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Urban (un)planning and social vulnerability in the context of rapid urbanization and data constraints: a quantitative study of Dar es Salaam, Tanzania.

Sheliza Bhanjee
University of Louisville

URBAN (UN)PLANNING AND SOCIAL VULNERABILITY IN THE CONTEXT OF RAPID URBANIZATION AND DATA CONSTRAINTS: A QUANTITATIVE STUDY OF DAR ES SALAAM, TANZANIA

By

Sheliza Bhanjee
B.S., Georgia Institute of Technology, 2009
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A Dissertation Approved on

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by the following Dissertation Committee:

_____
Dissertation Director
Dr. Sumei Zhang

_____
Dr. David Simpson

_____
Dr. Margath Walker

_____
Dr. Alex Awiti

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ABSTRACT

URBAN (UN)PLANNING AND SOCIAL VULNERABILITY IN THE CONTEXT OF RAPID URBANIZATION AND DATA CONSTRAINTS: A QUANTITATIVE STUDY OF DAR ES SALAAM, TANZANIA

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This dissertation explores intersections between vulnerability and urban planning in Sub-Saharan Africa, where distinct forms of urbanization are occurring and where there are significant data constraints limiting local studies and urban assessments in the region. The three studies which make up this dissertation offer methodological and theoretical pathways toward examining and measuring the influence of urbanization and planning factors on vulnerability of urban populations in the region. The first study is a literature review and examines existing literature for vulnerability conceptualization in urban environments, the notion of 'urban vulnerability', and roles of urban planning and related factors in relation to vulnerability specifically in the sub-Saharan context. The second study explores approaches to quantitatively constructing more recent urban land use data in the absence of available land use datasets in the Sub-Saharan context, particularly data with informal and formal urban land use distinctions. The third study offers a methodology and estimation models to measure and quantify planning and urbanization variables (sprawl) in

vulnerability assessment. Dar es Salaam, Tanzania serves as the study area because of its rapid urbanization processes, substantial informal development and sprawling, as well as availability of reliable datasets for recent years (2014/2015) for the vulnerability assessment.

Findings of the literature review include challenges in conceptualizing vulnerability in an urban environment beyond a climate focus, gaps in urban vulnerability conceptualization, underrepresentation of planning factors and measurement in vulnerability assessment, and limitations in local and urban data availability and studies in Sub-Saharan cities. Results for the second study include the construction of a 2014 urban land use dataset based on estimates from binomial logistic regression models. Results for the third study indicate formally planned urban areas are associated with higher level of quality of life and mobility. Further results indicate no impact of sprawl on social vulnerability factors of residents in the urban areas of Dar es Salaam, however, informal (i.e. unplanned) sprawl impacts residents negatively. These results provide initial steps toward investigating the influence of broader planning and spatial aspects in quantitative urban social vulnerability assessments in the Sub-Saharan context as well as similar contexts in the global south.

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CHAPTER ONE: INTRODUCTION

1.1 Background

In recent decades, Sub-Saharan countries have experienced high rates of urbanization caused by substantial rural-to-urban migrations as well as naturally growing urban populations (OECD, 2017). As African urban population rates continue to increase, and cities expand to accommodate growth with limited formal planning, consequent uncontrolled land use changes become a pressing concern. The rapid, unplanned growth has resulted in urban sprawl in many cases and poses challenges for sustainable land development (Cobbinah & Aboagye, 2017; Mercer, 2017). For example, uncontrolled sprawl is argued to increase air and water pollution, land and scenery pollution, and result in loss of biodiversity, which can increase vulnerabilities in populations subjected to these processes in various ways (Rugai & Kassenga, 2014). Furthermore, informal settlements have magnified vulnerability to climate change hazards by being located in physically risky areas (i.e low lying areas) and for poor populations who typically reside in those areas with limited choices for elsewhere to live (Tiepolo & Macchi, 2014). Scholars have noted low income populations are often the most vulnerable (Baker, 2012) and disasters can intensify poverty, creating more barriers to opportunities and growth for these populations (Salami et al., 2017).

Given the complex and dynamic form of urbanization, it is unclear how planning and government agencies can address issues effectively, especially with continuing informal growth. Watson (2002) suggests planners "should only proceed on the basis of a thorough understanding of the socio-spatial and political processes which shape the contexts" within which planners work (p.28). Similarly, Lupala (2002) citing Jelinek (1992) suggests that lack of knowledge of processes and development in cities leads to policy failures. Hence, a thorough understanding of the driving factors and the connections of these factors to the spatial form is necessary for planning as they impact the city, populations, and the surrounding environment. It is also useful to pinpoint these factors so that planners, decision makers, and stakeholders have accurate knowledge bases for understanding cities and thus direct development according to their objectives efficiently and equitably.

Although some theories have been put forth and tested by various scholars in the literature, there are not enough up-to-date studies with a better understanding of urbanization, urban planning, and vulnerability in African cities. Also, because of the various informal actors who contribute to informal growth outside of the knowledge and power of governing bodies, there is missing data on informal developments as well as unclear understanding of future directions of development (UN Habitat, 2015; Wehrmann, 2014). Therefore, scholars have suggested the need for more research and knowledge (Turok, 2016) as well as the need for a form of planning which cannot give in to "simplified importations from very different parts of the world" as pathways to move forward (Watson, 2002, p.47).

