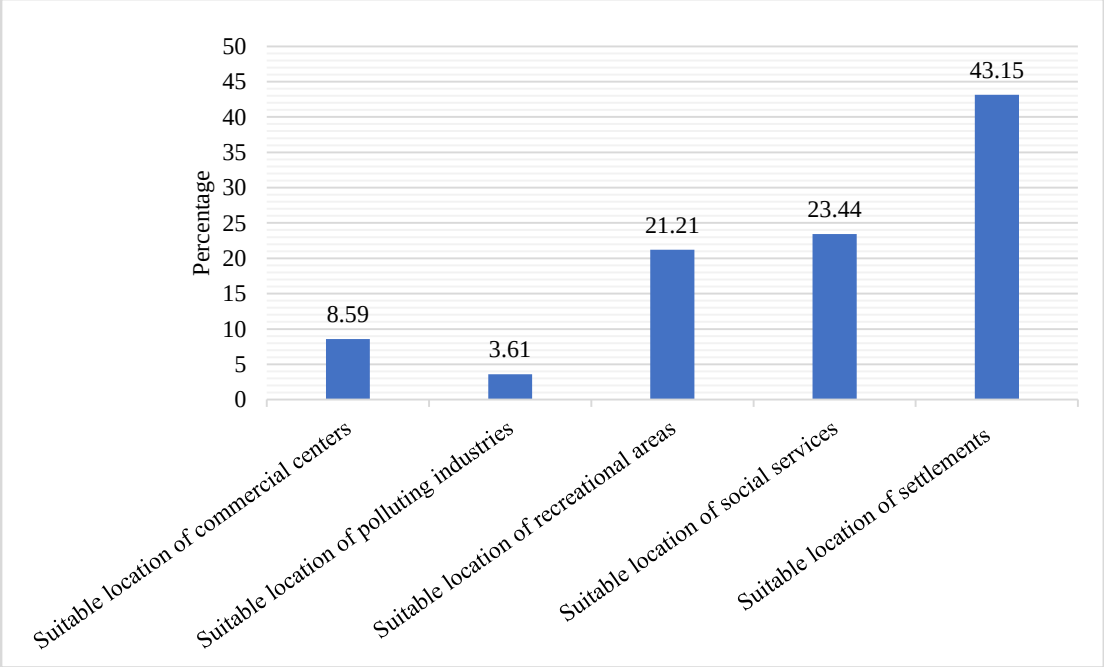

Figure 4:40 Mitigation measures implemented to land use planning & zoning (suitability).
Source: by the author (2023).

Figure 4:40 illustrates the level of mitigation measures in land use planning and zoning related to suitability. Suitability related to settlement developments relatively a preferred location (43%). However, the suitability of polluting industries (3.61%) and commercial centers were developed in inappropriate areas and without a proper impact assessment in 'Debre Birhan' city.

Transportation planning

The mitigation measures to improve social problems related transportation planning presented as follows.

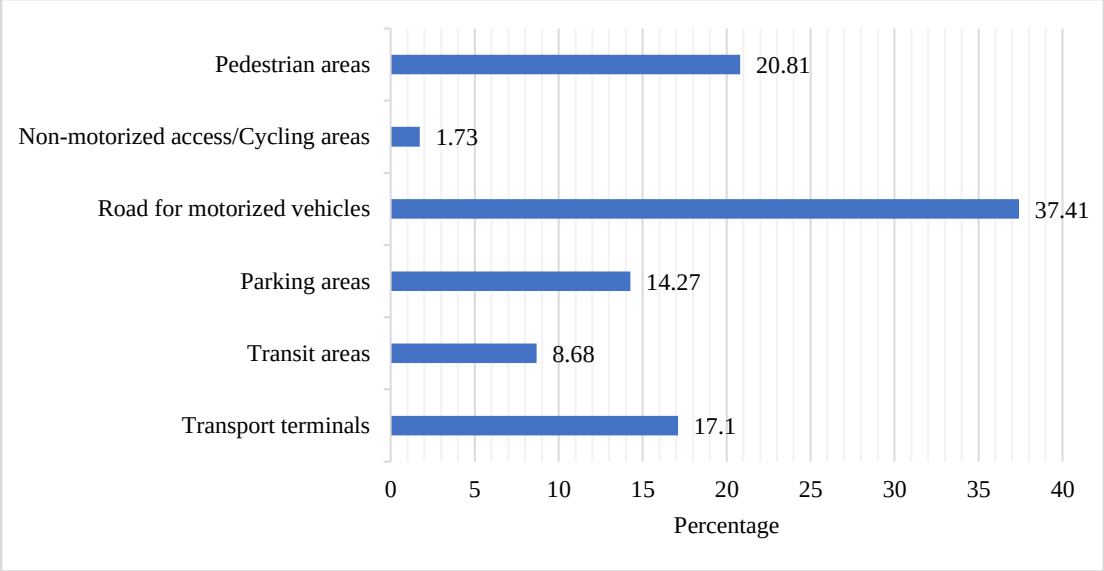

Figure 4:41 Mitigation measures implemented to transportation planning.
Source: Author (2023).

Based on the Figure 4:41, access roads for motorized vehicles is the most implemented measurement tools relative to others having 37%. Access to non-motorized/cycling area (1.73%) is the least implemented mitigation measures in the city. However, sustainable development concepts, such as smart city developments, are now associated with accessibility, encouraging the development of pedestrian and bicycle spaces. As a result, development practices of 'Debre Birhan' city has a limitation on the implementation of these concepts.

Control rapid land cover changes

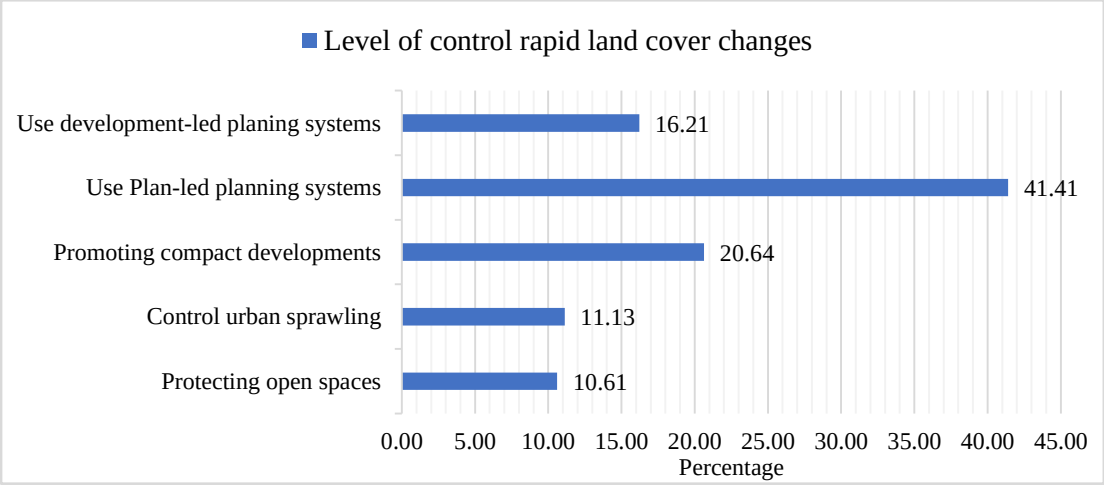

Figure 4:42 Mitigation measures implemented to control land cover changes.
Source: Author's computation (2023).

Figure 4:42 puts using of plan-led systems (41%) is the most implemented environmental management tools whereas, protecting open spaces (10.61%) and control urban sprawling (11.3%) were the least implemented management mechanisms. This implies little attention on environmental protection in the development practices of the city.

4.1.2.4. Environmental management tools implemented for institutional factors

This section of the paper presents the Management tools implemented to mitigate the institutional challenges in the city. The variables considered are as seen in the literature review section of the paper.

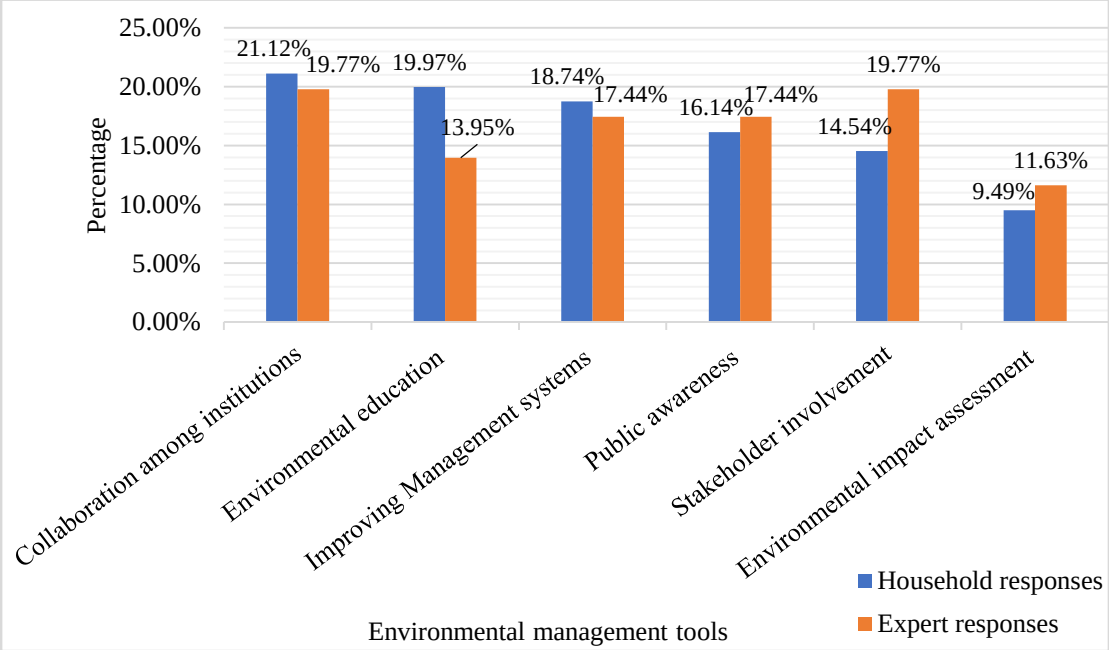

Figure 4:43 Environmental management tools implemented in the city.
Source: Author (2023).

Figure 4:43 indicates collaboration among concerned institutions, environmental education and improving Management systems were the most implemented management tools with respective values of 21%, 20% and 19% from household perceptions. Whereas, stakeholder involvement (20%), collaboration among concerned institutions (20%), improving Management systems (17%) and public awareness (17%) are the most implemented mitigation measures by the city in disclosure of tasks, alignment of tasks, objective setting and shared planning.

Environmental impact assessment is the least implemented environmental management tools in the city from both the households and experts perception. Based on Figure 4:43, the mitigation measures implemented in the city almost have similar results. This result implies reliability of the variables.

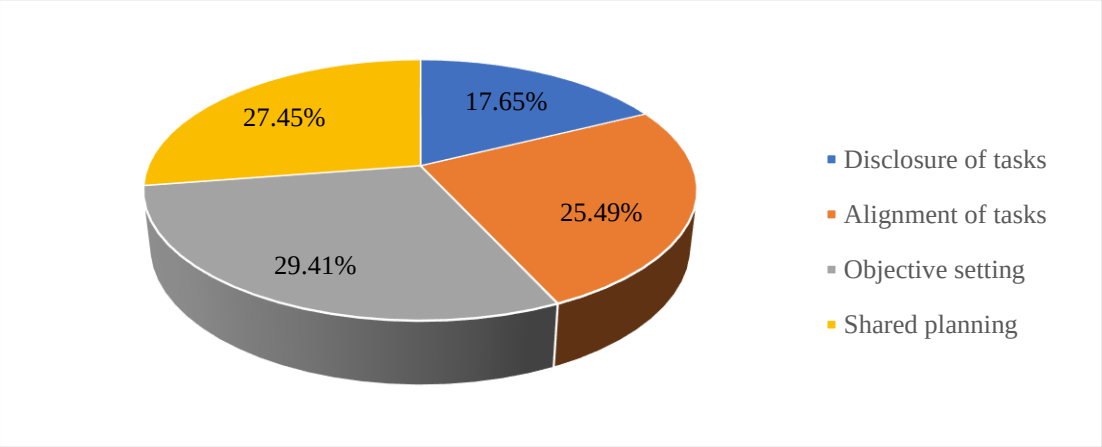

Figure 4:44 Mitigation measures implemented to control institutional factors.
Source: author (2023).

Figure 4:44 presents four major institutional working areas in 'Debre Birhan' city. Consequently, the Figure ranks objective setting first, shared planning second, and alignment of tasks third and disclosure of tasks last, with corresponding response values of 29.41%, 27.45%, 25.49% and 17.65% respectively.

Shared planning

Table 4:20 Implemented mitigation variables in shared planning practices.

No.	Shared planning issues	Responses weight in %
1	Planning new scheme of work between departmental experts and other staffs	45
2	Content preparing in the area of planning expertise	20
3	Department-wide approach for revision	25
4	Proper staff allocation to develop systems	10

Source: author (2023).

Table 4:20 shows four shared planning variables with their percentage value that implemented in 'Debre Birhan' city. Accordingly, planning new scheme of work between departmental experts and staffs takes the highest percentage value of 45%.

Objective setting

Table 4:21 Implemented mitigation variables in objective setting practices.

No.	Objective setting variables	Responses weight in %
1	Improve the institutions Management capability up to departmental level	29.03
2	Increase employees skills and improve performance	25.81
3	Create new and comfortable working environment	19.35
4	Increase the quality of environmental Management practices	25.81

Source: computed by the author (2023).

Table 4:21 illustrates four objective setting variables implemented in 'Debre Birhan' city. Based on the Table, improving the institutions Management capability up to departmental level ranked at the top with the value of 29.03%.

Alignment of tasks

Table 4:22 Implemented mitigation variables in alignment of tasks.

No.	Alignment of tasks	Responses weight in %
1	Configuration and relationship of legal, laws and policies from federal to regional and local levels	33.33
2	Assigning responsibilities from local government into departmental level	20
3	Vertical relationship of institution's task	23.34
4	Alignment of task from departmental level to individual level	23.34

Source: author's computation (2023).

Based on Table 4:22, configuration and relationship of legal, laws and policies from federal to regional and local levels scored the highest value of 33.33%. But both alignment of task from departmental level to individual levels and vertical relationship of institution's task scores at the last with the least value of 23.34% as shown in the Table.

Disclosure of tasks

Table 4:23 Implemented mitigation variables in disclosure of tasks.

No.	Disclosure of tasks	Responses weight in %
1	Proper distribution of tasks in the institution according to the professionals skill	38.89
2	Balanced task division	33.33
3	Consistent task division	16.67
4	Clear division of tasks	11.11

Source: author's computation (2023).

Table 4:23 puts proper distribution of tasks in the institution according to the professionals' skill top with respective value of 38.89% and clear division of tasks with the value 11.11%.

Most of local government offices in 'Debre Birhan' city are collaborated in decision-making processes. The collaboration are takes placed in plan preparation, plan implementation, and research and capacity building.

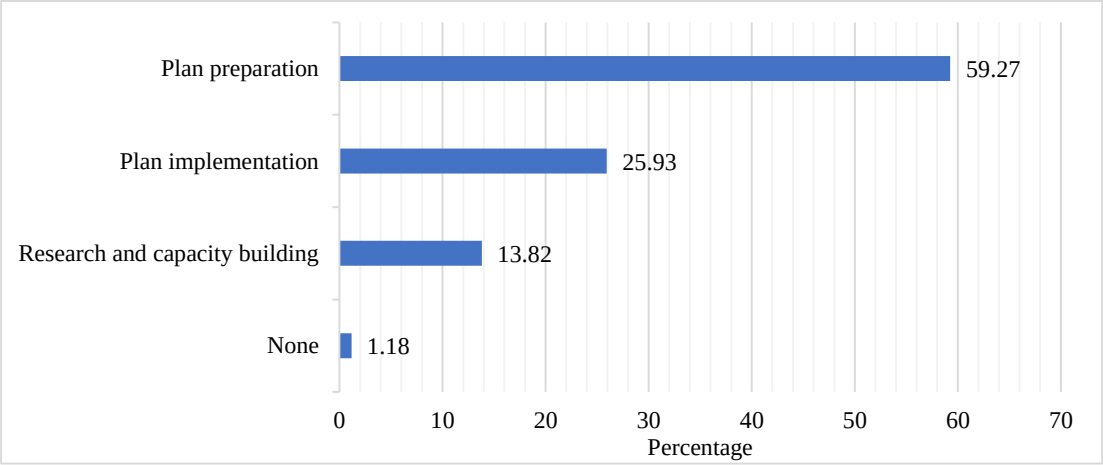

Figure 4:45 Level of collaboration among offices of Debre Birhan city.
Source: Author (2023).

The degree of collaboration among responding local government offices during the decision-making process is depicted in Figure 4:45. The greatest percentage (59.7%) in the Figure is ascribed to teamwork during the plan preparation phases, with plan implementation accounting for the second-highest percentage (25.93%). Additionally, with a value of 13.82% in the Figure, research and capacity-building programs are rated last.

4.1.3. Perception of experts on Resilience thinking applied to the environmental Management practices of the city

This section analyzes the perception of key informants on Resilience thinking and the principles applied to the environmental Management practices of 'Debre Birhan' city.

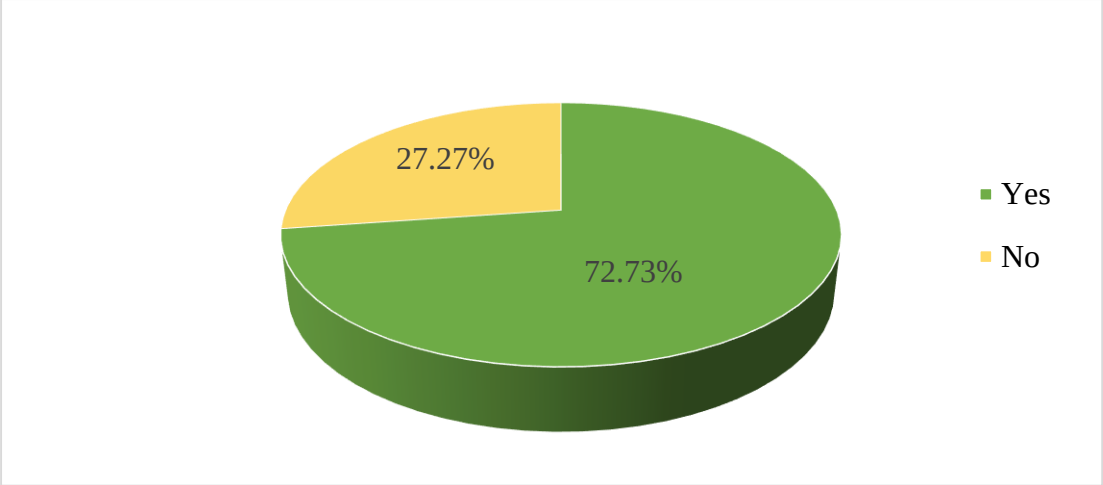

Figure 4:46 Views of experts towards Resilience thinking.
Source: author's computation (2023).

Most of the experts (72.73%) in the 'Debre Birhan' city sector are aware of resilience. Only 27.27% of experts are not familiar with the concept (Figure 4:46).

The six resilience principles, diversity, modularity, redundancy, robustness, interdependence, and integration, as applied in environmental management practices in the city of 'Debre Birhan', are examined as follows.

Table 4:24 Resilience attributes seen in environmental Management practices of Debre Birhan city.

No.	Resilience attributes	Responses weight in %
1	Diversity	25.79
2	Modularity	18.71
3	Redundancy	16.83
4	Robustness	13.22
5	Interdependence	12.97
6	Integration	12.48
	Total	**100.00**

Source: author (2023)

Table 4:24 illustrates the resilience attributes seen the management practice of 'Debre Birhan' city based on the experts opinion. Based on Table 4:24, diversity (25.79%) is the most applied resilience principles in land use planning. Whereas, integration among institutions the least applied principles with limited public participation.

Diversity

The diversity attributes so far applied to the environmental management practice of the city are ecological diversity, urban land use and road hierarchy, and diversity of service centers Figure 4:47.

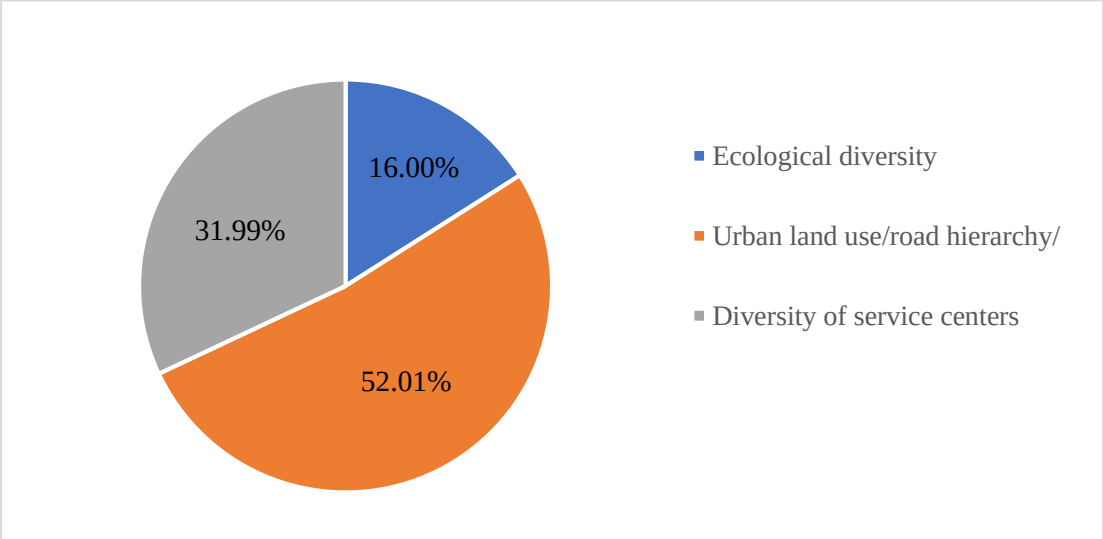

Figure 4:47 Condition of diversity seen in environmental management practices of Debre Birhan city.

Source: author's computation (2023).

Based on Figure 4:47, urban land use/road hierarchy covers more than half of the conditions in diversity attributes. Ecological diversity is the least variable with the value of around 18%.

Redundancy

Experts in the city evaluates the condition of redundancy in terms of multiple nodes, multiple green and open spaces, multiple forests and multiple road hierarchy applied in the environmental management practices that the city used (Figure 4:48).

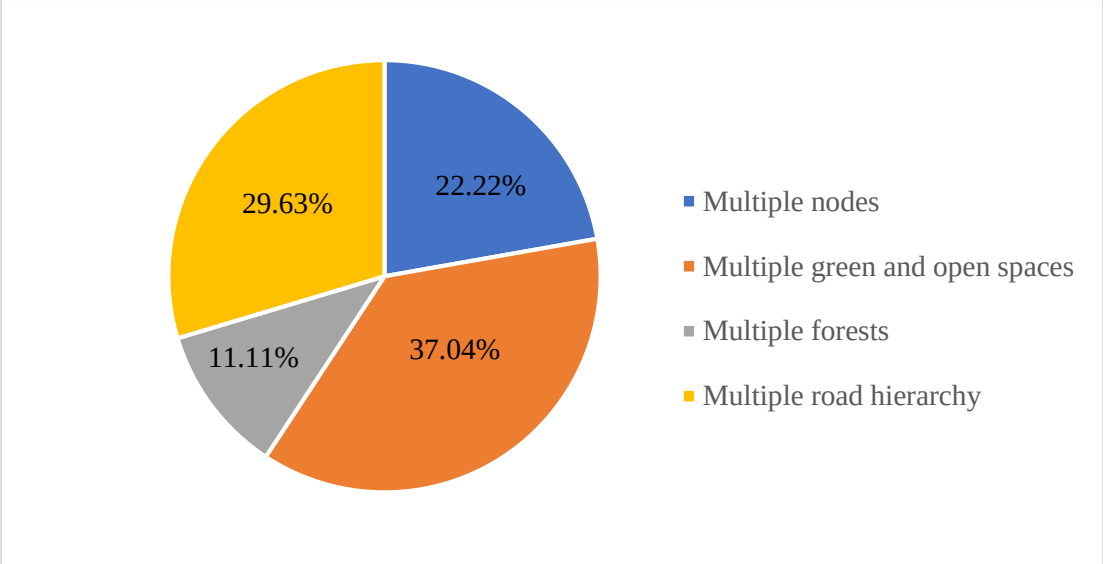

Figure 4:48 Condition of redundancy seen in environmental management practices of Debre Birhan city.
Source: computed by the author (2023).

Redundancy concept is mostly applied using multiple green and open spaces. However, it the least applied in multiple forests and moderately applied using multiple nodes and multiple open spaces (Figure 4:48).

Modularity

Experts were asked to evaluate the condition of modularity in green related aspects and street connectivity in the city (Figure 4:49).

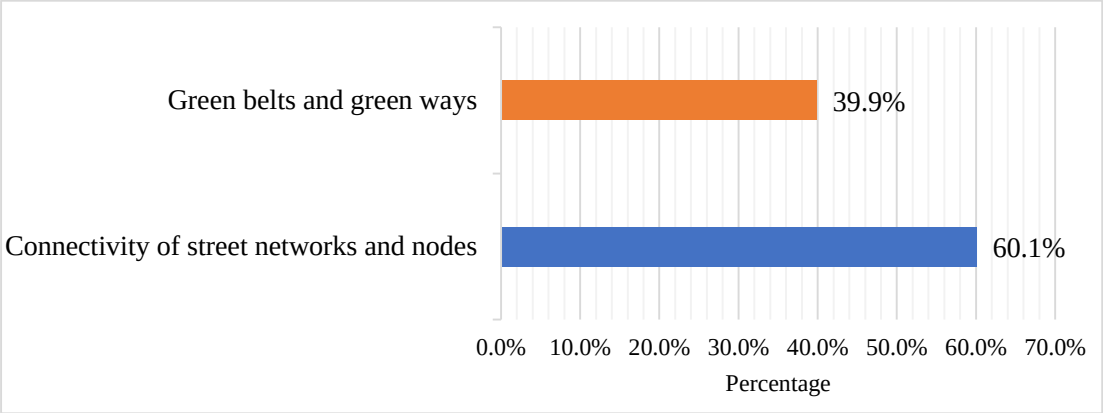

Figure 4:49 Condition of modularity seen in environmental management practices of Debre Birhan city.

Source: author's computation (2023).

As shown Figure 4:49, connectivity of street networks and nodes ranked first, and green belts and green ways at the second position with 60.1% and 39.9% values respectively. Modularity is applied in road related physical variables rather than green related environmental variables.

Robustness

Robustness principle were evaluated based on the sustainability of urban transportation network and sustainability of urban form variables (Figure 4:50).

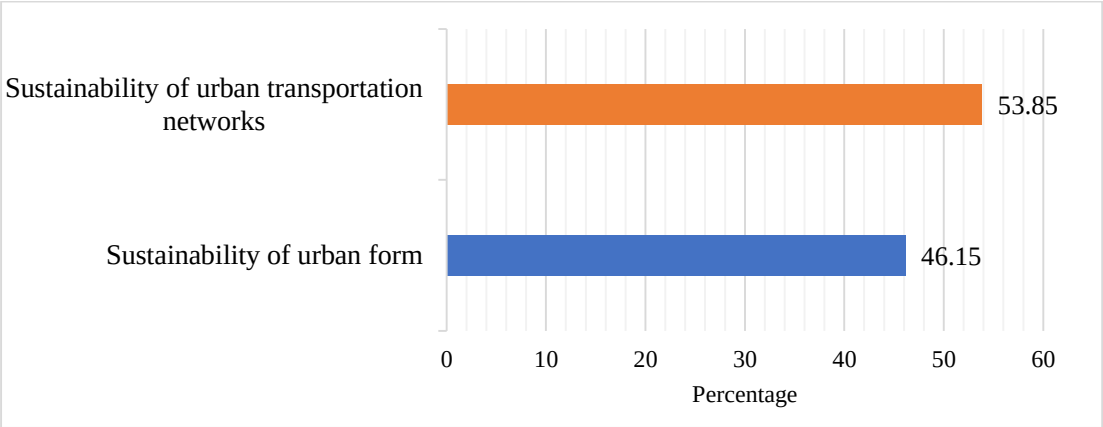

Figure 4:50 Condition of robustness seen in environmental management practices of Debre Birhan city. Source: author's computation (2023).

Figure 4:50 indicates that sustainability of urban transportation networks (53.85%) ranked at first and sustainability of urban form (46.15%) at second. This shows robustness principle is mostly applied in sustainability of transportation networks in the city.

Interdependence

The other resilience principle is principle is interdependence in the evaluation of its application in the environmental management practice of the 'Debre Birhan' city (Figure 4:51).

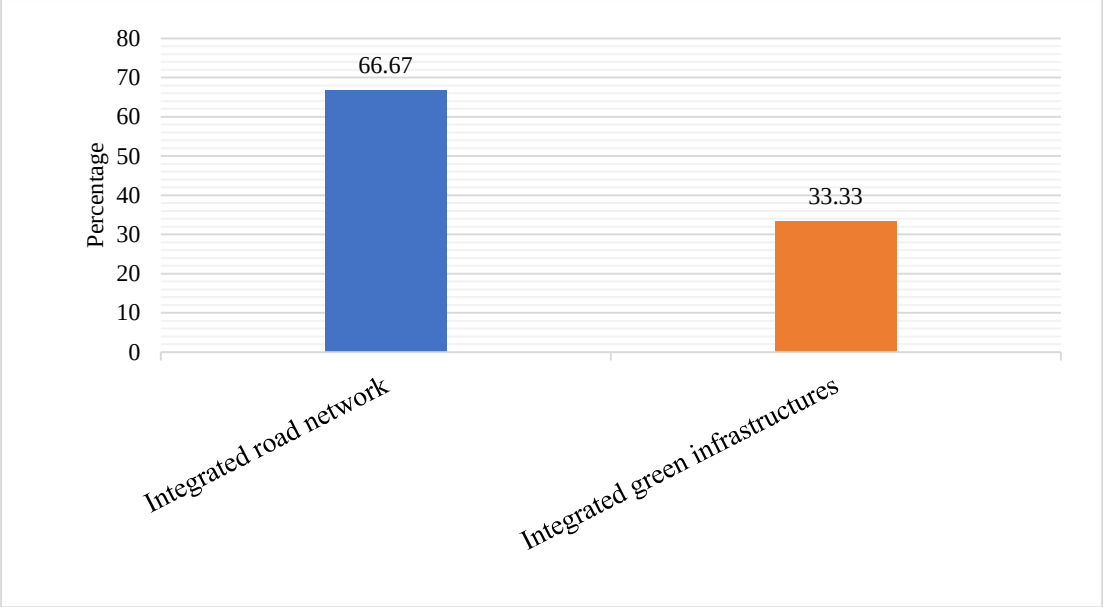

Figure 4:51 Condition of interdependence seen in environmental management practices of Debre Birhan city.
Source: author's computation (2023).

Figure 4:51 illustrates that integrated road network and integrated green infrastructures ranked at first and second with respective values of 66.67% and 33.33%. This principle also mostly applied road related variables in the city.

Integration

The last principle to evaluate the extent of resilience application is integration. Integration is the least applied resilience principle based on experts perception (Table 4:24). Only public participation in decision making process accounts the whole value in integration.

4.2. Discussions

The urban areas of SSA are home to many grave issues related to the environment (McGranahan et al., 2024). Secondary cities are where the majority of environmental issues occur (Sakketa, 2023). According to the Cities Alliance report, comparable environmental problems have been found in Ethiopia's secondary cities (Roberts, 2014).

Accordingly, this paper take account of fourteen environmental, eleven physical, nine social and six institutional urban challenges in 'Debre Birhan' city. The Pareto and BWM of analysis used to prioritize the environmental, physical and social as well as institutional factors in 'Debre Birhan' city.

Poor Management of both liquid and solid waste, resulted from a range of ineffective disposal facilities to non-existent collection systems and affects direct human health and urban environments (Gutberlet & Uddin, 2018). Both poor solid and liquid waste Management in cities can also create urban pollution (Ouattara et al., 2023). The efficiency of environmental Management practices concerning waste in developing cities is negatively affected by a lack of infrastructure for waste operations, such as waste collection bins, access to waste bins, and vehicles (Abubakar et al., 2022).

Similarly, inadequate waste Management practices in 'Debre Birhan' city affect drainage networks and lead to water and soil pollution. Consequently, the primary causes of flooding and urban pollution in the city are open ditches, clogging of drainages and uncontrolled waste disposal sites. Physical elements relating to waste Management in the city also include polluted riverbanks, especially in lower level of land, from poor disposal practices and ineffective trash collection bins.

In cities, a lack of designated public and on-street toilets promotes open feces and urination (Adjibolosoo et al., 2020). In this regard, findings of a household study indicate that open urination is a result of the city's lack of toilets. Similarly, basic demand for toilets is not being met by cities in SSA (Ohwo & Agusomu, 2018). Shortage of hygiene services in 'Debre Birhan' city contributes for health problems, land and water pollution. Urban pollution and health problems are caused by inadequate water and sanitation systems in SSA cities (Bishoge, 2021).

In line with this, Darkwah (2016) and Sujathamma (2019) also identified environmental problems such as flooding, destruction of green spaces, inadequate sanitation, land pollution, and water pollution. Deterioration of green spaces (Kovacs et al., 2017; Kim, Lee & Sung, 2016) and inadequate drainage systems (Jemberie, Melesse & Abate , 2023) results surface flooding in cities.

Green infrastructure and open spaces in general, including urban parks, green belts, trees, landscape services and playgrounds, are important in creating sustainable and integrative development and resilient cities (Breed et al., 2023; Kimengsi & Fogwe, 2017; Maranga, 2021 & O'Farrell et al., 2019;). However, 'Debre Birhan' city lacks enough green infrastructure, though, there are some parks, reserved forests, buffers along rivers and open spaces for recreation. The quality of life in urban areas is also negatively impacted by inadequate green infrastructure (Sangwan et al., 2022).

Furthermore, loss of urban agriculture, is one of the environmental problems and part of secondary cities, which increases surface flooding and reduces green area cover (Dubbeling, van Veenhuizen & Halliday, 2019). In this case, too, key informant comments indicate that horizontal city growth impacts sensitive areas and leads to environmental degradation, which includes loss of urban agriculture, biodiversity loss, and soil erosion. Consequently, urban agriculture is dwindling in the city, replaced by industrial and housing developments, and there are few urban agricultural activities.

Poor road infrastructure, such as inadequate street lighting, inaccessible for disables, insufficient road connectivity, and narrow road widths, negatively impacted both car and pedestrian accessibility in 'Debre Birhan' city. The absence of alternative routes and dead end roads cause poor connectivity in urban areas (van Eldijk et al., 2020).

Narrow and poor road conditions, low road coverage and improper road hierarchy are problems in secondary cities of SSA (Gwilliam et al., 2008). In this context, unpaved and gravel road types, deteriorated road surfaces, roads with no drainage, roads with potholes, road with debris, poor road hierarchy at the center and small road coverage are the major physical challenges in the city. Surface deterioration of roads from low to high severity in cities has effects on accessibility issues (Golov et al., 2022).

Furthermore, lack of physical infrastructure related to roads in secondary cities makes the mobility difficult and implies high transportation costs (Felixa & Mohareb, 2017). Lack of affordable roads in these cities provides unfair and unsustainable transport options. Similar to this, the unavailability of affordable roads to newly developed settlements and peripheral manufacturing sites results in additional costs and travel times within the city.

Road amenities like stations, street furniture, refreshments and toilets in the city centers and sub centers have vital role in improving urban livability and quality by providing physical and social facilities (Rui & Othengrafen, 2023). However, secondary cities in SSA lacks proper road amenities in general(Hove, Ngwerume & Muchemwa, 2013). Similarly, the 'Debre Birhan' city roadways are devoid of street furniture, transit hubs, and recreational areas, in line with the responses of key informants and households.

In addition to road amenities, ineffective drainage systems also affects environmental Management systems in cities by creating surface flooding, pollution and amenity issues (Bibi, Reddythta & Kebebew, 2023). Poor drainage systems in 'Debre Birhan' city is a factor for erosion and infrastructure destruction.

Urban environmental Management approaches also need to consider social aspects as important components (Ezeudu & Chukwudubem, 2023). Social variables are very important for sustainable development in cities (Prajapati, 2021). These social variables has an impact on urban morphology, spatial structures, services and transportation conditions.

Access problems to educational and health services, religious institutions, recreational space and agricultural lands are the social problems in 'Debre Birhan' city. Simultaneously, cities experienced issues with access to green and recreational places (Ridgley et al., 2020) and educational and health services (O'Donnell et al., 2016). Issues with urban traffic Management are linked to transportation systems and the city's spatial structure and urban forms. In line with this, the main transportation issues identified include limited car access, long travel distances, traffic congestion, accidents and parking challenges in cities.

In addition to transportation, locational preferences of urban activities and services in the city affects the environmental Management practices to achieve sustainable developments. Likewise, locational compatibility issues of industry sites, green and open spaces, market and service centers a cause for accessibility, urban pollution, land degradation, and transportation problems in 'Debre Birhan' city.

Most urban areas face challenges related to incompatible land uses in their central business districts including disorganized chaos and traffic jams (Bergstrom, Goetz &

Shortle, 2013). These problem categories are prevalent in most cities, where a wide range of activities, including residential, commercial, and service-related activities and as well as industrial and recreational areas.

In contrast, the center, sub centers, and peripheral areas of 'Debre Birhan' city have incompatible land uses. These land use incompatibility challenges in the city include industries with settlements, industries with commercial, industries with urban agriculture, river banks with industries and urban agriculture with river banks.

Numerous social issues, including social distress, criminality, urban slums, over crowdedness, and access to essential services, have been linked to informal settlements. Similarly, informal settlement developments along river banks, open spaces and the peri- urban areas of 'Debre Birhan' city creates access problems and security issues.

Land use/land cover change is also a serious problem and causes environmental degradation, land degradation and depletion of biodiversity in rapidly growing cities (Le Yin et al., 2022). Land use/land cover change in SSA show an increasing trend of conversion of natural land cover into arable land (Näschen et al., 2019). The major land use/land cover types in SSA include agriculture, forest, grassland, wetland, urban, and others such as bare land, water and sparse vegetation (Dahhani et al., 2023).

In the same vein, 'Debre Birhan' city's increasing built-up areas, disruption of productive land, urban encroachment, and loss of green spaces are all results of fast urbanization. In recent decades, the majority of land covers, including agricultural land, vegetation covers, forests, and grassland areas, have transformed into built-up areas and desolate areas on the outskirts of the city.

Local governments in SSA are unable to finance the most basic infrastructures for social and economic development due to the uncontrolled expansion of cities, which is causing a rapid increase in the number of people living in urban settlements without established urban governance structures (Satterthwaite, 2016). Similarly, the fast urbanization of 'Debre Birhan' city resulted in poor infrastructure, poorly accessible roads, and land use related concerns.

Urban planning, the creation of green spaces, and compact and mixed development methods are some tools used to mitigate urban social issues (Fan et al., 2019). Land use planning and zoning, green buffers, river bank rehabilitation, waste Management, and drainage provisions are Management tools that 'Debre Birhan' city is attempting to utilize to reduce social issues.

Successful urban environmental Management also requires an assessment of institutional dimensions in addition to environmental and social considerations (Patterson & Huitema, 2019; Spangenberg, 2007). Improving coordination between government offices and stakeholders throughout decision-making processes, as well as promoting strong urban governance and the execution of environmental policies, requires successful institutional structures (Teebken et al., 2022).

Effective decision-making procedures with a focus on sustainability are found to be significantly facilitated by overcoming institutional constraints (Broto, 2017). Building institutional capacity is therefore a prerequisite for setting and carrying out sustainable initiatives (Polk, 2011) and currently being discussed in several global urban policy and planning contexts (Rincón et al., 2021).

However, institutional constraints are causing issues for the local governments of developing countries (Dziva & Kabonga, 2021). These factors include a lack of strong institutional frameworks, public involvement, and coordination (Castañer & Oliveira, 2020). Apart from these issues, 'Debre Birhan' city also has poor Management systems, limited environmental assessment, low public awareness, and inadequate environmental education.

The above institutional problems are presented in shared planning, objective setting, alignment of tasks and disclosure of tasks in their environmental Management practices of 'Debre Birhan' city. Lack of public participation in decision-making processes and knowledge transfer among the professionals as well as inter-sectoral levels remains the major institutional problems in the city.

Growing cities in developing countries implementing to mitigate environmental factors affecting their management practices (Mukwarami & van der Poll, Huibrecht M., 2024). Similarly, 'Debre Birhan' city is trying to implement to mitigate environmental

factors. accordingly, promoting urban agriculture, increasing green cover, waste management techniques flood protection and control are environmental management tools implemented at lower levels than in other cities in 'Debre Birhan' city.

'Debre Birhan' city also implementing mitigation measures related to road conditions. Improving road connectivity and road hierarchy in the city is implemented to offset physical variables that affecting environmental management practices. Parallel to this other cities are also works on improving the existing road conditions.

Resilience thinking provides principles for environmental management practices of urban areas for their long-term sustainability. These principles can applied in waste management practices, green infrastructure developments, policy documents preparation and implementation in international, regional and local scales.

The expert's perception on resilience thinking in 'Debre Birhan' city is positive; they are willing, and some resilience principles are applied in their environmental management practices. Diversity of land uses, redundancy of service and market centers, connectivity of street networks and nodes, and integration of among some local government institutions in decision-making processes.

4.2.1 Implication of the study

This study has implications for other developing-country cities, which should focus on addressing the factors affecting environmental management practices, adopt and revise policies related to environmental management, and accept resilience-focused thinking. The results of this research will provide some contributions and point out resilience-based planning strategies that can be implemented to mitigate urban challenges in the physical, social, institutional, and environmental domains of environmental management practices.

CHAPTER FIVE: ENVIRONMENTAL MANAGEMENT STRATEGIES

5.1. Resilience-based environmental management strategies

Resilience-based environmental management strategies involves adaptive management, biodiversity conservation, green infrastructure and community engagement. Consequently, waste management, green cover, land use, and institutional variables are all addressed proactively in 'Debre Birhan' city using recommended environmental management strategies.

Concerning waste management, formulating and implementing integrated waste management systems with help of resilience principles including, diversified waste management options, circular economy approaches, community-based waste management approaches, using redundant waste treatment facilities or multiple disposal options, redundant waste collection bins, flexible and scalable waste management systems. Integrated waste management techniques basically includes source reduction, reuse, recycling, composting, energy recovery and landfill management.

In the context of green infrastructure development, creating interconnected networks of green infrastructure, such as parks, greenways, and urban forests, enhances resilience by facilitating ecological connectivity and promoting biodiversity. Redundant and diversified urban greening development also important for sustainability of cities. Adopting these green development initiatives also used for water conservation, climate regulation. Promoting urban agriculture using agro-ecological practices increases the greening aspects in the city.

Regarding land use compatibility, minimizing conflict of different land uses by incorporating and implementing, monitoring and evaluating proper and suitable land use planning and zoning, redundant and interconnected green buffer techniques in structure plan preparation. Land use planning and zoning are better to prepared with the help of environmental impact assessments and must allow smart growth principles in cities.

Implementing integrated and adaptive governance approaches, promoting cross-sectional collaboration among institutions, investing in capacity-building and training, and public participation in decision-making are essential for addressing complex environmental management challenges in cities.

5.2. Implementation strategies

The resiliency of the city shall be improved by implementing the following environmental management strategies.

- Applying integrated waste management systems shall be improved using diversified and redundant recycling, reuse, composting methods.
- Redundant waste management system elements including waste transfers stations and waste collection bins shall be carried out.
- The city shall use community-based waste management and ecological sanitation systems.
- Working on multiple and diversified forests and protected areas in and around the periphery of the city for maintaining biodiversity and increasing the capacity of water resources very important.
- Enhancing green cover and open spaces on vacant and other possible areas shall be carried out.
- Promoting urban agriculture shall be promoted and applied in the city.
- Keeping and working on river buffer zones shall be practiced in appropriate design considerations.
- Increasing connectivity, road hierarchy, and standardized road amenities shall be implemented in the city.
- Experienced professionals in structure plan proposal preparation and land use related planning and implementation phases shall be incorporated.
- Serious political commitment on sustainable development practices including public participation and capacity building shall be practiced.

CHAPTER SIX: CONCLUSIONS AND RECOMMENDATIONS

6.1. Conclusions

Resilience thinking is needed for sustainable development in local, national, and international contexts, including in sector-specific development plans, policies, and initiatives. In an urban setting, the general resilience idea helps in identifying issues inside the city and in responding to stressors and shocks to preserve vital services and functions. It has comprehensive approach regarding the environmental, social, economic, physical, and social aspects.

Sustainable environmental management practices of 'Debre Birhan' city is affected by environmental, physical, social and institutional factors. The major factors include; poor waste management problems, limited green and open spaces, loss of agricultural fields, lack of access to social services, land use incompatibility issues, and lack of public and active participation in decision-making processes using empirical data from household and expert perceptions.

Concerning the mitigation measures, this study looks the environmental management tools implemented to offset the environmental, physical, social and institutional problems using empirical data from households and key informants perception in the city. Consequently, it deliberated seven for environmental factors, five for physical, four for social and six environmental management tools implemented for institutional factors.

Top environmental management tools implemented in the city are related to solid waste management, enhancing green cover, road network related variables and public awareness and participation by utilizing empirical data from urban households and experts' perspectives. The current environmental management practices didn’t meet the sustainability development of the city.

Other factors for environmental management practices includes lack of enough experienced expertize about detail urban planning and environmental protections, lack of good working environments, lack of understanding the extent of the problems faced

in the city. In addition to this, low level of political commitments in sustainable development initiatives in the city.

Concerning resilience thinking, the study looks at the resilience principles applied to the environmental management practices of the city. These resilience principles, examined are based on the data provided by experts from 'Debre Birhan' city, are diversity, modularity, redundancy, robustness, interdependence and integration.

Resilience-based environmental management strategies support the processes of sustainable growth of cities, and it is important to integrate environmental management recommendations and the best practices in policy frameworks helping to maintain sustainability and scaling up resiliency of cities. Better political commitment on the policy implementation techniques to practice in the ground is very crucial.

In general, formulating surprising objective setting and better plan preparation does not give an assurance to achieve the predetermined goals rather it is supplemented by proper alignment, disclosure and implementation of tasks and working on capacity buildings for professional and other concerning institutions in local government. This study has implications for urban uncertainties and challenges on the growing cities in the global south.

6.2. Recommendations

Working towards sustainability requires collective action, creativity, and a commitment to striking a balance between the needs of the environment, society, and the economy for all. It is crucial for safeguarding our planet, enhancing quality of life, and guaranteeing sustainability. Consequently, the most up-to-date and effective environmental management techniques should be adopted, together with creative and practical methods to deal with pressing environmental management issues in urban areas.

This study advises decision-makers to include resilience thinking in environmental management practices to improve sustainability initiatives' and long-term viability. Formulating and implementing resilience-based environmental management strategies focuses building systems to mitigate and withstand from urban challenges.

Therefore, the recommended environmental management tools in the city include: protecting diversity and redundancy of green spaces and functional groups, maintaining different road networks and hierarchies, maintain green infrastructure concept and ecological connectivity, maintain and enhance multiple forests, integrated road network, environmental education or training for the community, creating public awareness and including the community and creating public participation platforms in the city.

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Annexes

Annex I: Publishable article

INVESTIGATING ENVIRONMENTAL MANAGEMENT PRACTICES IN SECONDARY CITIES OF ETHIOPIA: EVIDENCE FROM DEBRE-BIRHAN CITY, AMHARA REGIONAL STATE.

Current research advocates that studies in cities of developing countries need special attention related to environmental management practices. Accordingly, this study aims to investigate the variables affecting environmental management practices based on household perceptions of the experts on resilience thinking applied to environmental management practices of Debre Birhan City. Data were collected through questionnaires, and site observations. The results are analyzed using Pareto and Best Worst Method (BWM. The study used random sampling techniques. Three hundred ninety five households were contacted to collect data for the study. Accordingly, the result revealed eleven environmental, nine physical, ten social, and four institutional vital variables in the city. The BWM weight values rank waste management and land expropriation (0.5625) first, urban planning elements (0.3125) second, and urban green and recreation (0.1250) third based on households. The five physical factors ranked included lack of toilet facilities, poor road lighting systems, narrow sidewalks for wheelchairs, narrow-width roads, and lack of road connectivity at the top. The city's most important critical social variables are access-related and polluted industriesThe study, therefore, recommends the enforced application of resilience principles into environmental management tools in environmental management policy documents, the increase in the application of mainstream resilience principles into environmental management tools in environmental management policy documents, and the increased implementation to improve sustainability in the city.

Keywords: *Debre Birhan; Resilience thinking; Environmental Management practices; Environmental Management tools; Secondary city;*

1. Introduction

In the last ten years, urban Resilience has drawn a lot more attention in academic and political domains. The concept of Resilience, which originated in ecology and system dynamics in particular, is currently applied in a wide range of fields, including disaster Management, adaptive Management, biodiversity Management, risk governance, spatial planning, and many more (Bahadur, Tanner & Pichon, 2016).

Resilience is a key concept in the policies and practices of many cities and organizations (Woodruff et al., 2021; Wardekker, 2018; Wardekker, 2018). International agreements such as the EU Urban Agenda, UN Habitat III, Sustainable Development Goals, UNFCC Paris Agreement, and Sendai Framework for Disaster Risk Reduction, have also taken on the task of integrating the concept of Resilience into societies' fabric and ensuring its widespread adoption (Wang, Li & Li, 2021; ARUP, 2015).

Resilience is a crucial quality of complex systems, and in cities, it can be interpreted as the capacity to sustain both environmental and human activities over the long term (OECD, 2014). Resilience in urbanizing regions depends on various biophysical, socioeconomic, and urban development stages; infrastructure significantly impacts a city’s Resilience and its surrounding region (Elmqvist et al., 2018).

Urban growth is interrelated to the three dimensions of sustainable development: social, economic, and environmental (UN ESCAP, 2015). Problems associated with urbanization include high population density, poor infrastructure, lack of cheap housing, flooding, pollution, the development of slums, crime, traffic congestion, and poverty (Lumun & Edwe, 2019).

Urbanization also alters the biophysical structure of the landscape (Grimm et al. , 2008), which impacts biodiversity change both directly within cities due to changing habitat quality and connectivity brought on by growing built environments (UNEP & UN-Habitat, 2005), as well as indirectly at much larger scales due to trade demands for food and resources (Elmqvist, Zipperer & Güneralp, 2015; Ke et al., 2018).

In urban areas, it is unusual for a city to face just one kind of difficulty at once. Instead, a mix of acute shocks and long-term pressures is what cities must deal with (UNDP, 2020). Chronic pressures that gradually erode a community's fabric, such as frequent flooding, high unemployment, a lack of social safety nets, and unequal public transit systems, amplify the effects of severe shocks (Fahlberg et al., 2020).

In light of both the favorable and unfavorable social, economic, political, cultural, and environmental repercussions of urbanization (Mutuku, 2018), and the existence of challenging problems makes it seems as though sustainability in urban development in developing countries cannot be realized (Sakka, 2016). Large agglomerations, a lack of institutional capacity, and improper urban planning are some obstacles to urban sustainability in developing countries (UN , 2012).

The environmental Management practices in SSA countries have low internalization of ISO standards due to the high power distance (low power of action) of ISO Management standards and the role of orality such as poorly formalized interactions between employees, in the implementation of ISO 14001 certifiable voluntary standard (Tene, Boiral & Heras-Saizarbitoria, 2020).

The research gap regarding inadequate environmental disclosure in the research on urban environmental Management practices in Sub-Saharan Africa (SSA) need further study. The uncertain importance of environmental Management tools and Resilience in sustainable development integration, conceptual and methodological frameworks for data collection, and governance knowledge gaps must be better understood (Jabbarzadeh, Fahimnia & Sabouhi, 2017).

The aim of this paper is to fill the gap is by determining the environmental, physical, social and institutional variables affecting the environmental management practices of secondary cities of Ethiopia using the household perception of 'Debre Birhan' city.

2. Literature review

2.1 Environmental and physical variables

The most common environmental challenges that need to be addressed as a priority in cities in developing countries are water, and soil pollution; flooding; desertification; a

lack of a waste management system; untreated and contaminated areas; and inefficient infrastructure, ecosystem destruction, and a reduction in green spaces (Imuraa et al., 2005). The most environmental and physical variables are summarized in Table 1. Significant environmental and physical variables affecting urban environmental management practicesTable 1.

Table 1. Significant environmental and physical variables affecting urban environmental management practices

Environmental variables	References	Physical variables	References
Waste management problem • Solid waste management • Liquid waste management	Victoire et al. (2020) & Abubakar et al. (2022) Aneesa, Arathi & Geetha (2021)	Lack of toilet	(Burgess, 2016)
Lack of green and open spaces • Lack of forests • Lack of gardens • Lack of playgrounds • Lack of parks • Lack of squares • Lack of plazas • Lack of buffer zones	Ferreira et al. (2023) Clarke et al. (2019) & Schwarz et al. (2016) Katsavounidou (2021) González et al. (2023) & Loughran (2020) Maslovskaya (2019) Kelbaugh (2014) Petrova et al. (2022) & Al Mamun & Kim (2020)	Road related problems • Lack of road connectivity • Narrow width roads • Lack of road hierarchy • Lack of road amenities • Surface deterioration of roads • Narrow sidewalks for wheelchairs • Poor road lighting systems	Saikia & Kar (2023) Makori & Kitosi (2023) Valença, Moura & Morais (2021) Gaigne et al. (2017) Kuleno & Lera (2020) Hatzakis, Alčiauskaitė & König (2024) Perkins et al. (2015)

Pollution • Water pollution • Land pollution	Singh, Andaluri & Pandey (2022), Vallero & Vallero (2019)	Lack of efficient waste collection bins	Rossit, D. G., & Nesmachnow, S. (2022) Leeabai et al. (2019)
Loss of agricultural fields	Muchelo (2017)	Pollution of river banks	Mondal & Tripathy (2020)
Surface flooding	Cea & Costabile (2022)	Poor drainage systems	Francisco et al. (2023)
Water and wind erosion	Tuo et al., (2023) & Yang et al. (2023)		

2.2 Social and institutional variables

Social factors create a challenge to environmental Management systems and also impacts on sustainable development in an urbanizing world (Friel et al., 2011; Mahzun et al., 2020). These social issues include land use related problems (Cengiz, 2013), rapid land cover change (Vadrevu et al., 2015), access to social services and amenities (Cissé, 2022; Colombo et al., 2023), informal settlements (Jean-Baptiste et al., 2018) and urban expansion (Arku & Marais, 2021).

On the other hand, urban sprawl poses its own problems on environmental Management systems in urban development (Shao et al., 2021). Its impact in cities include environmental, physical, social and administrative aspects (OECD , 2020b).

Severe structural issues of city administrations make impossible to anticipate and plan urban development (Linares, 2003). Poor public participation in policy making processes and lack of collaboration in horizontal institutional structures impacts successful execution in urban environmental Management practices (Ganeshu, Fernando & Keraminiyage, 2023).

Lack of coordination between local government and communities as well as multilevel government sectors also affect the sustainability of environmental management in urban areas (Dawkins et al., 2019).

Table 2. Significant social and institutional variables affecting urban environmental management practices.

Social variables	References	Institutional variables	References
Spatial access related problems • **Access to educational services** • **Access to health services** • **Access to playgrounds** • **Access to religious services** • **Access to urban agricultural fields**	Podawca & Pawłat-Zawrzykraj (2018) Dumedah et al. (2023) Czalczynska-Podolska (2014) Kozma et al. (2023) Meenar (2017)	Lack of community participation in decision making processes	Zanudin, Ngah & Misnan (2019)
Existence of polluted industries	Wu (2020)	Poor management systems	Cities Alliance (2017)
Transportation	Nikiforov (2020) & Mbuzi (2020)	Lack of environmental impact assessment	Ho, Nor-Hisham & Zhao (2020)
Traffic accidents	Cabrera-Arnau, Curiel & Bishop (2020)		
traffic congestion	Mbuzi (2020) & Choudhary et al. (2022)	Lack of public awareness	Odoom et al. (2024)
Compatibility issues • **Land use incompatibility**		Lack of environmental education	Nyika & Mwema (2021)

• **Locational incompatibility**	Ifediora (2019) (Grodach, C., & Martin, D.)		
Land cover change	González-Jaramillo, V. H., & Novelli, A. (2022)	Lack of collaboration	Rubado, M. E. G. H. A. N. (2019)
Informal settlements	Fard (2018)		
Urban expansion & sprawling	Jarah et al. (2019) & Bhatta (2010)		

3. Methods and materials

Ethiopian cities, except Addis Ababa, are secondary cities that participated in the Urban Local Growth Development Project (ULGDP), which focuses on a key economic activity or is defined by a nationally significant piece of infrastructure, such as a special economic zone or a prominent university (Woldeyes & Bisshop, 2015).

However, (USAID , 2020) recently identified secondary cities in Ethiopia with additional criteria of geography, demography, economy, governance, health, education and infrastructure. These cities are namely; Dire Dawa, Harar, Hawassa, Shashemene, Mekelle, Dessie, Kombolcha, Bahir Dar, Adama, Bishoftu, Jijiga, Debre Birhan, Gondar, Jimma, Dilla, Debre Markos.

Debre Birhan city is a regio-politan city with a rapidly growing population, and that is developing into a mix of industrial zones. It is also a place where many displaced people have resided without adequate services. However, the city is currently building a new master plan that incorporates numerous nearby rural areas.

3.1 Description of the study area, Debre Birhan city

Debre Birhan is a city in central Ethiopia and is located in the North Shewa Zone of the Amhara Region, about 130 kilometers northeast of Addis Ababa on the paved highway to Dessie, with latitude and longitude of 9°41′ N 39°32′ E and an elevation of 2,840 meters. It was an early capital of Ethiopia and later, along with 'Ankober' and 'Angolalla', one of the capitals of the kingdom of Shewa (Chisholm, 1911).

Today, Debre Birhan city is the administrative center of the North Shewa Zone of the Amhara Region, and it has nine Kebeles and sixteen newly added rural areas with a total population of 202,227.

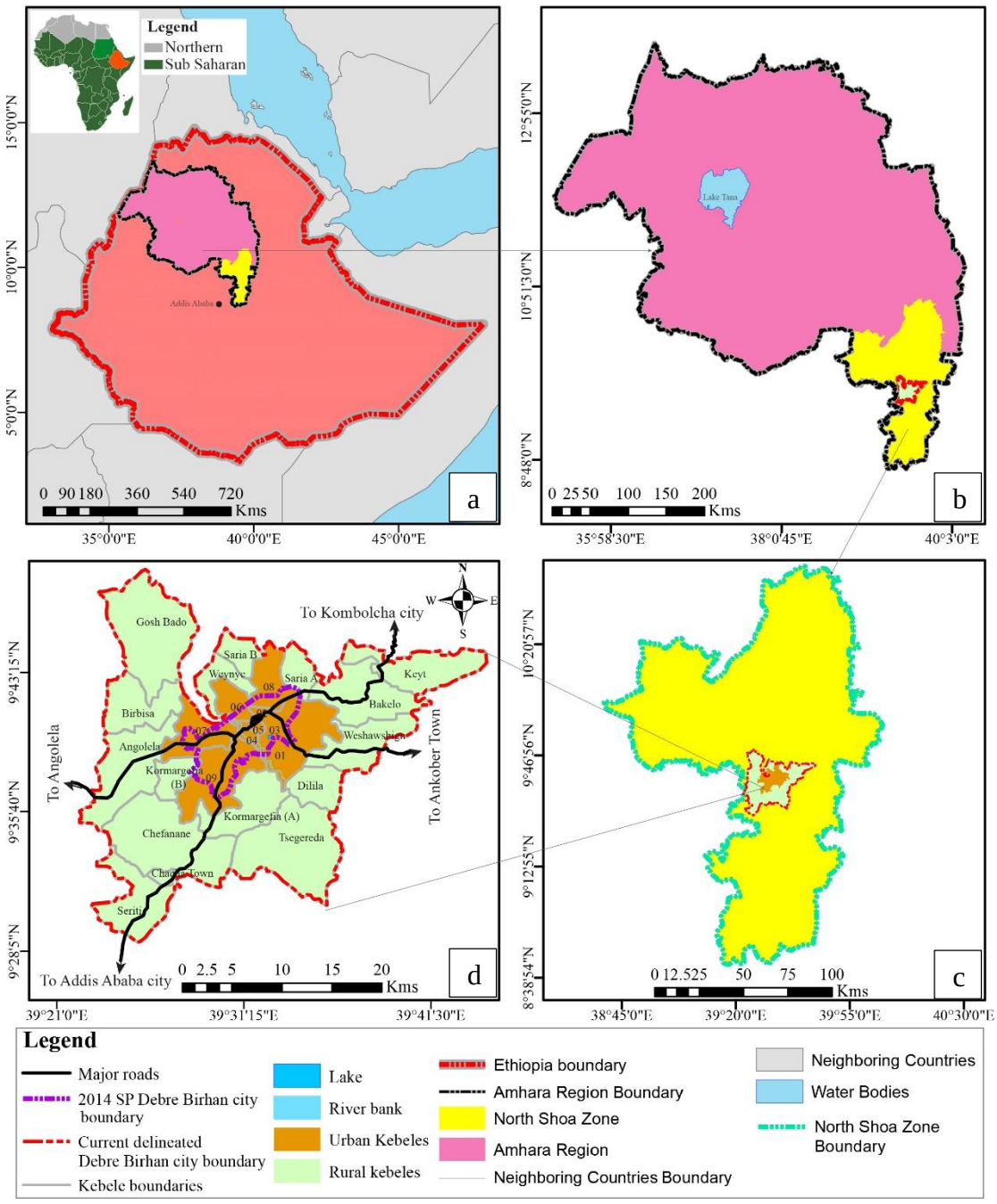

Figure 1. Location map of Ethiopia (a), Amhara region (b), North Shoa zone(c) and Debre Birhan city (d).

Source: Author's Computation from Google Earth Pro using ArcGIS 10.8 based on urban expansion study of Debre Birhan city in 2014 & 2022.

3.2 Data type and sources

Multiple sources of data were used in this study to better understand concerns of urban Resilience and development strategies, as well as to answer research questions through analysis. The primary data were collected from local residents of 'Debre Birhan' city, urban and engineering consulting offices in the city, non-government organizations and local government offices.

Secondary data were obtained from an aerial photograph from Google Earth pro, information from base map of the city, websites, the various policy documents, urban development plans, strategy documents, published and unpublished document, project documents, works of literature and reports.

Households

Sampling is a group of people from a population in order to estimate the characteristics of the entire population (Turner, 2020). Depending on the nature of the study and population size, different methods for choosing individuals are described in the literature (Tripathi, Khatri & Mamde, 2020). Applying one of numerous formulas is one method of calculating sample size (Singh & Masuku, 2014). Hence, researchers created the equations to produce a representative sample for the proportions of a large sample.

Yamane (1967) provides a simplified formula to determine sample sizes from a given population (Singh & Masuku, 2014). According to Birhan Health and Demographic Surveillance System (HDSS) 2019 survey the number of households in 'Debre Birhan city' was 18,933 with totaling 77,766 individuals (Bekele et al., 2022). In similar consideration, this study were used a simplified formula from Yamane (1967) to determine the required sample size at 95% confidence level and 5% margin of error based on this sampling unit. The Yamane formula is expressed as;

$$n = \frac{N}{1 + N(e)^2}$$

Where n = Desired sample size

N = Total number of households lived (i.e., 18,933)

e = Precision of sampling error (it could be 0.10, 0.05 or 0.01 usually 0.05)

$$n = \frac{18{,}933}{1 + 18{,}933(0.05)^2} = 391.72$$

Hence, the total sample households determined for this study were 395.

3.3 Methods of data collection

They are data collection techniques to gather information from direct sources as well as from existing repositories (Kothari, 2017). There are types of data collection methods in research (Mazhar et al., 2021). These types are basically primary and secondary data collection methods (Kabir, 2018). The research has gathered different data types from different sources. In this study the following data collection method and collection instruments were used for both primary and secondary data types.

Methods of data collection for primary data type

Both qualitative and quantitative data collection methods were used in this study.

Site observations: an investigation to describe qualitative data and support findings from the site. The study were need investigations on environmental, physical and social problems as well as practical actions and Management practices in the city at various locations. Recording, capturing photo using camera, Google earth images, recording geographic position from mobile GPS (GPS essentials app) tracking for selected spot points or issues were used during site observation to support the research findings.

The sites visited included residential and commercial areas, public areas (nodes), industrial areas, urban agriculture sites, dominant urban expansion and informal

settlement sites and inner city (Figure 3:2). This method were applied for conducting for current drainage condition, river bank condition, waste Management systems, road condition in terms of accessibility, surface material and other amenities, public spaces, and vegetation covers using existing base map of 'Debre Birhan' city.

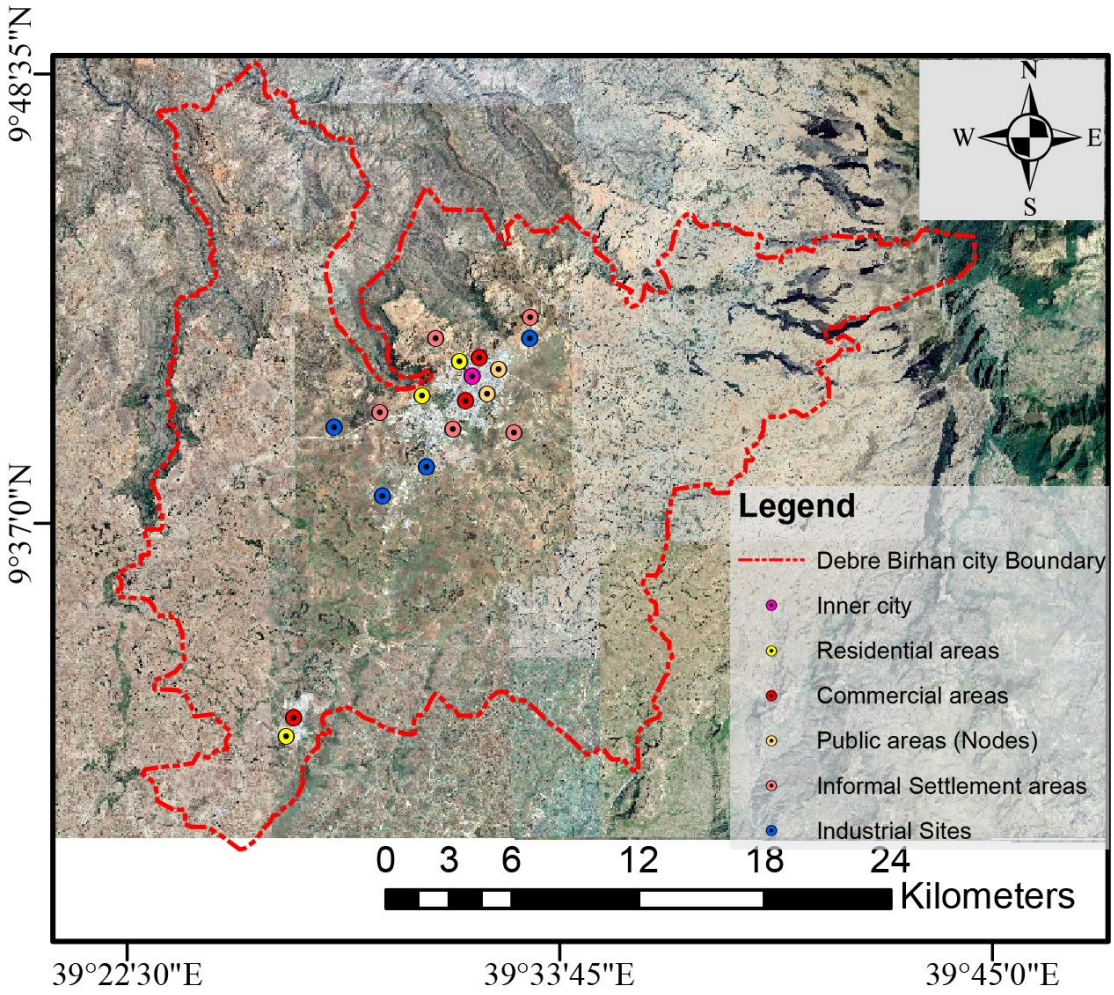

Figure 2. Sample location points for observations in Debre Birhan city.

Source: Author's Computation from Google Earth Pro using ArcGIS 10.8 based on urban expansion study of Debre Birhan city in 2022.

Questionnaires or household surveys:

There are various aspects of the design of survey instruments are considered in research to gather information and insights from the communities on environmental Management (Canals, 2017). One of the most popular method for gathering data from community members on many variables, including behaviors, preferences, attitudes,

traits, and facts, is the use of questionnaires (Kabir, 2018; Wellington & Szczerbinski, 2007). These questionnaires can be open or closed-ended based on the behavior of the study (Dalati & Marx Gómez, 2018).

Closed-ended questions allows to easily group, compare, or rank environmental Management variables or problems in urban areas (Baburajan, Silva & Pereira , 2020). In current digital world, there are different types of web-based data collection tools to utilize these closed-ended questions (Cooper et al., 2006). These data collection tools helps to save money, time and increases accuracy and quick to analyze (Dray, Dunsch & Holmlund, 2016; Chaudhuri et al., 2022).

Kobo Collect/Toolbox as the research instrument

The Harvard Humanitarian Initiative created KoboCollect/Toolbox (KoBotoolbox, 2023), an open-source and free field data collection instrument or tool that is used for mobile data collection (Poloju et al., 2022). The KoboCollect/Toolbox forms can be rapidly updated during data collection to accommodate field circumstances even in remote areas where the internet facility is uncertain (Poloju et al., 2022).

Accordingly, this study used closed-ended questions on environmental, physical and social variables with a predefined range of possible answers and Likert Scale measurements or ranks from nine items ranging from 1 to 9 (from strongly agree to strongly disagree). The questionnaires created and compiled in Kobo Toolbox then deployed into KoboCollect based on predetermined criteria. Finally, the environmental Management variables data results/outputs in Microsoft Excel was downloaded from Kobo Toolbox for further analysis.

3.4 Method of data analysis

3.4.1 Pareto analysis

Pareto analysis, as stated by Vilfredo Pareto around 1895, is statistical approach that applied in decision-making to identify the small number of tasks that have the greatest overall impact (Goodman, 2007). The Pareto principle applies the idea of figuring out which of the top 80% of the issues are reasons or causes for the remaining 20% of issues (Juran, 2019). For this study, the purpose is to identifying and prioritizing the

vital problems that have critical impact on the environmental Management practices of 'Debre Birhan' city. An 80% cumulative percentage was used as the criterion for choosing the most important variables.

A Pareto chart is a graphical tool used to illustrate analytical results by displaying the variables' relative importance that is easy to interpret (Alkiayat, 2021). It has both bars and lines. The bars show the individual values in descending order of height from left to right, while the curve line shows the sample's cumulative proportion. To show the crucial few variables that require the greatest attention when applying the 80/20 rule, an 80% cut-off line was also provided.

3.4.2 The application of Improved Best Worst Method

The Best Worst Method (BWM) is a relatively new decision-making tool created by Rezaei (2015) for multi-criteria decision-making problems (Liang et al., 2021). BWM requires the pairwise comparisons known as reference, or 2n-3 pairwise comparisons (Rezaei, 2015).

Consequently, pairwise comparisons using two vectors and BWM were utilized to calculate the weights of the criteria that required fewer comparisons and more consistent comparisons (Moslem et al., 2020). Based on Rezaei (2016), decision maker, an expert, or a group of specialists first determine which criteria are best (most desirable, most important, etc.) and worst (least desirable, least important, etc.). Subsequently, the criteria that yields the best results is contrasted with the others, and the latter with the former. Next, by creating a maxmin issue, the weight of each criterion is ascertained. The comparison or criteria ranges from 3 to 9. The criteria greater than nine in numbers need thematic grouping.

$$\text{Min } \xi = wB + wW + \sum_{j=1}^{n-(mb+mw)} wj = 1,\ wB,\ W, \geq 0 \forall j \quad \text{..... (eq. 1)}$$

$$mb>1\ mb>1 \text{ and/or } mw>1$$

But, should be $mb=mw=1$, for Improved Best Worst Method (BWM-I)

$$w*B1=wB/mb \text{ and } w*W1=wW/mw.$$

$$Weight\ (w) = wB/2 \text{ and } wW/2$$

Where AjB= represents the preferences of the best criterion

AjW= represents the preferences over the worst criterion

Min ξ= Minimum possible consistency index

Using the Improved Best Worst Method (BWM-I), decision-makers can select as many best/worst criteria as there are in the real issue (Pamučar et al., 2020). This results in a reduction of the total number of comparisons in the model from 2n - 3 (in the traditional BWM) to 2n - 5 (in the BWM-I). At last a consistency ratio is calculated for BWM to check the reliability of the comparisons. These values are ranging from 0 to 1, and a value closer to 0 is indicates higher consistency (Liang, Brunelli & Rezaei, 2020).

Consistency ratio of BWM calculated using the following formula.

$$CR = \frac{\xi}{\max \xi}$$

Where CR= Consistency Ratio

ξ= the optimal objective value of model

$\max \xi$= the maximum possible consistency index

Pareto analysis is used to optimize the variables into 80% of the total variables or factors for MCDM process (Anysz et al., 2021). The scale responses of the vital indicators, identified from Pareto chart, are need pairwise comparison based analysis method. Therefore, the Likert scale responses are further analyzed using BWM of analysis for prioritizing the vital indicators.

3.4.3 Geospatial Analytic Method: GIS-based spatial analysis

Geospatial analysis remote sensing and thematic mapping (i.e., satellite imaging of land use/ land cover change) for social variables in the city. Qualitative data analysis like mapping using arc GIS were used.

4. Results

4.1 Environmental variables

The environmental challenges, according to the perception of sampled household and key informant respondents' in 'Debre Birhan' city presented as follows. The variables considered are based on the literature review section of this paper (Table 1). Fourteen environmental variables are presented based on the perception of households in this section of the paper.

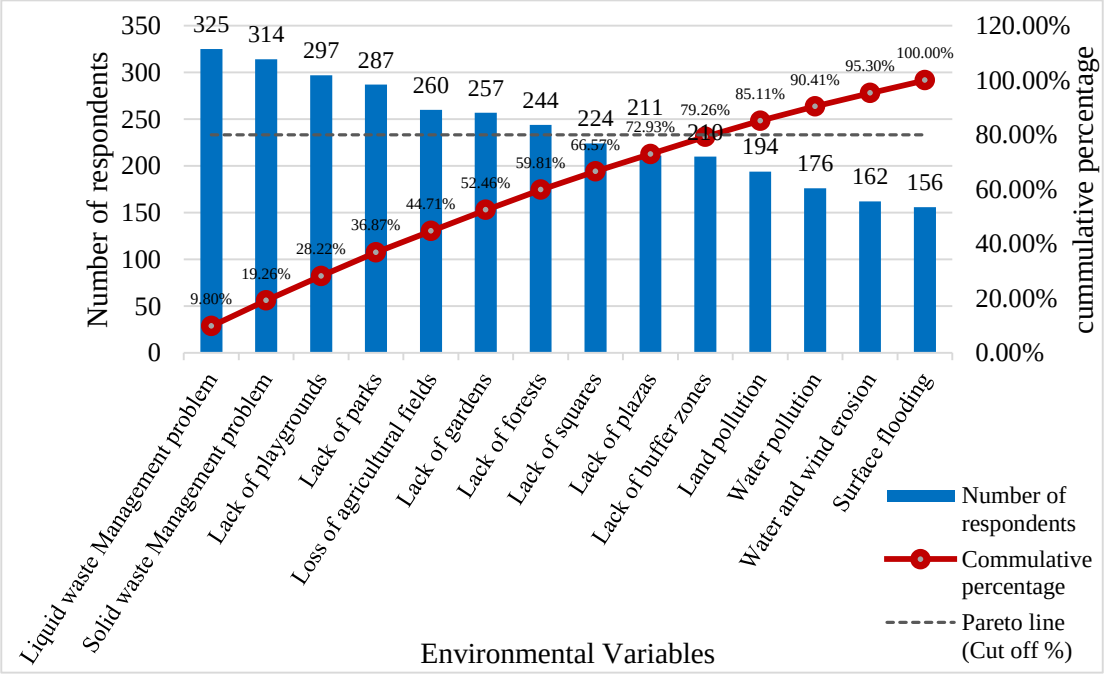

Figure 3. Pareto chart of environmental variables based on the responses from households in Debre Birhan city.

Figure 3 shows the Pareto chart of environmental variables using the Pareto analysis from household responses. Since the cumulative percentage of the variables with less than or equal to 80% considered as the most important.

Based on Pareto 80/20 principle, **ten environmental variables** including liquid waste Management problem, solid waste Management problem, lack of playgrounds, lack of urban parks, loss of urban agriculture, lack of gardens, lack of forests, lack of squares, lack of plazas and lack of buffer zones are considered as vital and causes for the five least important (surface flooding, water and wind erosion, land and water pollution) factors in the city as shown Figure 3.

The ten vital variables (obtained from Pareto analysis) are the vital criteria's for the second approach of Best Worst Method (BWM). These most important variables are also assigned to best-to-others and others-to-best pairwise comparison vectors for the analysis of BWM. However, variables greater than nine in numbers must be grouped based on their themes to reduce between three and nine indicators.

Table 3. The best-to-others and others-to-worst pairwise comparison of environmental vectors by the household respondents.

No	**Main and sub-vital environmental indicators**	**Best to Others Preferences**	**Others to Worst Preferences**	**Weights**	**Ksi* value**
1	**Urban waste management and land expropriation (EN-1)**				
	• Solid waste	**6**	**1**	0.031335	
	• Liquid waste management.	**9**	**1**	0.040269	0.0604
	• Loss of urban agriculture	**1**	**7**	0.261751	
2	**Urban Green and Recreation (EN-2)**				
	• Lack of forests	**2**	**5**	0.09604	
	• Lack of Urban Public Squares	**1**	**9**	0.172311	0.059
	• Lack of playgrounds	**9**	**1**	0.016934	
	• Lack of gardens	**4**	**5**	0.048003	
3	**Urban planning elements (EN-3)**				
	• Lack of buffer zones	**5**	**1**	0.041669	
	• Urban parks	**1**	**2**	0.187513	0.0625
	• Lack of plazas	**2**	**4**	0.104174	

Table 3 shows the assigned best-to-others and others-to-worst environmental vectors and the average values assigned by the household for the main variables identified using Pareto analysis on the scale of 1 to 9.

For the household's best-to-others and others-to-worst average scale responses, further BWM steps were taken to calculate the relative weight and consistency ratio for each grouped vital indicators based on Table 4. Following that, each main element is ranked according to its relative weight. Higher reliability of the households' opinions is implied by a lower consistency ratio number, and vice versa.

Table 4. Average weight and relative ranking of main environmental variables by the household respondents.

No	Environmental variables	Weights	Relative rank
1	Urban waste management and land expropriation (EN-1)	0.5625	1
2	Urban Green and Recreation (EN-2)	0.1250	3
3	Urban planning elements (EN-3)	0.3125	2
	Average consistency ratio (CR)	= (0.059+0.0625+0.0604)/3=0.061	

Source: Author's computation (2023).

Table 4 indicates waste management problem and land expropration (0.5625) is the most prioritized environmental factors affecting environmental management of the city. Whereas, urban planning elements (0.3125), and lack of urban green and recreational spaces (0.1250) are the second and third variables. In this result, the average consistency ratio is 0.061 that indicates highly consistent comparison made by the household respondents.

Solid waste Management problem

Solid waste management problems are observed on streets, river sides, drainage lines and open spaces of the city.

Figure 4. Solid waste Management problem in Debre Birhan city: solid waste on streets (a), on open spaces (b), on open drainage lines(c), and along river bank sides (d).

Figure 4 shows how vacant open spaces, river banks, and drainage lines are used to dumping solid waste. Poor Solid waste Management techniques by the communities, with waste dumped on city center streets (Figure 4a). Solid waste is also being dumped on vacant open spaces with little regard for the environment (Figure 4b). Figure 4c shows solid wastes on exposed drainage lines and Figure 4d along river bank sides utilized inadequate Management procedures, polluting the river banks and causing flood.

Liquid waste Management problem

Liquid waste Management problem in 'Debre Birhan' city caused by poor drainage and sanitation systems as claimed by the key informants and households.

Figure 5. Liquid waste Management problems: liquid waste on land (a) and liquid waste on drainage line (b).

Source: computed by the author (2023).

Figure 5 indicates that liquid waste on open space of the city (Figure 5a) and liquid waste on open drainage lines in front of residents as shown Figure 5b.

4.2 Physical variables

In this section of the paper, the physical factors indicated in on Table 2 of the literature section are analyzed in terms of household and key informant perceptions. Accordingly, eleven physical predefined variables are analyzed and presented as follows.

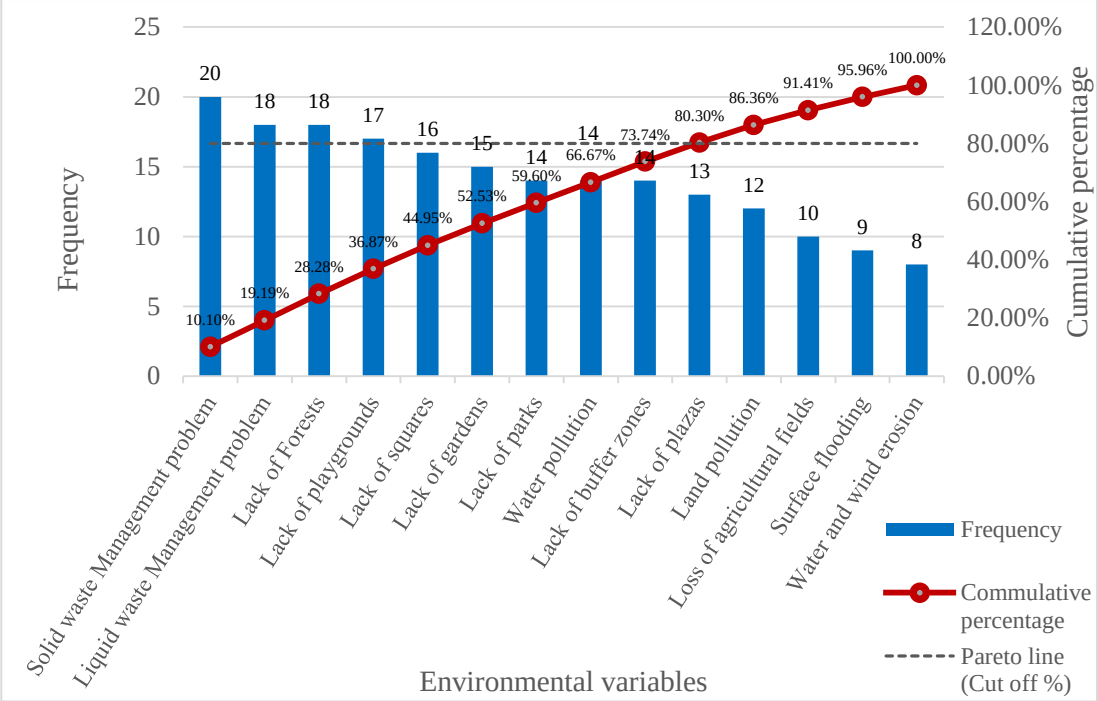

Figure 6. Pareto chart of physical variables from household responses in Debre Birhan city.

Source: Author's computation (2023).

Figure 6 shows the Pareto chart of environmental variables utilizing Pareto analysis in household responses. With similar principles, eight vital physical variables are identified for BWM as shown in the Figure. The symbols representing the environmental variables are arranged from C1 to C8, from left to right order (increasing order) of Pareto chart.

Table 5. The best-to-others and others-to-worst pairwise comparison physical vectors given by the household respondents.

No	Main and sub-vital Physical indicators	Best to Others Preferences	Others to Worst Preferences	Weights
1	**Poor Infrastructures (PH-1)**			
	• Lack of road connectivity	**1**	**6**	0.079696
	• Surface deterioration of roads	**4**	**4**	0.056926
	• Poor drainage systems	**4**	**5**	0.033207
	• Poor road lighting systems	**6**	**1**	0.199241
2	**Accessibility Concerns (PH-2)**			
	• Narrow width roads	**3**	**5**	0.09962
	• Narrow sidewalks for wheelchairs	**5**	**2**	0.132827
3	**Urban amenities and services (PH-3)**			
	• Lack of efficient waste collection bins	**7**	**3**	0.066414
	• Lack of road amenities	**8**	**2**	0.332068

Source: author's computation (2023)

Table 5. shows the physical vectors and their best-to-others and others-to-worst average preferences given by the household for further BWM analysis of the variables in the city.

Table 6. Average weight and relative ranking of main physical variables given by the household respondents.

No	Physical variables	Weights	Relative rank
1	Poor Infrastructures (PH-1)	0.5	1
2	Accessibility Concerns (PH-2)	0.3333	2
3	Urban amenities and services (PH-3)	0.1667	3
	Average consistency ratio (CR)	0.100	

Source: by the author (2023).

Table 6 indicates urban amenities and services (0.55), accessibility concerns (0.3333), and poor infrastructures (0.1667) are the three prioritized physical variables respectively. The average consistency ratio (0.100) of the BWM results show very high reliability among the household respondents.

Lack of road connectivity

The condition road connectivity in 'Debre Birhan' city presented as follows

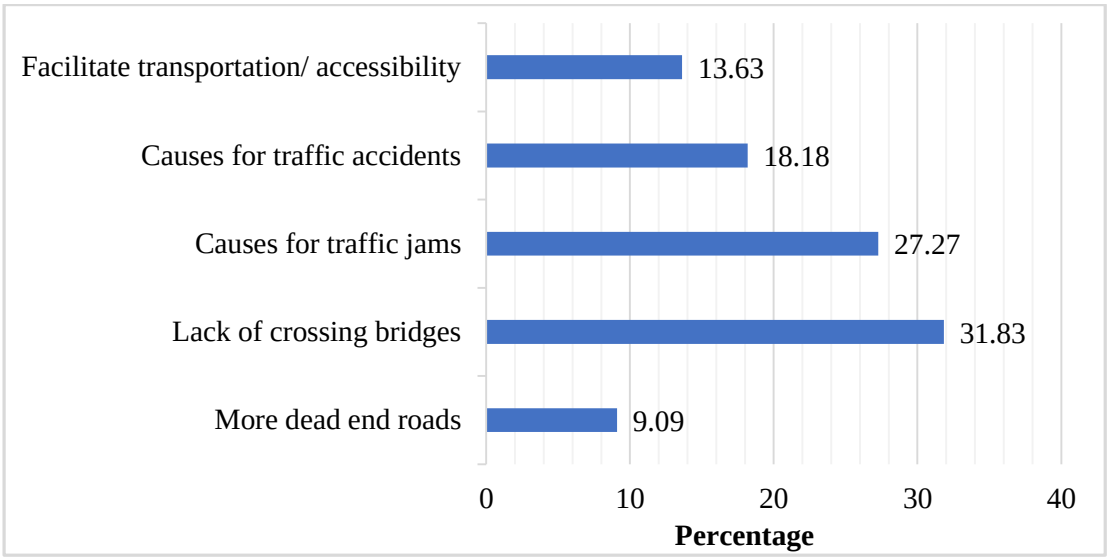

Figure 7. Condition of road network related to connectivity in Debre Birhan city.

Figure 7 illustrates the condition of road network conditions related to connectivity in 'Debre Birhan' city. Based on the Figure, 31.83% of the respondents shows lack of crossing bridges on river banks and high way roads.

Figure 8. Connectivity issues in Debre Birhan city: dead end roads (a) and causes for transportation issues (b).

Figure 8 indicates lack of road connectivity in the city. The Figure shows the accessibility issues (Figure 8a) and dead end roads (Figure 8b).

Narrow width roads

According to key sources from the Urban Infrastructure Office, narrow roadways that are less than four meters wide cause problems since they restrict accessibility inside the city. The majority of these roads exist in the city centers and creates vehicle accessibility issues.

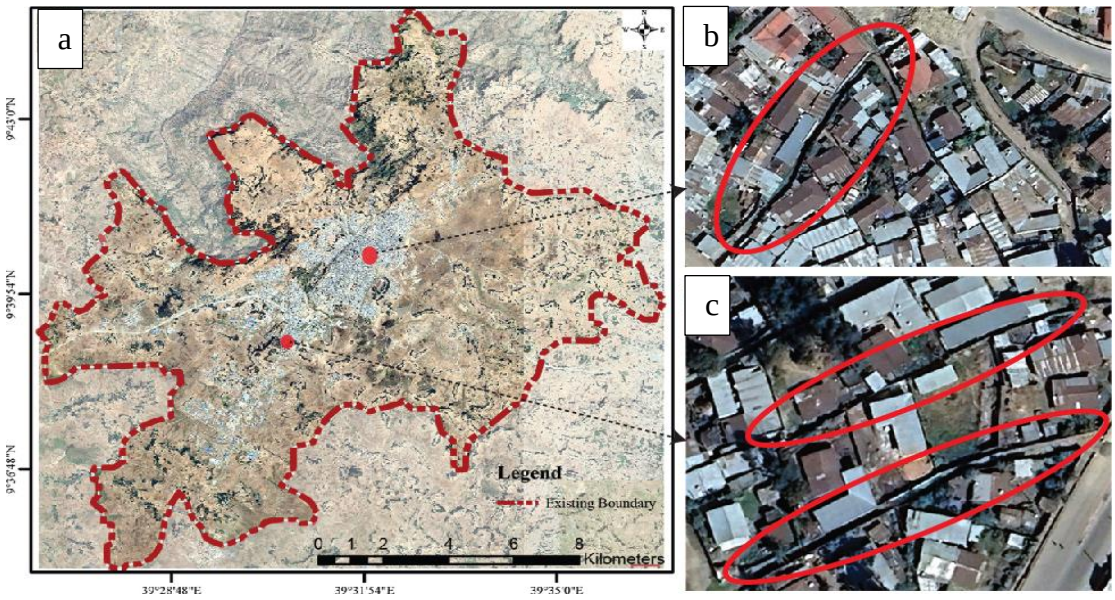

Figure 9. Debre Birhan city (a), narrow width roads in the city center (b) and narrow width roads in the sub center of the city (c).

Figure 9 depicts narrow street widths in the city centers (b) and sub centers (c), marked in red shapes.

4.3 Social variables

This section of the paper analyzed the social variables indicated on Table 2 based on the perception household and key informants in 'Debre Birhan' city.

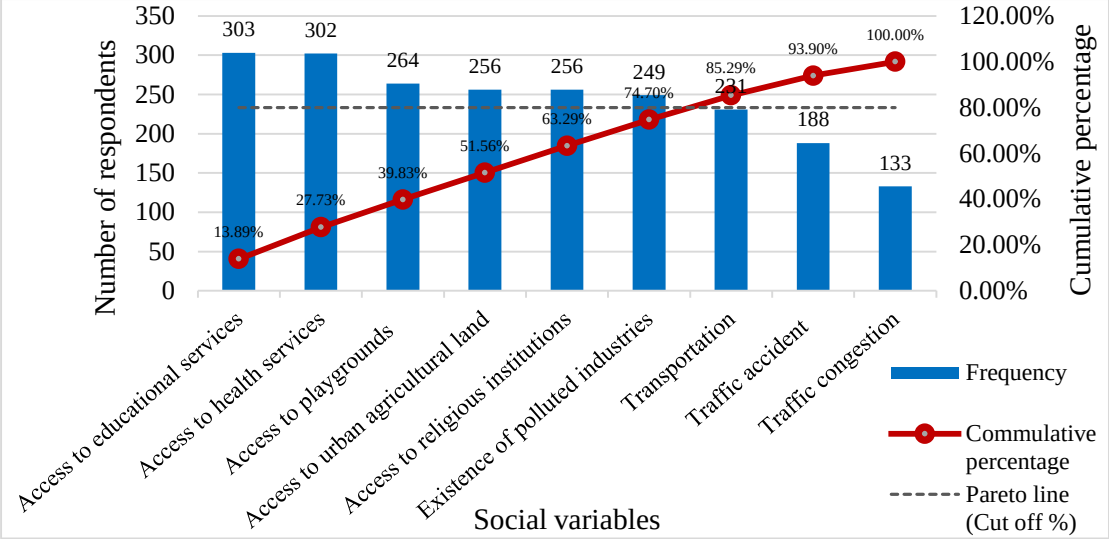

Figure 10. Pareto chart of social variables based on households in Debre Birhan city.

Access to educational services, access to health services, access to playgrounds, access to urban agricultural land, access to religious institutions and existence of polluted industries are identified as vital social variables and causes for transportation, traffic accidents and traffic congestion (Table 7) by using Pareto analysis for BWM of analysis technique.

Table 7. The best-to-others and others-to-worst pairwise comparison social vectors given by the household respondents.

Vital social indicators	Best to Others Preferences	Others to Worst Preferences
Access to educational services	5	2
Access to health services	5	2
Access to playgrounds	1	5
Access to urban agricultural land	2	3
Access to religious institutions	6	1
Existence of polluted industries	3	5

Source: author's computation (2023).

Access to educational services, access to health services, access to playgrounds, access to urban agricultural land, access to religious institutions and existence of polluted industries are identified as vital social variables and causes for transportation, traffic accidents and traffic congestion (Table 7) by using Pareto analysis for BWM of analysis technique.

Table shows the best-to-others and others-to-worst variables and the average preferences given by the household respondents.

Table 8. Average weight and relative ranking of main social variables given by the household respondents.

Social variables	Weights	Relative rank
Access to playgrounds	0.336	1
Access to urban agricultural land	0.236	2
Existence of polluted industries	0.157	3
Access to health services	0.096	4
Access to educational services	0.094	5
Access to religious institutions	0.052	6
Average consistency ratio (CR)	**0.105**	

Source: author's computation (2023).

Table indicates the weight and relative rank of social variables using BWM analysis technique. Based on Table 8, access to playgrounds ranked first, access to urban agricultural land (0.236) second and existence of polluted industries (0.157) third.

4.4 Institutional variables

This part of the study covers the current institutional variables as well as the vertical and horizontal structures or collaborations in decision-making processes in 'Debre Birhan' city. The variables considered in the literature review section Table 2. These variables are analyzed from the data collected from households and key informants from the city.

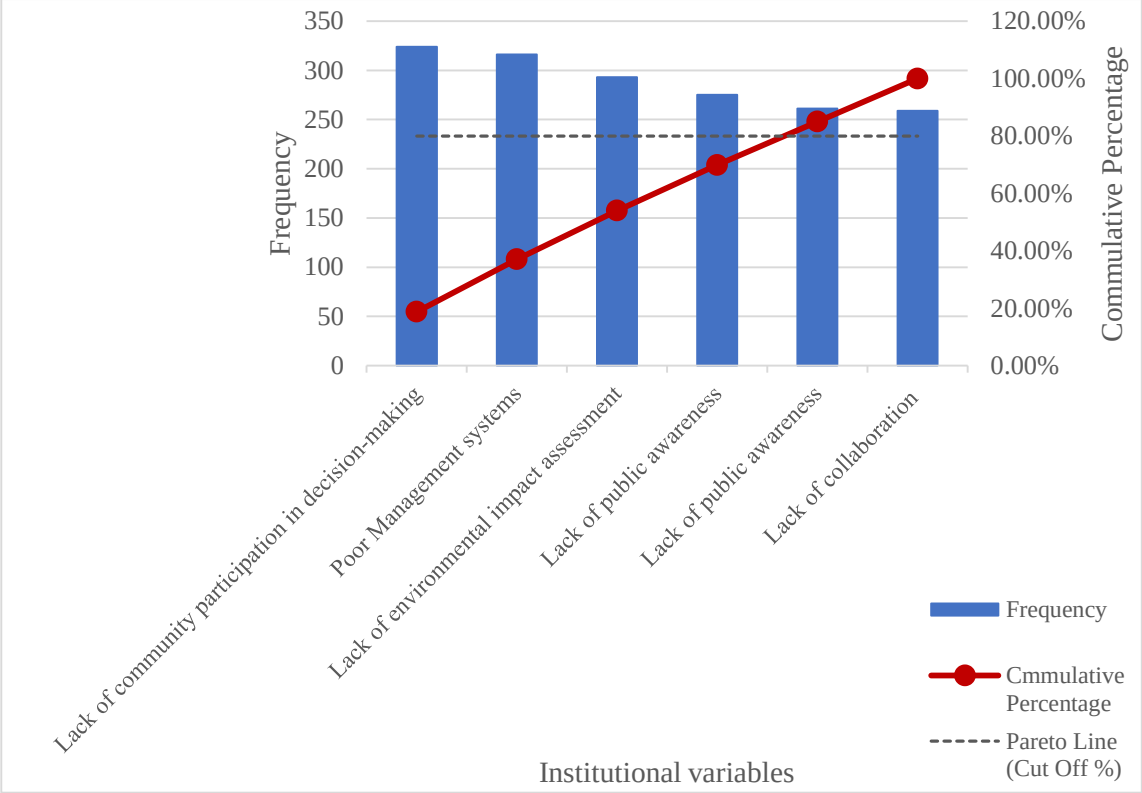

Figure 11. Pareto chart of institutional variables from households perception.

Figure 11 indicates the Pareto chart of institutional variables affecting the Management practices of the city based on household responses. Accordingly, lack of community participation, poor Management systems, lack of environmental impact assessment and lack of public awareness are the most important factors as shown in the Figure.

Table 9. Average weight and relative ranking of main institutional variables given by household respondents.

Code	Institutional variables	Weights	Relative rank
C1	Lack of community participation in decision-making	0.538	1
C3	Lack of environmental impact assessment	0.231	2
C2	Poor Management systems	0.154	3
C4	Lack of public awareness	0.077	4
	Average consistency ratio (CR)	0.077	

Lack of community participation in decision-making ranked first and lack of public awareness at last based on BWM as shown Table 9.

5. Discussions

The urban areas of SSA are home to many grave issues related to the environment (McGranahan et al., 2024). Secondary cities are where the majority of environmental issues occur (Sakketa, 2023). According to the Cities Alliance report, comparable environmental problems have been found in Ethiopia's secondary cities (Roberts, 2014).

Accordingly, this paper take account of fourteen environmental, eleven physical, nine social and six institutional urban challenges in 'Debre Birhan' city. The Pareto & BWM analysis identifies the most important environmental, physical and social as well as institutional urban problems in 'Debre Birhan' city.

Poor Management of both liquid and solid waste, resulted from a range of ineffective disposal facilities to non-existent collection systems and affects direct human health and urban environments (Gutberlet & Uddin, 2018). Poor solid waste Management can contribute to the impact of urban flooding by blocking drainage lines and increasing debris in secondary cities of Ethiopia (Derdera & Ogato, 2023). Both poor solid and liquid waste Management in cities can also create urban pollution (Ouattara et al., 2023).

Similarly, inadequate waste Management practices in 'Debre Birhan' city affect drainage networks and lead to water and soil pollution. Consequently, the primary causes of flooding and urban pollution in the city are open ditches, clogging of drainages and uncontrolled waste disposal sites.

Darkwah (2016) and Sujathamma (2019) also identifies a variety of other concerning environmental issues in their study. The main environmental problems from these studies include flooding, destruction of green spaces, inadequate sanitation, land pollution, and water pollution. Deterioration of green spaces (Kovacs et al., 2017; Kim, Lee & Sung, 2016) and inadequate drainage systems (Jemberie, Melesse & Abate , 2023) results surface flooding in cities.

Green infrastructure and open spaces in general, including urban parks, green belts, trees, landscape services and playgrounds, are important in creating sustainable and integrative development and resilient cities (Maranga, 2021; O'Farrell et al., 2019; Breed et al., 2023; Kimengsi & Fogwe, 2017). However, 'Debre Birhan' city lacks enough green infrastructure, though, which includes parks, reserved forests, buffers along rivers and open spaces for recreation. The quality of life in extensive developing urban areas is still negatively impacted by inadequate green infrastructure (Sangwan et al., 2022).

Poor road types, poor road conditions, low road coverage and improper road hierarchy are problems in secondary cities of SSA (Gwilliam et al., 2008). In this context, much earth and gravel road types, deteriorated and uneven road surfaces, roads with lack of drainage, roads with potholes, eroded roads, road debris, poor mix of road hierarchy at the center and small road coverage are the major physical challenges in the city. Surface deterioration of roads from low to high severity in cities also has effects on accessibility issues (Golov et al., 2022).

Furthermore, lack of physical infrastructure related to roads in secondary cities makes the distribution difficult and implies high transportation costs (Felixa & Mohareb, 2017). Lack of affordable roads in these cities provides unfair and unsustainable transport options. Similar to this, the unavailability of affordable roads to newly developed settlements and peripheral manufacturing sites results in additional costs and travel times within the city.

The major social factors in most SSA cities include informal settlements, insufficient access to social services and land use incompatibilities. In addition, a study by Barbosa, Pradilla & Rajendran (2022) land use land cover change, urban expansion and sprawling are the social challenges in the peri-urban areas of cities. Cities in developing countries also suffer transportation-related difficulties (Goetz, 2019; Dimitriou & Gakenheimer, 2012).

Similarly, this paper identifies social challenges related to access, transportation and functional land use related variables from household responses in the city. Land use and land cover change, informal settlements, uncontrolled urban expansion and

sprawling are additional social challenges that impact the city's environmental Management strategies.

Access problems to educational and health services, religious institutions, recreational space and agricultural lands are the social problems in 'Debre Birhan' city. Simultaneously, cities experienced issues with access to green and recreational places (Ridgley et al., 2020) and educational and health services (O'Donnell et al., 2016).

Effective decision-making procedures with a focus on sustainability are found to be significantly facilitated by overcoming institutional constraints (Broto, 2017). Building institutional capacity is therefore a prerequisite for setting and carrying out sustainable initiatives (Polk, 2011) and currently being discussed in several global urban policy and planning contexts (Rincón et al., 2021).

However, institutional constraints are causing issues for the local governments of developing countries (Dziva & Kabonga, 2021). These factors include a lack of strong institutional frameworks, public involvement, and coordination (Castañer & Oliveira, 2020). Apart from these issues, 'Debre Birhan' city also has poor Management systems, limited environmental assessment, low public awareness, and inadequate environmental education.

5.1 Implication of the study

This study has implications for other developing-country cities, which should focus on addressing the factors affecting environmental management practices, adopt and revise policies related to environmental management, and accept resilience-focused thinking. The results of this research will provide some contributions in the need of investigating variables in physical, social, institutional, and environmental domains of environmental management practices.

6. Conclusions

Resilience thinking is needed for both present and future development in local, national, and international contexts, including in sector-specific development plans, policies, and initiatives. In an urban setting, the general resilience idea aids in identifying issues inside the city and in responding to stressors and shocks to

preserve vital services and functions. It has comprehensive approach regarding the environmental, social, economic, physical, and social aspects.

This study, however, focuses only on the environmental, physical, social, and institutional aspects that affects urban environmental management practices; it also discusses the resilience principles that are implemented in the city and the mitigation strategies used to counteract those effects.

Concerning the environmental management practices context, the research investigates the fourteen environmental, eleven physical, twelve social and six institutional variables that influence the environmental management practices of 'Debre Birhan' city, using empirical data from the household and experts perception. This study has implications for urban uncertainties and challenges on the growing cities of developing countries.

About the context of environmental management practices, the study investigates the fourteen environmental, eleven physical, twelve social, and six institutional variables that affect the environmental management practices of 'Debre Birhan's city using empirical data from household and expert perceptions. This study has implications for urban challenges and uncertainties associated with other growing cities in the global south.

Concerning the mitigation measures, this study looks the environmental management tools implemented to offset the environmental, physical, social and institutional problems using empirical data from households and key informants perception in the city. Consequently, it deliberated seven for environmental factors, five for physical, four for social and six environmental management tools implemented for institutional factors

Successful environmental management practice requires a holistic approach that integrates environmental, physical, social and institutional considerations to foster sustainability and resilience. Therefore, resilience-based environmental management is an approach that involves integrating resilience principles into all aspects of environmental management practices including planning and decision-making, and implementation to withstand urban uncertainties. Therefore, adopting resilience

principles of diversity, redundancy, modularity, robustness, interdependence and integration in policy documents enhances sustainability development in cities.

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Annex II: Household questionnaires

Questionnaires for households of Debre Birhan city

Dear respondents,

I request your voluntary and polite cooperation in providing information requested in this questionnaire to address thesis research entitled "Mainstreaming Resilience thinking into environmental Management practices of Debre Birhan city, Ethiopia". It is provided to collect primary data needed the preparation of a thesis research paper for the partial fulfilment of the degree of Masters of Sciences in Environmental planning and Landscape Design. Therefore, your honest, precise and clear responses will be contributed for success and validity of the study .The study will take full secrecy and confidentiality of the respondents and the data collected.

General Assessment

Educational status

a) Read and Write b) Diploma c) Degree d) Masters and above

Occupational status

a) Student b) Unemployed c) Employed d) Private Business

How long did you live in the city?

☐ Below 5 years ☐ 6-10 years ☐ 11-20 years ☐ Above 20 years

Environmental variables related questions

What environmental variables/problems are exist in Debre Birhan city? (Multiple answers are possible).

☐ Surface flooding	☐ Solid waste Management problem	☐ Liquid waste Management problem
☐ Water and wind erosion	☐ Lack of buffer zones	☐ Lack of forests
☐ Lack of urban parks	☐ Lack of playgrounds	☐ Lack of gardens

☐ Lack of squares ☐ Lack of plazas ☐ Land pollution

☐ Water pollution ☐ Loss of urban agriculture

In your opinion, in what extent following environmental variables can affect the environmental Management practices of 'Debre Birhan' city?	**None**	**Low**	**Medium**	**High**	**Very high**
	1	**2**	**3**	**4**	**5**
Surface flooding	☐	☐	☐	☐	☐
Solid waste Management problem	☐	☐	☐	☐	☐
Liquid waste Management problem	☐	☐	☐	☐	☐
Water and wind erosion	☐	☐	☐	☐	☐
Lack of buffer zones	☐	☐	☐	☐	☐
Lack of forests	☐	☐	☐	☐	☐
Lack of urban parks	☐	☐	☐	☐	☐
Lack of playgrounds	☐	☐	☐	☐	☐
Lack of gardens	☐	☐	☐	☐	☐
Lack of squares	☐	☐	☐	☐	☐
Lack of plazas	☐	☐	☐	☐	☐
Land pollution	☐	☐	☐	☐	☐

Water pollution	☐	☐	☐	☐	☐
Loss of agricultural fields	☐	☐	☐	☐	☐

Physical variables related questions

What physical variables/problems are exist in Debre Birhan city? (Multiple answers are possible).

☐ Lack of road connectivity	☐ Narrow width roads	☐ Narrow sidewalks for wheelchairs
☐ Poor road lighting systems	☐ Lack of road amenities	☐ Lack of road heirarchies
☐ Lack of toilet	☐ Lack of efficient waste collection bins	☐ Pollution of river banks
☐ Poor drainage systems	☐ Surface deterioration of roads	

In your opinion, in what extent the following physical variables can affect the environmental Management practices of 'Debre Birhan' city?	**None**	**Low**	**Medium**	**High**	**Very high**
	1	**2**	**3**	**4**	**5**
Lack of road connectivity	☐	☐	☐	☐	☐
Narrow width roads	☐	☐	☐	☐	☐
Narrow sidewalks for wheelchairs	☐	☐	☐	☐	☐
Poor road lighting systems	☐	☐	☐	☐	☐
Lack of road amenities	☐	☐	☐	☐	☐

Lack of road hierarchies	☐	☐	☐	☐	☐
Lack of toilet	☐	☐	☐	☐	☐
Lack of efficient waste collection bins	☐	☐	☐	☐	☐
Pollution of river banks	☐	☐	☐	☐	☐
Poor drainage systems	☐	☐	☐	☐	☐
Surface deterioration of roads	☐	☐	☐	☐	☐

Social problems/variables related questions

What social problems are exist in Debre Birhan city? (Multiple answers are possible).

☐ Access to educational services	☐ Access to health services	☐ Access to playgrounds
☐ Access to urban agricultural land	☐ Access to religious institutions	☐ Existence of polluted industries
☐ Transportation	☐ Traffic accident	☐ Traffic congestion

In your opinion, in what extent the following social variables can affect the environmental Management practices of 'Debre Birhan' city?	**None**	**Low**	**Medium**	**High**	**Very high**
	1	**2**	**3**	**4**	**5**
Access to educational service	☐	☐	☐	☐	☐
Access to health services	☐	☐	☐	☐	☐
Access to playgrounds	☐	☐	☐	☐	☐

Access to urban agricultural land	☐	☐	☐	☐	☐
Access to religious institutions	☐	☐	☐	☐	☐
Existence of polluted industries	☐	☐	☐	☐	☐
Transportation	☐	☐	☐	☐	☐
Traffic accident	☐	☐	☐	☐	☐
Traffic congestion	☐	☐	☐	☐	☐

Institutional problems/variables related questions

What institutional problems are exist in Debre Birhan city? (Multiple answers are possible).

- ☐ Lack of community participation in decision-making process
- ☐ Poor management systems
- ☐ Lack of public awareness
- ☐ Lack of environmental education
- ☐ Lack of environmental impact assessment
- ☐ Lack of collaboration

In your opinion, in what extent the following social variables can affect environmental Management practices 'Debre Birhan' city?	**None**	**Low**	**Medium**	**High**	**Very high**
	1	**2**	**3**	**4**	**5**
Lack of community participation in decision-making process	☐	☐	☐	☐	☐
Poor management systems	☐	☐	☐	☐	☐
Lack of public awareness	☐	☐	☐	☐	☐

Lack of environmental education	☐	☐	☐	☐	☐
Lack of environmental impact assessment	☐	☐	☐	☐	☐
Lack of collaboration	☐	☐	☐	☐	☐

Annex III: Experts' questionnaires

Questionnaires for experts (Solid waste Management office)

Dear respondents,

I request your voluntary and polite cooperation in providing information requested in this questionnaire to address thesis research entitled "Mainstreaming Resilience thinking into environmental Management practices of Debre Birhan city, Ethiopia". It is provided to collect primary data needed the preparation of a thesis research paper for the partial fulfilment of the degree of Masters of Sciences in Environmental planning and Landscape Design. Therefore, your honest, precise and clear responses will be contributed for success and validity of the study .The study will take full secrecy and confidentiality of the respondents and the data collected.

General Assessment

Profession

☐ Urban planner ☐ Architect ☐ Environmentalist

☐ Geologist ☐ Economist ☐ Sociologist

Position

☐ Department ☐ Case process ☐ Case team

☐ Others (please specify) ----------

Number of years in current working position?

☐ Below 5 years ☐ 6-10 years ☐ 11-20 years ☐ above 20 years

Environmental variables related questions.

Which of the following environmental variables/problems exist in Debre Birhan city?

☐ Surface flooding ☐ Solid waste Management problem ☐ Liquid waste Management problem

☐ Water and wind erosion ☐ Lack of buffer zones ☐ Lack of forests

☐ Lack of urban parks ☐ Lack of playgrounds ☐ Lack of gardens

☐ Lack of squares ☐ Lack of plazas ☐ Land pollution

☐ Water pollution ☐ Loss of agricultural fields

Which of the following environmental Management tools are implemented to offset the environmental problems? (Multiple selection is allowed).

☐ Land use planning and zoning (compatibility) ☐ Land use planning and zoning (suitability) ☐ Flood protection and control

☐ Environmental impact assessment ☐ Watershed Management ☐ Solid waste Management

☐ Sanitary codes ☐ Boosting green spaces ☐ Promoting urban agriculture

What solid waste Management mechanisms are practicing in your city to avoid waste problems? (Multiple selection is allowed).

☐ Avoid/reduce at source ☐ Avoid/reduce at transfer station ☐ Reuse at source

☐ Recycle ☐ Compost ☐ Burning

☐ Dispose in landfill

If you are implementing recycling, where? (Multiple answers are possible).

☐ Recycling center/industry sites ☐ Public space ☐ Other (please specify) ----------

If you are implementing burning, where? (Multiple answers are possible)

☐ Open spaces ☐ Street ☐ Open drainage

☐ Other (please specify) ----------

If you are implementing burning, what processes you are following. (Multiple answers are possible).

☐ Open burning ☐ Incineration ☐ Other (please specify) ----------

How solid wastes are being collected in the city? (Multiple selection is allowed).

☐ Municipal vehicles ☐ Private entrepreneurs

☐ Micro and small enterprises (MSEs) ☐ None

If you select municipal vehicles, how many employees hold in it?

☐ Below 10 ☐ 10-20 ☐ 21-30 ☐ Above 30

If you select municipal vehicles, specify the number of containers contain?

☐ Below 10 ☐ 10-20 ☐ 21-30 ☐ Above 30

If you select municipal vehicles, specify the number of vehicles contain?

☐ Below 3 ☐ 3-5 ☐ 6-10 ☐ Above 10

If you select municipal vehicles, what about solid waste collection plan/time?

☐ Once a day ☐ Twice per day ☐ Three times per day

☐ More than times per day

From the above information, can you say well addressed and enough for the city?

☐ Yes ☐ No

If you select MSEs, how many number of enterprises are there?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ Above 5

If you select MSEs, how many members in each enterprises?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ Above 5

If you select MSEs, what are the collection mechanisms?

☐ Door to door ☐ Transportation to collection sites ☐ Transporting from communal collection to disposal sites

☐ Material recovery

How solid wastes are disposed? (Multiple options are possible).

☐ Landfill sites ☐ Open dumping ☐ River system

☐ Green space ☐ Open space ☐ Street

☐ Arranged system ☐ Drainage lines ☐ None

Is the city provided with solid waste transfer station?

☐ Yes ☐ No

If yes, where are the locations of solid waste transfer station?

☐ Beyond roadways ☐ Queuing area ☐ Car parking areas

☐ Near to service areas ☐ Buffer areas ☐ Employee buildings

☐ Recycling areas ☐ Near to water bodies

How do you rate the current condition of landfill site in the city?

☐ As per land use type ☐ Not as per land use ☐ Near to river banks

☐ Covered from the wind's blowing

☐ Not compacted

☐ Near to residential areas

Please rate the influence of the following solid waste management mechanisms implemented in the city to mitigate waste problems.	**Unimportant**	**Of little important**	**Moderately important**	**Important**	**Very important**
	1	**2**	**3**	**4**	**5**
Avoid/reduce at source	☐	☐	☐	☐	☐
Avoid/reduce at transfer station	☐	☐	☐	☐	☐
Reuse at source	☐	☐	☐	☐	☐
Recycle	☐	☐	☐	☐	☐
Compost	☐	☐	☐	☐	☐
Burning	☐	☐	☐	☐	☐
Dispose in landfill	☐	☐	☐	☐	☐

Physical variables related questions.

What is the state of the drainage systems in the city of Debre Birhan?

- ☐ Connected to river banks
- ☐ Closed drainage system
- ☐ Causes for land & water pollution
- ☐ Open drainage system
- ☐ Designed in a proper density
- ☐ Create flooding

In what condition are the city's riverbanks?

- ☐ Polluted
- ☐ Clean and used for recreation
- ☐ Used as waste disposal site
- ☐ Protected with proper buffering

What is the city's sanitation condition like?

- ☐ Provided with proper sanitation facilities
- ☐ With inadequate toilet facilities
- ☐ Provided with proper storm water drainages
- ☐ With poor water supply

Institutional variables related questions.

Which of the following institutional variables are practicing in Debre Birhan city?

- ☐ Shared planning
- ☐ Alignment of tasks
- ☐ Objective setting
- ☐ Disclosure of tasks

If you choice shared planning in what issues?

- ☐ Planning new scheme of work between departmental experts and other staffs
- ☐ Content preparing in the area of planning expertise
- ☐ Department-wide approach for revision
- ☐ Proper staff allocation to develop systems

If you choice objective setting in what issues?

☐ Increase employees skills and improve performance

☐ Improve the institutions Management capability up to departmental level

☐ Create new and comfortable working environment

☐ Increase the quality of environmental Management practices

If you choice alignment of tasks in what issues?

☐ Configuration and relationship of legal, laws and policies from federal to regional and local levels

☐ Assigning responsibilities from local government into departmental level

☐ Vertical relationship of institution's task

☐ Alignment of task from departmental level to individual level

If you choice disclosure of tasks in what issues?

☐ Clear division of tasks

☐ Consistent task division

☐ Balanced task division

☐ Proper distribution of tasks in the institution according to the professionals skill

How do you evaluate the following institutional mitigation mechanisms the city?	**None**	**Low**	**Medium**	**High**	**Very high**
	1	**2**	**3**	**4**	**5**
Stakeholder involvement in decision-making process	☐	☐	☐	☐	☐
Collaboration among concerned institutions	☐	☐	☐	☐	☐
Management systems	☐	☐	☐	☐	☐
Public awareness	☐	☐	☐	☐	☐

Environmental education	☐	☐	☐	☐	☐
Environmental impact assessment	☐	☐	☐	☐	☐

Resilience related questions.

Have you seen any of the following listed Resilience principles in your city? (ecological diversity, urban land use /road network condition/, diversity of service centers, multiple nodes, multiple green and open spaces, multiple forests, multiple road hierarchy, connectivity of street networks and nodes, green belts and green ways, and stakeholder involvement).

Yes ☐ No ☐

If yes, please choose from the following options (multiple selection is possible)

☐ Ecological diversity	☐ Urban land use /road network condition/	☐ Diversity of service centers
☐ Multiple nodes	☐ Multiple green and open spaces	☐ Multiple forests
☐ Multiple road hierarchy	☐ Connectivity of street networks and nodes	☐ Green belts and green ways
☐ Stakeholder involvement in decision-making		

Questionnaires for experts (Sanitation and beautification office)

Dear respondents,

I request your voluntary and polite cooperation in providing information requested in this questionnaire to address thesis research entitled "Mainstreaming Resilience thinking into environmental Management practices of Debre Birhan city, Ethiopia". It is provided to collect primary data needed the preparation of a thesis research paper for the partial fulfilment of the degree of Masters of Sciences in Environmental planning and Landscape Design. Therefore, your honest, precise and clear responses will be contributed for success and validity of the study .The study will take full secrecy and confidentiality of the respondents and the data collected.

General Assessment

Profession

☐ Urban planner ☐ Architect ☐ Environmentalist

☐ Geologist ☐ Economist ☐ Sociologist

Position

☐ Department ☐ Case process ☐ Case team

☐ Others (please specify) ----------

Number of years in current working position?

☐ Below 5 years ☐ 6-10 years ☐ 11-20 years ☐ above 20 years

Environmental variables related questions.

Which of the following environmental variables/problems exist in Debre Birhan city?

☐ Surface flooding ☐ Solid waste Management problem ☐ Liquid waste Management problem

☐ Water and wind erosion ☐ Lack of buffer zones ☐ Lack of forests

☐ Lack of urban parks ☐ Lack of playgrounds ☐ Lack of gardens

☐ Lack of squares ☐ Lack of plazas ☐ Land pollution

☐ Water pollution ☐ Loss of agricultural fields

What are the major environmental problems caused by poor Management of the development of green infrastructure and open space in the city?

☐ Land pollution ☐ Water pollution ☐ Soil erosion

☐ Surface flooding ☐ Lack of recreational space ☐ Loss of biodiversity

Which environmental Management tools are implemented to improve urban green and open spaces in the city? (Multiple selection is allowed).

☐ Green space planning ☐ Public park ☐ Urban agriculture

☐ Green campaign ☐ Green buffering ☐ Provision of playground space

☐ Private garden

How to rate the influence of the following environmental management tools implemented to improve green and open spaces in the city.	**Unimportant**	**Of little important**	**Moderately important**	**Important**	**Very important**
	1	**2**	**3**	**4**	**5**
Green space planning	☐	☐	☐	☐	☐
Urban Park development	☐	☐	☐	☐	☐
Green campaign	☐	☐	☐	☐	☐
Green buffering	☐	☐	☐	☐	☐
Urban agriculture	☐	☐	☐	☐	☐
Provision of playground space	☐	☐	☐	☐	☐

Physical variables related questions.

What is the state of the drainage systems in the city of Debre Birhan?

- ☐ Connected to river banks
- ☐ Closed drainage system
- ☐ Causes for land & water pollution
- ☐ Open drainage system
- ☐ Designed in a proper density
- ☐ Create flooding

In what condition are the city's riverbanks?

- ☐ Polluted
- ☐ Clean and used for recreation
- ☐ Used as waste disposal site
- ☐ Protected with proper buffering

What is the city's sanitation condition like?

- ☐ Provided with proper sanitation facilities
- ☐ With inadequate toilet facilities
- ☐ Provided with proper storm water drainages
- ☐ With poor water supply

Institutional variables related questions.

What are the major Management problems with the development of green infrastructure and open space in the city?

- ☐ Lack of collaboration
- ☐ Lack public awareness
- ☐ Lack of environmental education
- ☐ Poor Management systems
- ☐ Lack of community participation in decision-making
- ☐ Lack of environmental impact assessment

Which of the following institutional variables are practicing in Debre Birhan city? (Multiple answers are possible).

- ☐ Shared planning
- ☐ Alignment of tasks
- ☐ Objective setting
- ☐ Disclosure of tasks

If you choice shared planning in what issues?

- ☐ Planning new scheme of work between departmental experts and other staffs
- ☐ Content preparing in the area of planning expertise
- ☐ Department-wide approach for revision
- ☐ Proper staff allocation to develop systems

If you choice objective setting in what issues?

- ☐ Increase employees skills and improve performance
- ☐ Improve the institutions Management capability up to departmental level
- ☐ Create new and comfortable working environment
- ☐ Increase the quality of environmental Management practices

If you choice alignment of tasks in what issues?

- ☐ Configuration and relationship of legal, laws and policies from federal to regional and local levels
- ☐ Assigning responsibilities from local government into departmental level
- ☐ Vertical relationship of institution's task
- ☐ Alignment of task from departmental level to individual level

If you choice disclosure of tasks in what issues?

- ☐ Clear division of tasks
- ☐ Consistent task division
- ☐ Balanced task division
- ☐ Proper distribution of tasks in the institution according to the professionals skill

Resilience related questions

Have you seen any of the following listed Resilience principles in your city? (ecological diversity, urban land use /road network condition/, diversity of service centers, multiple nodes, multiple green and open spaces, multiple forests, multiple road hierarchy,

connectivity of street networks and nodes, green belts and green ways, and stakeholder involvement).

Yes ☐ No ☐

If yes, please choose from the following options (multiple selection is possible).

☐ Ecological diversity	☐ Urban land use /road network condition/	☐ Diversity of service centers
☐ Multiple nodes	☐ Multiple green and open spaces	☐ Multiple forests
☐ Multiple road hierarchy	☐ Connectivity of street networks and nodes	☐ Green belts and green ways
☐ Stakeholder involvement in decision-making		

If yes, please rate the importance of the following resilience principles integrated urban environmental management practices.	**Unimportant**	**Of little important**	**Moderately important**	**Important**	**Very important**
	1	**2**	**3**	**4**	**5**
Diversity					
Ecological diversity	☐	☐	☐	☐	☐
Urban land use /road network condition/	☐	☐	☐	☐	☐
Service centers	☐	☐	☐	☐	☐
Redundancy					
Multiple nodes	☐	☐	☐	☐	☐
Multiple green and open spaces	☐	☐	☐	☐	☐
Multiple forests	☐	☐	☐	☐	☐

Multiple road hierarchy	☐	☐	☐	☐	☐
Road condition	☐	☐	☐	☐	☐
Modularity					
Connectivity of street networks and nodes	☐	☐	☐	☐	☐
Green belts and green ways	☐	☐	☐	☐	☐
Robustness					
Sustainability of urban transportation networks (roads, brideges, etc)	☐	☐	☐	☐	☐
Sustainabiloity of urban form	☐	☐	☐	☐	☐
Interdependence					
Integrated road networks	☐	☐	☐	☐	☐

Integrated green infrastructures	☐	☐	☐	☐	☐

Integration

Stakeholder involvement in decision-making process	☐	☐	☐	☐	☐

Questionnaires for experts (Environmental protection Office)

Dear respondents,

I request your voluntary and polite cooperation in providing information requested in this questionnaire to address thesis research entitled "Mainstreaming Resilience thinking into environmental Management practices of Debre Birhan city, Ethiopia". It is provided to collect primary data needed the preparation of a thesis research paper for the partial fulfilment of the degree of Masters of Sciences in Environmental planning and Landscape Design. Therefore, your honest, precise and clear responses will be contributed for success and validity of the study .The study will take full secrecy and confidentiality of the respondents and the data collected.

General Assessment

Profession

☐ Urban planner ☐ Architect ☐ Environmentalist

☐ Geologist ☐ Economist ☐ Sociologist

Position

☐ Department ☐ Case process ☐ Case team

☐ Others (please specify) ----------

Number of years in current working position?

☐ Below 5 years ☐ 6-10 years ☐ 11-20 years ☐ above 20 years

Environmental variables related questions.

Which of the following environmental variables/problems exist in Debre Birhan city?

☐ Surface flooding ☐ Solid waste Management problem ☐ Liquid waste Management problem

☐ Water and wind erosion ☐ Lack of buffer zones ☐ Lack of forests

☐ Lack of urban parks ☐ Lack of playgrounds ☐ Lack of gardens

☐ Lack of squares ☐ Lack of plazas ☐ Land pollution

☐ Water pollution ☐ Loss of agricultural fields

What are the major environmental problems caused by poor Management of the development of green infrastructure and open space in the city?

☐ Land pollution ☐ Water pollution ☐ Soil erosion

☐ Surface flooding ☐ Lack of recreational space ☐ Loss of biodiversity

Which environmental Management tools are implemented to improve urban green and open spaces in the city? (Multiple selection is allowed).

☐ Green space planning ☐ Public park ☐ Urban agriculture

☐ Green campaign ☐ Green buffering ☐ Provision of playground space

☐ Private garden

What solid waste Management mechanisms are practicing in your city to avoid waste problems? (Multiple selection is allowed).

☐ Avoid/reduce at source ☐ Avoid/reduce at transfer station ☐ Reuse at source

☐ Recycle ☐ Compost ☐ Burning

☐ Dispose in landfill

What mitigation measures are being implemented to restore the degraded environment following surface flooding? (Multiple selection is allowed).

☐ Land use planning and zoning	☐ Green campaign	☐ Control land cover change /plan led system of land conversion/
☐ Drainage density	☐ Bench terracing	☐ Proper solid waste Management
☐ Green buffering	☐ Drain diversion	☐ Gabion and sandbagging

Please rate the influence of the aforementioned solutions implemented in the city to mitigate surface flooding.	**Unimportant**	**Of little important**	**Moderately important**	**Important**	**Very important**
	1	**2**	**3**	**4**	**5**
Land use planning and zoning	☐	☐	☐	☐	☐
Green campaign	☐	☐	☐	☐	☐
Control land cover change	☐	☐	☐	☐	☐
Drainage density	☐	☐	☐	☐	☐
Bench terracing	☐	☐	☐	☐	☐
Proper solid waste Management	☐	☐	☐	☐	☐
Green buffering	☐	☐	☐	☐	☐
Drain diversion	☐	☐	☐	☐	☐
Gabion and sandbagging	☐	☐	☐	☐	☐

Which of the following environmental Management tools are implemented to reduce land and water pollution in the city?

☐ Integrated waste Management	☐ Land use planning and zoning	☐ Control land cover change /plan led system land conversion/
☐ River bank rehabilitation	☐ Green campaign	☐ Green buffering
☐ Design of transportation systems	☐ Flood control and protection	☐ Ecological planning /carrying capacity/

Please rate the influence of the following environmental management tools implemented in the city to reduce land and water pollution.	**Unimportant**	**Of little important**	**Moderately important**	**Important**	**Very important**
	1	**2**	**3**	**4**	**5**
Integrated waste management	☐	☐	☐	☐	☐
Land use planning and zoning	☐	☐	☐	☐	☐
Plan led system of land conversion	☐	☐	☐	☐	☐
River bank rehabilitation	☐	☐	☐	☐	☐
Green campaign	☐	☐	☐	☐	☐
Green buffering	☐	☐	☐	☐	☐
Design of transport systems	☐	☐	☐	☐	☐
Flood control and protection	☐	☐	☐	☐	☐
Ecological planning /carrying capacity/	☐	☐	☐	☐	☐

Physical variables related questions.

What mechanisms are implemented to reduce sanitation problems in the city? (Multiple selection is allowed).

- ☐ Providing toilets
- ☐ Providing safe enclosure of the sewerage line
- ☐ Improving drainage facilities
- ☐ Environmental education

What solutions are proposed to improve the city's drainage facilities? (Multiple answers are possible).

- ☐ Increase drain capacity
- ☐ Developing green belts
- ☐ Apply drain cleaner
- ☐ Build rain garden
- ☐ Ecological planning
- ☐ Green belt and green road initiative policy

What is the state of the drainage systems in the city of Debre Birhan?

- ☐ Connected to river banks
- ☐ Closed drainage system
- ☐ Causes for land & water pollution
- ☐ Open drainage system
- ☐ Designed in a proper density
- ☐ Create flooding

Social variables related questions.

What are the social problems/variables exist in Debre Birhan city?

- ☐ Land use compatibility
- ☐ Locational compatibility
- ☐ Informal settlements
- ☐ Access to social service and amenities
- ☐ Land cover change
- ☐ Urban expansion
- ☐ Urban sprawl

Which of the following land use compatibility issue are exist in the city?

- ☐ Polluting industries with settlements
- ☐ Polluting industries with commercial
- ☐ Polluting industries with urban agriculture
- ☐ Urban agriculture with iver banks
- ☐ River with settlements
- ☐ River banks with polluting industries

What environmental Management tools are implemented to reduce the compatibility issues in the city? (Multiple answers are possible).

- ☐ Land use planning and zoning
- ☐ Green buffering
- ☐ River bank rehabilitation
- ☐ Improve drainage systems
- ☐ Waste management

Please rate the following environmental Management tools for the aforementioned compatibility issues in the city.	**Unimportant**	**Of little important**	**Moderately important**	**Important**	**Very important**
	1	2	3	4	5
Land use planning and zoning	☐	☐	☐	☐	☐
Green buffering	☐	☐	☐	☐	☐
River bank rehabilitation	☐	☐	☐	☐	☐
Improve drainage systems	☐	☐	☐	☐	☐
Waste Management	☐	☐	☐	☐	☐

Institutional variables related questions.

What are the major Management problems with the development of green infrastructure and open space in the city?

- ☐ Lack of collaboration
- ☐ Lack public awareness
- ☐ Lack of environmental education
- ☐ Poor Management systems
- ☐ Lack of community participation in decision-making
- ☐ Lack of environmental impact assessment

Which of the following institutional variables are practicing in Debre Birhan city? (Multiple answers are possible).

- ☐ Shared planning
- ☐ Alignment of tasks
- ☐ Objective setting
- ☐ Disclosure of tasks

If you choice shared planning in what issues?

- ☐ Planning new scheme of work between departmental experts and other staffs
- ☐ Content preparing in the area of planning expertise
- ☐ Department-wide approach for revision
- ☐ Proper staff allocation to develop systems

If you choice objective setting in what issues?

- ☐ Increase employees skills and improve performance
- ☐ Improve the institutions Management capability up to departmental level
- ☐ Create new and comfortable working environment
- ☐ Increase the quality of environmental Management practices

If you choice alignment of tasks in what issues?

- ☐ Configuration and relationship of legal, laws and policies from federal to regional and local levels
- ☐ Assigning responsibilities from local government into departmental level
- ☐ Vertical relationship of institution's task
- ☐ Alignment of task from departmental level to individual level

If you choice disclosure of tasks in what issues?

- ☐ Clear division of tasks
- ☐ Consistent task division
- ☐ Balanced task division
- ☐ Proper distribution of tasks in the institution according to the professionals skill

Resilience related questions

Have you seen any of the following listed Resilience principles in your city? (ecological diversity, urban land use /road network condition/, diversity of service centers, multiple nodes, multiple green and open spaces, multiple forests, multiple road hierarchy, connectivity of street networks and nodes, green belts and green ways, and stakeholder involvement).

Yes ☐ No ☐

If yes, please choose from the following options (multiple selection is possible).

- ☐ Ecological diversity
- ☐ Urban land use /road network condition/
- ☐ Diversity of service centers
- ☐ Multiple nodes
- ☐ Multiple green and open spaces
- ☐ Multiple forests
- ☐ Multiple road hierarchy
- ☐ Connectivity of street networks and nodes
- ☐ Green belts and green ways
- ☐ Stakeholder involvement in decision-making

If yes, please rate the importance of the following resilience principles integrated urban environmental management practices.	**Unimportant**	**Of little important**	**Moderately important**	**Important**	**Very important**
	1	**2**	**3**	**4**	**5**
Diversity					
Ecological diversity	☐	☐	☐	☐	☐
Urban land use /road network condition/	☐	☐	☐	☐	☐
Service centers	☐	☐	☐	☐	☐
Redundancy					
Multiple nodes	☐	☐	☐	☐	☐
Multiple green and open spaces	☐	☐	☐	☐	☐
Multiple forests	☐	☐	☐	☐	☐

Multiple road hierarchy	☐	☐	☐	☐	☐
Road condition	☐	☐	☐	☐	☐
Modularity					
Connectivity of street networks and nodes	☐	☐	☐	☐	☐
Green belts and green ways	☐	☐	☐	☐	☐
Robustness					
Sustainability of urban transportation networks (roads, brideges, etc)	☐	☐	☐	☐	☐
Sustainabiloity of urban form	☐	☐	☐	☐	☐
Interdependence					
Integrated road networks	☐	☐	☐	☐	☐

Integrated green infrastructures	☐	☐	☐	☐	☐

Integration

Stakeholder involvement in decision-making process	☐	☐	☐	☐	☐

Questionnaires for experts (Agriculture office)

Dear respondents,

I request your voluntary and polite cooperation in providing information requested in this questionnaire to address thesis research entitled "Mainstreaming Resilience thinking into environmental Management practices of Debre Birhan city, Ethiopia". It is provided to collect primary data needed the preparation of a thesis research paper for the partial fulfilment of the degree of Masters of Sciences in Environmental planning and Landscape Design. Therefore, your honest, precise and clear responses will be contributed for success and validity of the study .The study will take full secrecy and confidentiality of the respondents and the data collected.

General Assessment

Profession

☐ Urban planner ☐ Architect ☐ Environmentalist

☐ Geologist ☐ Economist ☐ Sociologist

Position

☐ Department ☐ Case process ☐ Case team

☐ Others (please specify) ----------

Number of years in current working position?

☐ Below 5 years ☐ 6-10 years ☐ 11-20 years ☐ above 20 years

Environmental variables related questions.

Which of the following environmental variables/problems exist in Debre Birhan city?

☐ Surface flooding ☐ Solid waste Management problem ☐ Liquid waste Management problem

☐ Water and wind erosion ☐ Lack of buffer zones ☐ Lack of forests

☐ Lack of urban parks ☐ Lack of playgrounds ☐ Lack of gardens

☐ Lack of squares ☐ Lack of plazas ☐ Land pollution

☐ Water pollution ☐ Loss of agricultural fields

What mitigation measures are being implemented to restore the degraded environment following surface flooding? (Multiple selection is allowed).

☐ Land use planning and zoning ☐ Green campaign ☐ Control land cover change /plan led system of land conversion/

☐ Drainage density ☐ Bench terracing ☐ Proper solid waste Management

☐ Green buffering ☐ Drain diversion ☐ Gabion and sandbagging

What mitigation measures are being implemented to improve urban agriculture in the city? (Multiple selection is allowed).

☐ Green buffering ☐ Landscape planning ☐ Drain diversion

☐ Bench terracing ☐ Gabion and sandbagging ☐ Wastewater recycling

☐ Rain harvesting ☐ Irrigation ☐ Maintain biodiversity

Physical variables related questions.

What mechanisms implemented to controlling land and water pollution in the city? (Multiple answers are possible).

☐ Waste Management ☐ River bank rehabilitation ☐ Green buffering

☐ Flood control and protection ☐ Controlling informal settlements ☐ Improve drainages systems

What mechanisms are implemented to improve water resource in the city? (Multiple selection is allowed).

- ☐ Green campaign
- ☐ Bench terracing
- ☐ Irrigation systems
- ☐ Preserving biodiversity

Institutional variables related questions.

Which of the following institutional variables are practicing in Debre Birhan city? (Multiple answers are possible).

- ☐ Shared planning
- ☐ Alignment of tasks
- ☐ Objective setting
- ☐ Disclosure of tasks

If you choice shared planning in what issues?

- ☐ Planning new scheme of work between departmental experts and other staffs
- ☐ Content preparing in the area of planning expertise
- ☐ Department-wide approach for revision
- ☐ Proper staff allocation to develop systems

If you choice objective setting in what issues?

- ☐ Increase employees skills and improve performance
- ☐ Improve the institutions Management capability up to departmental level
- ☐ Create new and comfortable working environment
- ☐ Increase the quality of environmental Management practices

If you choice alignment of tasks in what issues?

- ☐ Configuration and relationship of legal, laws and policies from federal to regional and local levels
- ☐ Assigning responsibilities from local government into departmental level
- ☐ Vertical relationship of institution's task
- ☐ Alignment of task from departmental level to individual level

If you choice disclosure of tasks in what issues?

- ☐ Clear division of tasks
- ☐ Consistent task division
- ☐ Balanced task division
- ☐ Proper distribution of tasks in the institution according to the professionals skill

Resilience related questions

Have you seen any of the following listed Resilience principles in your city? (ecological diversity, urban land use /road network condition/, diversity of service centers, multiple nodes, multiple green and open spaces, multiple forests, multiple road hierarchy, connectivity of street networks and nodes, green belts and green ways, and stakeholder involvement).

Yes ☐ No ☐

If yes, please choose from the following options (multiple selection is possible).

- ☐ Ecological diversity
- ☐ Urban land use /road network condition/
- ☐ Diversity of service centers
- ☐ Multiple nodes
- ☐ Multiple green and open spaces
- ☐ Multiple forests
- ☐ Multiple road hierarchy
- ☐ Connectivity of street networks and nodes
- ☐ Green belts and green ways
- ☐ Stakeholder involvement in decision-making

If yes, please rate the importance of the following resilience principles integrated urban environmental management practices.	**Unimportant**	**Of little important**	**Moderately important**	**Important**	**Very important**
	1	**2**	**3**	**4**	**5**
Diversity					
Ecological diversity	☐	☐	☐	☐	☐
Urban land use /road network condition/	☐	☐	☐	☐	☐
Service centers	☐	☐	☐	☐	☐
Redundancy					
Multiple nodes	☐	☐	☐	☐	☐
Multiple green and open spaces	☐	☐	☐	☐	☐
Multiple forests	☐	☐	☐	☐	☐

Multiple road hierarchy	☐	☐	☐	☐	☐
Road condition	☐	☐	☐	☐	☐
Modularity					
Connectivity of street networks and nodes	☐	☐	☐	☐	☐
Green belts and green ways	☐	☐	☐	☐	☐
Robustness					
Sustainability of urban transportation networks (roads, brideges, etc)	☐	☐	☐	☐	☐
Sustainabiloity of urban form	☐	☐	☐	☐	☐
Interdependence					
Integrated road networks	☐	☐	☐	☐	☐

Integrated green infrastructures	☐	☐	☐	☐	☐

Integration

Stakeholder involvement in decision-making process	☐	☐	☐	☐	☐

Questionnaires for experts (Urban infrastructure office)

Dear respondents,

I request your voluntary and polite cooperation in providing information requested in this questionnaire to address thesis research entitled "Mainstreaming Resilience thinking into environmental Management practices of Debre Birhan city, Ethiopia". It is provided to collect primary data needed the preparation of a thesis research paper for the partial fulfilment of the degree of Masters of Sciences in Environmental planning and Landscape Design. Therefore, your honest, precise and clear responses will be contributed for success and validity of the study .The study will take full secrecy and confidentiality of the respondents and the data collected.

General Assessment

Profession

☐ Urban planner ☐ Architect ☐ Environmentalist

☐ Geologist ☐ Economist ☐ Sociologist

Position

☐ Department ☐ Case process ☐ Case team

☐ Others (please specify) ----------

Number of years in current working position?

☐ Below 5 years ☐ 6-10 years ☐ 11-20 years ☐ above 20 years

Environmental variables related questions.

Which of the following environmental variables/problems exist in Debre Birhan city?

☐ Surface flooding ☐ Solid waste Management problem ☐ Liquid waste Management problem

☐ Water and wind erosion ☐ Lack of buffer zones ☐ Lack of forests

- ☐ Lack of urban parks
- ☐ Lack of playgrounds
- ☐ Lack of gardens
- ☐ Lack of squares
- ☐ Lack of plazas
- ☐ Land pollution
- ☐ Water pollution
- ☐ Loss of agricultural fields

Which of the following environmental Management tools are implemented to avoid traffic accident and congestion in the city?

- ☐ Land use Management & transportation planning integration
- ☐ Inclusion of bike lanes
- ☐ Clearly delineated side walks
- ☐ Widening the existing street width

How to rate the influence of the following environmental Management tools implemented in the city to avoid traffic accident and congestion.	**Unimportant**	**Of little important**	**Moderately important**	**Important**	**Very important**
	1	**2**	**3**	**4**	**5**
Land use Management & transportation planning integration	☐	☐	☐	☐	☐
Clearly delineated side walk**s**	☐	☐	☐	☐	☐
Inclusion of bike lanes	☐	☐	☐	☐	☐
Widening the existing street width	☐	☐	☐	☐	☐

Physical variables related questions

Which of the following physical variables/problems in Debre Birhan city?

- ☐ Lack of hierarchy of roads
- ☐ Poor road types
- ☐ Poor road condition
- ☐ Lack of connectivity
- ☐ Narrow street width less than 4 meters
- ☐ Road coverage
- ☐ Poor drainage facilities
- ☐ River bank pollution

What environmental management tools are being implemented to improve road conditions in 'Debre Birhan' city? (Multiple selection is allowed).

- ☐ Road network hierarchy
- ☐ Connectivity
- ☐ Spatial planning
- ☐ Clearly delineated side walks
- ☐ Inclusion of bike lanes
- ☐ Widening the existing street width

Please rate the influence of the above mentioned solutions to improve the road condition in the city.	**Unimportant**	**Of little important**	**Moderately important**	**Important**	**Very important**
	1	2	3	4	5
Road network hierarchy	☐	☐	☐	☐	☐
Connectivity	☐	☐	☐	☐	☐
Spatial planning	☐	☐	☐	☐	☐
Clearly delineated side walks	☐	☐	☐	☐	☐
Inclusion of bike lanes	☐	☐	☐	☐	☐
Widening the existing street width	☐	☐	☐	☐	☐

Is there any road and greening integration in the city?

Yes ☐ No ☐

If yes, what mitigation measures are implemented in road and green development integration?

☐ Collaborative urban design	☐ Creating green vehicular roadways	☐ Integration with footways
☐ Incorporating road median	☐ Ecological planning	☐ Green belt and green road initiative policy

What solutions are proposed to improve the city's drainage facilities?

☐ Increase drain capacity	☐ Developing green belts	☐ Apply drain cleaner
☐ Build rain garden	☐ Ecological planning	☐ Green belt and green road initiative policy

Institutional variables related questions.

What are the major Management problems with the development of green infrastructure and open space in the city? (Multiple answers are possible).

☐ Lack of collaboration	☐ Lack public awareness	☐ Lack of environmental education
☐ Poor Management systems	☐ Lack of community participation in decision-making	☐ Lack of environmental impact assessment

Which of the following institutional variables are practicing in Debre Birhan city? (Multiple answers are possible).

☐ Shared planning ☐ Alignment of tasks

☐ Objective setting ☐ Disclosure of tasks

If you choice shared planning in what issues?

☐ Planning new scheme of work between departmental experts and other staffs

☐ Content preparing in the area of planning expertise

☐ Department-wide approach for revision

☐ Proper staff allocation to develop systems

If you choice objective setting in what issues?

☐ Increase employees skills and improve performance

☐ Improve the institutions Management capability up to departmental level

☐ Create new and comfortable working environment

☐ Increase the quality of environmental Management practices

If you choice alignment of tasks in what issues?

☐ Configuration and relationship of legal, laws and policies from federal to regional and local levels

☐ Assigning responsibilities from local government into departmental level

☐ Vertical relationship of institution's task

☐ Alignment of task from departmental level to individual level

If you choice disclosure of tasks in what issues?

☐ Clear division of tasks ☐ Consistent task division

☐ Balanced task division ☐ Proper distribution of tasks in the institution according to the professionals skill

How do you evaluate the following institutional mitigation mechanisms in the city?	**None**	**Low**	**Medium**	**High**	**Very high**
	1	**2**	**3**	**4**	**5**
Stakeholder involvement	☐	☐	☐	☐	☐
Collaboration among concerned institutions	☐	☐	☐	☐	☐
Management systems	☐	☐	☐	☐	☐
Public awareness	☐	☐	☐	☐	☐
Environmental education	☐	☐	☐	☐	☐
Environmental impact assessment	☐	☐	☐	☐	☐

Resilience related questions

Have you seen any of the following listed Resilience principles in your city? (ecological diversity, urban land use /road network condition/, diversity of service centers, multiple nodes, multiple green and open spaces, multiple forests, multiple road hierarchy, connectivity of street networks and nodes, green belts and green ways, and stakeholder involvement).

Yes ☐ No ☐

If yes, please choose from the following options (multiple selection is possible).

☐ Ecological diversity	☐ Urban land use /road network condition/	☐ Diversity of service centers
☐ Multiple nodes	☐ Multiple green and open spaces	☐ Multiple forests

☐ Multiple road hierarchy

☐ Connectivity of street networks and nodes

☐ Green belts and green ways

☐ Stakeholder involvement in decision-making

If yes, please rate the importance of the following resilience principles integrated urban environmental management practices.	**Unimportant**	**Of little important**	**Moderately important**	**Important**	**Very important**
	1	**2**	**3**	**4**	**5**
Diversity					
Ecological diversity	☐	☐	☐	☐	☐
Urban land use /road network condition/	☐	☐	☐	☐	☐
Service centers	☐	☐	☐	☐	☐
Redundancy					
Multiple nodes	☐	☐	☐	☐	☐
Multiple green and open spaces	☐	☐	☐	☐	☐
Multiple forests	☐	☐	☐	☐	☐

Multiple road hierarchy	☐	☐	☐	☐	☐
Road condition	☐	☐	☐	☐	☐
Modularity					
Connectivity of street networks and nodes	☐	☐	☐	☐	☐
Green belts and green ways	☐	☐	☐	☐	☐
Robustness					
Sustainability of urban transportation networks (roads, brideges, etc)	☐	☐	☐	☐	☐
Sustainabiloity of urban form	☐	☐	☐	☐	☐
Interdependence					
Integrated road networks	☐	☐	☐	☐	☐

Integrated green infrastructures	☐	☐	☐	☐	☐

Integration

Stakeholder involvement in decision-making process	☐	☐	☐	☐	☐

Questionnaires for experts (Land administration and Management)

Dear respondents,

I request your voluntary and polite cooperation in providing information requested in this questionnaire to address thesis research entitled "Mainstreaming Resilience thinking into environmental Management practices of Debre Birhan city, Ethiopia". It is provided to collect primary data needed the preparation of a thesis research paper for the partial fulfilment of the degree of Masters of Sciences in Environmental planning and Landscape Design. Therefore, your honest, precise and clear responses will be contributed for success and validity of the study .The study will take full secrecy and confidentiality of the respondents and the data collected.

General Assessment

Profession

☐ Urban planner ☐ Architect ☐ Environmentalist

☐ Geologist ☐ Economist ☐ Sociologist

Position

☐ Department ☐ Case process ☐ Case team

☐ Others (please specify) ----------

Number of years in current working position?

☐ Below 5 years ☐ 6-10 years ☐ 11-20 years ☐ above 20 years

Environmental variables related questions.

Which of the following environmental variables/problems exist in Debre Birhan city?

☐ Surface flooding ☐ Solid waste Management problem ☐ Liquid waste Management problem

☐ Water and wind erosion ☐ Lack of buffer zones ☐ Lack of forests

☐ Lack of urban parks ☐ Lack of playgrounds ☐ Lack of gardens

☐ Lack of squares ☐ Lack of plazas ☐ Land pollution

☐ Water pollution ☐ Loss of agricultural fields

Which of the following environmental Management tools are implemented to avoid traffic accident and congestion in the city? (Multiple answers are possible).

☐ Land use Management & transportation planning integration ☐ Inclusion of bike lanes

☐ Clearly delineated side walks ☐ Widening the existing street width

Social variables related questions

What are the social problems/variables exist in Debre Birhan city?

☐ Land use compatibility ☐ Locational compatibility ☐ Informal settlements

☐ Access to social service and amenities ☐ Land cover change ☐ Urban expansion

☐ Urban sprawl

Which of the following land use compatibility issue are exist in the city?

☐ Polluting industries with settlements ☐ Polluting industries with commercial ☐ Polluting industries with urban agriculture

☐ Urban agriculture with river banks ☐ River with settlements ☐ River banks with polluting industries

What do you say about the location of polluting industries in the city? (Multiple answers are possible).

☐ Near to river banks
☐ Near to urban agriculture
☐ Ease of accessibility /comfortable to transportation/
☐ Based on structural plan of the city
☐ Considering landscape of the city
☐ River banks with polluting industries

How are the location of urban settlement developments in the area? (Multiple answers are possible).

☐ Near to river banks and polluters
☐ Affects urban agriculture
☐ Protected from polluted industries
☐ Affected by flooding
☐ Informal settlements
☐ Affect sensitive areas /forests, water sources etc/

What environmental Management tools are implemented to reduce the compatibility issues in the city? (Multiple answers are possible).

☐ Land use planning and zoning
☐ Green buffering
☐ River bank rehabilitation
☐ Improve drainage systems
☐ Waste management
☐ Other (please specify)…….

Please rate the following environmental Management tools for the aforementioned compatibility issues in the city.	**Unimportant**	**Of little important**	**Moderately important**	**Important**	**Very important**
	1	2	3	4	5
Land use planning and zoning	☐	☐	☐	☐	☐
Green buffering	☐	☐	☐	☐	☐
River bank rehabilitation	☐	☐	☐	☐	☐
Improve drainage systems	☐	☐	☐	☐	☐
Waste Management	☐	☐	☐	☐	☐

Which of the following mechanisms implemented to reduce informal settlements in the city? (Multiple answers are possible).

- ☐ Compact planning in ecological limits
- ☐ Improve sanitation systems
- ☐ Improve the existing road networks
- ☐ Improving solid waste Management systems
- ☐ Increase vertical developments
- ☐ Develop green infrastructures

What plans do you have to improve access to social services and amenities in the city? (Multiple answers are possible).

- ☐ Land use planning and zoning
- ☐ Making access easier by removing barriers to community services
- ☐ Constructing public spaces (parks, playground etc.)
- ☐ Rehabilitation and concreting of roads
- ☐ Provide walkable access to a complete range of amenities, services and infrastructure
- ☐ Other (please specify)…….

What mitigation measures are you implementing to reduce rapid land cover change in the city? (Multiple answers are possible).

- ☐ Plan led system of land conversion
- ☐ Control of urban expansion
- ☐ Flood control and protection
- ☐ Control urban sprawl

What controlling mechanisms are using to reduce urban sprawling in the city? (Multiple answers are possible).

- ☐ Land use planning and zoning
- ☐ Imparting proper environmental education
- ☐ Compact and mixed urban development strategies

☐ Revitalizing existing urban centers

Institutional variables related questions

Which of the following institutional variables are practicing in Debre Birhan city? (Multiple answers are possible).

☐ Shared planning

☐ Alignment of tasks

☐ Objective setting

☐ Disclosure of tasks

If you choice shared planning in what issues?

☐ Planning new scheme of work between departmental experts and other staffs

☐ Content preparing in the area of planning expertise

☐ Department-wide approach for revision

☐ Proper staff allocation to develop systems

If you choice objective setting in what issues?

☐ Increase employees skills and improve performance

☐ Improve the institutions Management capability up to departmental level

☐ Create new and comfortable working environment

☐ Increase the quality of environmental Management practices

If you choice alignment of tasks in what issues?

☐ Configuration and relationship of legal, laws and policies from federal to regional and local levels

☐ Assigning responsibilities from local government into departmental level

☐ Vertical relationship of institution's task

☐ Alignment of task from departmental level to individual level

If you choice disclosure of tasks in what issues?

☐ Clear division of tasks ☐ Consistent task division

☐ Balanced task division ☐ Proper distribution of tasks in the institution according to the professionals skill

How do you evaluate the following institutional mitigation mechanisms in the city?	**None** **1**	**Low** **2**	**Medium** **3**	**High** **4**	**Very high** **5**
Stakeholder involvement	☐	☐	☐	☐	☐
Collaboration among concerned institutions	☐	☐	☐	☐	☐
Management systems	☐	☐	☐	☐	☐
Public awareness	☐	☐	☐	☐	☐
Environmental education	☐	☐	☐	☐	☐
Environmental impact assessment	☐	☐	☐	☐	☐

Which of the following offices collaborated in the decision-making process?	None	Plan preparation	Plan implementa	Research capacity building
Infrastructure Development Office (Drainage)	☐	☐	☐	☐
Sanitation and Beautification Office	☐	☐	☐	☐
Urban Development and Housing office	☐	☐	☐	☐
Environment Protection Office	☐	☐	☐	☐
Urban agriculture office	☐	☐	☐	☐
Land administration and management	☐	☐	☐	☐
Waste management	☐	☐	☐	☐
Water and sewerage service	☐	☐	☐	☐

Resilience related questions

Have you seen any of the following listed Resilience principles in your city? (ecological diversity, urban land use /road network condition/, diversity of service centers, multiple nodes, multiple green and open spaces, multiple forests, multiple road hierarchy, connectivity of street networks and nodes, green belts and green ways, and stakeholder involvement).

Yes ☐ No ☐

If yes, please choose from the following options (multiple selection is possible).

☐ Ecological diversity

☐ Urban land use /road network condition/

☐ Diversity of service centers

☐ Multiple nodes

☐ Multiple green and open spaces

☐ Multiple forests

☐ Multiple road hierarchy

☐ Connectivity of street networks and nodes

☐ Green belts and green ways

☐ Stakeholder involvement in decision-making

If yes, please rate the importance of the following resilience principles integrated urban environmental management practices.	**Unimportant**	**Of little important**	**Moderately important**	**Important**	**Very important**
	1	**2**	**3**	**4**	**5**
Diversity					
Ecological diversity	☐	☐	☐	☐	☐
Urban land use /road network condition/	☐	☐	☐	☐	☐
Service centers	☐	☐	☐	☐	☐
Redundancy					
Multiple nodes	☐	☐	☐	☐	☐
Multiple green and open spaces	☐	☐	☐	☐	☐
Multiple forests	☐	☐	☐	☐	☐

Multiple road hierarchy	☐	☐	☐	☐	☐
Road condition	☐	☐	☐	☐	☐
Modularity					
Connectivity of street networks and nodes	☐	☐	☐	☐	☐
Green belts and green ways	☐	☐	☐	☐	☐
Robustness					
Sustainability of urban transportation networks (roads, brideges, etc)	☐	☐	☐	☐	☐
Sustainabiloity of urban form	☐	☐	☐	☐	☐
Interdependence					
Integrated road networks	☐	☐	☐	☐	☐

Integrated green infrastructures	☐	☐	☐	☐	☐

Integration

Stakeholder involvement in decision-making process	☐	☐	☐	☐	☐

Questionnaires for experts (Urban development and Housing office)

Dear respondents,

I request your voluntary and polite cooperation in providing information requested in this questionnaire to address thesis research entitled "Mainstreaming Resilience thinking into environmental Management practices of Debre Birhan city, Ethiopia". It is provided to collect primary data needed the preparation of a thesis research paper for the partial fulfilment of the degree of Masters of Sciences in Environmental planning and Landscape Design. Therefore, your honest, precise and clear responses will be contributed for success and validity of the study .The study will take full secrecy and confidentiality of the respondents and the data collected.

General Assessment

Profession

☐ Urban planner ☐ Architect ☐ Environmentalist

☐ Geologist ☐ Economist ☐ Sociologist

Position

☐ Department ☐ Case process ☐ Case team

☐ Others (please specify) ----------

Number of years in current working position?

☐ Below 5 years ☐ 6-10 years ☐ 11-20 years ☐ above 20 years

Environmental variables related questions.

Which of the following environmental variables/problems exist in Debre Birhan city?

☐ Surface flooding ☐ Solid waste Management problem ☐ Liquid waste Management problem

☐ Water and wind erosion ☐ Lack of buffer zones ☐ Lack of forests

☐ Lack of urban parks ☐ Lack of playgrounds ☐ Lack of gardens

☐ Lack of squares ☐ Lack of plazas ☐ Land pollution

☐ Water pollution ☐ Loss of agricultural fields

What are the major environmental problems caused by poor Management of the development of green infrastructure and open space in the city? (Multiple answers are possible).

☐ Land pollution ☐ Water pollution ☐ Soil erosion

☐ Surface flooding ☐ Lack of recreational space ☐ Loss of biodiversity

Which environmental Management tools are implemented to improve urban green and open spaces in the city? (Multiple selection is allowed).

☐ Green space planning ☐ Public park ☐ Urban agriculture

☐ Green campaign ☐ Green buffering ☐ Provision of playground space

How to rate the influence of the following environmental management tools implemented to improve green and open spaces in the city.	**Unimportant**	**Of little important**	**Moderately important**	**Important**	**Very important**
	1	**2**	**3**	**4**	**5**
Green space planning	☐	☐	☐	☐	☐
Urban Park development	☐	☐	☐	☐	☐
Green campaign	☐	☐	☐	☐	☐
Green buffering	☐	☐	☐	☐	☐
Urban agriculture	☐	☐	☐	☐	☐
Provision of playground space	☐	☐	☐	☐	☐

Institutional variables related questions

Which of the following institutional variables are practicing in Debre Birhan city? (Multiple answers are possible).

- ☐ Shared planning
- ☐ Alignment of tasks
- ☐ Objective setting
- ☐ Disclosure of tasks

If you choice shared planning in what issues?

- ☐ Planning new scheme of work between departmental experts and other staffs
- ☐ Content preparing in the area of planning expertise
- ☐ Department-wide approach for revision
- ☐ Proper staff allocation to develop systems

If you choice objective setting in what issues?

- ☐ Increase employees skills and improve performance
- ☐ Improve the institutions Management capability up to departmental level
- ☐ Create new and comfortable working environment
- ☐ Increase the quality of environmental Management practices

If you choice alignment of tasks in what issues?

- ☐ Configuration and relationship of legal, laws and policies from federal to regional and local levels
- ☐ Assigning responsibilities from local government into departmental level
- ☐ Vertical relationship of institution's task
- ☐ Alignment of task from departmental level to individual level

If you choice disclosure of tasks in what issues?

- ☐ Clear division of tasks
- ☐ Consistent task division

☐ Balanced task division ☐ Proper distribution of tasks in the institution according to the professionals skill

How do you evaluate the following institutional mitigation mechanisms in the city?	**None** **1**	**Low** **2**	**Medium** **3**	**High** **4**	**Very high** **5**
Stakeholder involvement	☐	☐	☐	☐	☐
Collaboration among concerned institutions	☐	☐	☐	☐	☐
Management systems	☐	☐	☐	☐	☐
Public awareness	☐	☐	☐	☐	☐
Environmental education	☐	☐	☐	☐	☐
Environmental impact assessment	☐	☐	☐	☐	☐

Resilience related questions

Have you seen any of the following listed Resilience principles in your city? (ecological diversity, urban land use /road network condition/, diversity of service centers, multiple nodes, multiple green and open spaces, multiple forests, multiple road hierarchy, connectivity of street networks and nodes, green belts and green ways, and stakeholder involvement).

Yes ☐ No ☐

If yes, please choose from the following options (multiple selection is possible).

☐ Ecological diversity ☐ Urban land use /road network condition/ ☐ Diversity of service centers

- ☐ Multiple nodes
- ☐ Multiple green and open spaces
- ☐ Multiple forests
- ☐ Multiple road hierarchy
- ☐ Connectivity of street networks and nodes
- ☐ Green belts and green ways
- ☐ Stakeholder involvement in decision-making

If yes, please rate the importance of the following resilience principles integrated urban environmental management practices.	**Unimportant**	**Of little important**	**Moderately important**	**Important**	**Very important**
	1	**2**	**3**	**4**	**5**
Diversity					
Ecological diversity	☐	☐	☐	☐	☐
Urban land use /road network condition/	☐	☐	☐	☐	☐
Service centers	☐	☐	☐	☐	☐
Redundancy					
Multiple nodes	☐	☐	☐	☐	☐
Multiple green and open spaces	☐	☐	☐	☐	☐
Multiple forests	☐	☐	☐	☐	☐

Multiple road hierarchy	☐	☐	☐	☐	☐
Road condition	☐	☐	☐	☐	☐
Modularity					
Connectivity of street networks and nodes	☐	☐	☐	☐	☐
Green belts and green ways	☐	☐	☐	☐	☐
Robustness					
Sustainability of urban transportation networks (roads, brideges, etc)	☐	☐	☐	☐	☐
Sustainabiloity of urban form	☐	☐	☐	☐	☐
Interdependence					
Integrated road networks	☐	☐	☐	☐	☐

Integrated green infrastructures	☐	☐	☐	☐	☐

Integration

Stakeholder involvement in decision-making process	☐	☐	☐	☐	☐

Questionnaires for experts (Water and Sewerage service)

Dear respondents,

I request your voluntary and polite cooperation in providing information requested in this questionnaire to address thesis research entitled "Mainstreaming Resilience thinking into environmental Management practices of Debre Birhan city, Ethiopia". It is provided to collect primary data needed the preparation of a thesis research paper for the partial fulfilment of the degree of Masters of Sciences in Environmental planning and Landscape Design. Therefore, your honest, precise and clear responses will be contributed for success and validity of the study .The study will take full secrecy and confidentiality of the respondents and the data collected.

General Assessment

Profession

☐ Urban planner ☐ Architect ☐ Environmentalist

☐ Geologist ☐ Economist ☐ Sociologist

Position

☐ Department ☐ Case process ☐ Case team

☐ Others (please specify) ----------

Number of years in current working position?

☐ Below 5 years ☐ 6-10 years ☐ 11-20 years ☐ above 20 years

Environmental variables related questions.

Which of the following environmental variables/problems exist in Debre Birhan city?

☐ Surface flooding ☐ Solid waste Management problem ☐ Liquid waste Management problem

☐ Water and wind erosion ☐ Lack of buffer zones ☐ Lack of forests

☐ Lack of urban parks ☐ Lack of playgrounds ☐ Lack of gardens

☐ Lack of squares ☐ Lack of plazas ☐ Land pollution

☐ Water pollution ☐ Loss of agricultural fields

What are the major environmental problems caused by poor Management of the development of green infrastructure and open space in the city? (Multiple answers are possible).

☐ Land pollution ☐ Water pollution ☐ Soil erosion

☐ Surface flooding ☐ Lack of recreational space ☐ Loss of biodiversity

Which environmental Management tools are implemented to improve urban green and open spaces in the city? (Multiple selection is allowed).

☐ Green space planning ☐ Public park ☐ Urban agriculture

☐ Green campaign ☐ Green buffering ☐ Provision of playground space

☐ Private garden

What greening mitigation measures are being implemented to control water pollution? (Multiple selection is allowed).

☐ Green space planning ☐ Green campaign

☐ Green buffering ☐ Rain garden

Physical variables related questions.

What mechanisms are implemented to reduce sanitation problems in the city? (Multiple selection is allowed).

☐ Providing toilets

☐ Providing safe enclosure of the sewerage line

☐ Improving drainage facilities

☐ Environmental education

What mechanisms are implemented to improve water resource in the city? (Multiple selection is allowed).

☐ Green campaign

☐ Bench terracing

☐ Irrigation systems

☐ Preserving biodiversity

Institutional variables related questions

Which of the following institutional variables are practicing in Debre Birhan city? (Multiple answers are possible).

☐ Shared planning

☐ Alignment of tasks

☐ Objective setting

☐ Disclosure of tasks

If you choice shared planning in what issues?

☐ Planning new scheme of work between departmental experts and other staffs

☐ Content preparing in the area of planning expertise

☐ Department-wide approach for revision

☐ Proper staff allocation to develop systems

If you choice objective setting in what issues?

☐ Increase employees skills and improve performance

☐ Improve the institutions Management capability up to departmental level

☐ Create new and comfortable working environment

☐ Increase the quality of environmental Management practices

If you choice alignment of tasks in what issues?

☐ Configuration and relationship of legal, laws and policies from federal to regional and local levels

☐ Assigning responsibilities from local government into departmental level

☐ Vertical relationship of institution's task

☐ Alignment of task from departmental level to individual level

If you choice disclosure of tasks in what issues?

☐ Clear division of tasks

☐ Consistent task division

☐ Balanced task division

☐ Proper distribution of tasks in the institution according to the professionals skill

How do you evaluate the following institutional mitigation mechanisms in the city?	**None** **1**	**Low** **2**	**Medium** **3**	**High** **4**	**Very high** **5**
Stakeholder involvement	☐	☐	☐	☐	☐
Collaboration among concerned institutions	☐	☐	☐	☐	☐
Management systems	☐	☐	☐	☐	☐
Public awareness	☐	☐	☐	☐	☐
Environmental education	☐	☐	☐	☐	☐
Environmental impact assessment	☐	☐	☐	☐	☐

Resilience related questions

Have you seen any of the following listed Resilience principles in your city? (ecological diversity, urban land use /road network condition/, diversity of service centers, multiple nodes, multiple green and open spaces, multiple forests, multiple road hierarchy, connectivity of street networks and nodes, green belts and green ways, and stakeholder involvement).

Yes ☐ No ☐

If yes, please choose from the following options (multiple selection is possible).

☐ Ecological diversity	☐ Urban land use /road network condition/	☐ Diversity of service centers
☐ Multiple nodes	☐ Multiple green and open spaces	☐ Multiple forests
☐ Multiple road hierarchy	☐ Connectivity of street networks and nodes	☐ Green belts and green ways
☐ Stakeholder involvement in decision-making		

If yes, please rate the importance of the following resilience principles integrated urban environmental management practices.	**Unimportant**	**Of little important**	**Moderately important**	**Important**	**Very important**
	1	**2**	**3**	**4**	**5**
Diversity					
Ecological diversity	☐	☐	☐	☐	☐
Urban land use /road network condition/	☐	☐	☐	☐	☐
Service centers	☐	☐	☐	☐	☐
Redundancy					
Multiple nodes	☐	☐	☐	☐	☐
Multiple green and open spaces	☐	☐	☐	☐	☐
Multiple forests	☐	☐	☐	☐	☐

Multiple road hierarchy	☐	☐	☐	☐	☐
Road condition	☐	☐	☐	☐	☐
Modularity					
Connectivity of street networks and nodes	☐	☐	☐	☐	☐
Green belts and green ways	☐	☐	☐	☐	☐
Robustness					
Sustainability of urban transportation networks (roads, brideges, etc)	☐	☐	☐	☐	☐
Sustainabiloity of urban form	☐	☐	☐	☐	☐
Interdependence					
Integrated road networks	☐	☐	☐	☐	☐

Integrated green infrastructures	☐	☐	☐	☐	☐

Integration

Stakeholder involvement in decision-making process	☐	☐	☐	☐	☐

Annex IV: Site observation checklist

Observation using base map of the city, Google Earth images of the city, tracking using GPS essential from mobile and photograph.

1. Identification of land use compatibility in inner cities and the periphery of the city.
2. Identifying the condition of agricultural fields at the city center and city interface.
3. Assessing the condition of river banks in the city.
4. Observation on main nodes and sub centers.
5. Assessing the waste management mechanisms in the city.
6. Road network condition in inner and the periphery of the city.
7. Topographic conditions and the most flooded areas in the city.
8. Road network and transportation condition of the inner and periphery of the city.
9. The main municipal drainage condition and waste management systems of the city.

Annex v: Urban environmental management tools and problems to addressed in cities

Urban environmental Management tools	Mitigation techniques in each Management tools	Major problems to addressed in cities
Land use planning & zoning	Green buffering, improving drainage systems, waste management, functional land use planning, river bank rehabilitation	Land use & locational incompatibility, lack of access to social services and amenities, urban expansion, urban sprawl
Solid waste Management	Avoid/reduce at source and transfer station, recycling, composting, open burn, dispose landfill	Land & water pollution
Watershed Management	River rehabilitation, green buffering, green space planning	Land & water pollution, flooding
Flood protection & control	Land use planning & zoning, drainage density, green campaign, green buffering, drain diversion, bench terracing, gabion & sand bagging, controlling land cover change	Land & water pollution, flooding
Green and open space planning	Green campaign, green space planning, park development, open field development, green buffering	Lack of green & open spaces, land & water pollution
Urban agriculture	Manage farming plots	Shortage of greening
Transportation planning	Road hierarchy & connectivity, clearly delineated sidewalks, inclusion of bike lanes, widening existing road width.	Physical problem (road condition), traffic accident & congestion
Environmental impact assessment	Environmental management plan, risk assessment, impact zone	Water & land pollution
River bank rehabilitation	Green buffering, drainage and sanitation improvement, ecological planning	Water & land pollution, flooding

Collaboration among institutional structures and stakeholder involvement	Public participation and collaboration	Decision-making process