1.2 Study overview

The situation presented led to a proposal of the following broad questions: (1) what is the current knowledge of intersections between Sub-Saharan urbanization, urban planning, and vulnerability in the scholarly literature (2) how to address the issues of limited availability of data in the juncture of these fields, and (3) what is the influence of urban planning in mitigating vulnerabilities of urban populations in Sub-Saharan cities? The dissertation aims to engage these questions, first by synthesis of Sub-Saharan scholarly literature and second by focusing on the East African coastal city of Dar es Salaam in Tanzania as the case study area for specific quantitative analysis. This research makes contributions to understanding how distinct urbanization factors and urban planning in Sub-Saharan Africa intersect with vulnerability. It also quantifies planning, informal settlement, and sprawl variables for vulnerability assessment and develops quantitative models measuring the influence of these variables on household vulnerability. Because of global datasets used, these models could be applied to other global south contexts as well.

1.3 The Dar es Salaam Context

The East African country of Tanzania alone is expected to add 61.5 million people to its urban areas from 2010 to 2050 (Locke & Henley, 2016). The city of Dar es Salaam is notable to focus on as it has been urbanizing rapidly in recent decades. Figure 1 illustrates the location of Dar es Salaam. In 2010 it was ranked the 10th fastest growing city globally and the third fastest growing city on the continent of Africa (Dar es Salaam City Council, 2010; Hill & Lindner, 2011). Within Tanzania, it is the largest city and home to one third of the country's urban residents (Andreasen & Moller-Jenson, 2017; Locke & Henley,

2016). The city has a high population density, with 90% of its population residing on 12.5% of the city area (Lupala, 2015).

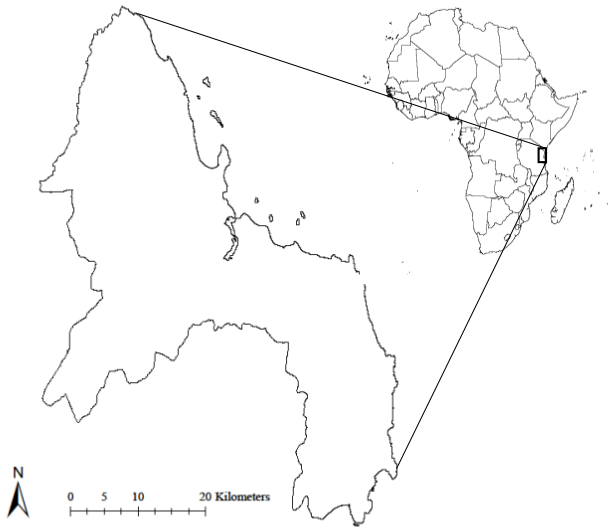

Figure 1.1: Location of Dar es Salaam, Tanzania in Africa.

1.3.1 History of Planning in Dar es Salaam

Colonial planning practices shaped the Dar es Salaam urban form from the early 20th century and continued to influence planning practice until 1979, when the last master plan was approved (Bissell, 2011; Lupala, 2002). With regard to informal settlements in particular, "accurate, localized, standardized, and available qualitative and quantitative data…remain limited" and the data which does exist is "often ad hoc…so the dimensions of inhabitants' lives remain unknown to policy and planning responses" (UN Habitat, 2015, p.5). Furthermore, there are peri-urban areas which fall outside of the city jurisdictions, making governance and planning challenging (ibid).

1.3.2 Land Tenure and Land Markets

Land in Tanzania was nationalized in 1967, making the sale of land illegal (Briggs & Mwapfupe, 1999; Kombe, 1994). This is not uncommon throughout Sub-Saharan Africa. As of the year 2000, at least 20 out of 40 Sub-Saharan countries had nationalized land (Kironde, 2000). Since 1974, land in Dar es Salaam has been allocated administratively (Kironde, 1995), but allocation standards and administrative systems put in place to manage land and planning have been proven to be inadequate, impractical, and unable keep up with the demand of the growing population (Briggs & Mwapfupe, 1999; Kironde, 2006).

These inadequacies of planning and government administration opened the way for unregulated, informal land markets to thrive and constitute a majority of the land transactions in Dar es Salaam (Hill et al, 2014). For example, Kironde (2006) notes that the process for making legal land available typically takes more than nine years, leading to another process of access to the legalized land, which takes another minimum of three years to complete. He notes from the period 1990 to 2001, only 8209 plots were allocated out of 243,473 applications submitted. Compared to access of formal land which can take years, access to informal land can take as little time as one week (ibid). It is not surprising that over 70% of residents in Tanzania live in informal areas, one of the highest percentages in all of Sub-Saharan Africa, with estimates of around 65% to 90% informal residency in Dar es Salaam (Kombe & Kreibich, 2006; Kyessi & Furaha, 2010; Penrose et al., 2010; Rasmussen, 2013). Kironde (2006) also notes that from 1990 the count of informal settlements more than doubled from 40 settlements to over 100 in 2002.

In Dar es Salaam, various forms of unplanned land exist including informal land (with vague tenure status), customary land (communal or customary land occupation), and quasi-customary land (formerly customary land but no longer) (Kironde, 2006; Hill & Lindner, 2010). Unplanned land in Dar es Salaam is not necessarily illegal or disorganized (Kironde, 2006; Kombe, 2001). The Land Act of 1999 and National Land Policy of 1995 both "validate much of the urban land acquired otherwise than through the grant of a right occupancy" (p.464) and provide licenses of residency to land owners in unplanned areas. Based on these policies, a backward formalization process was implemented in which land informally acquired and developed was given some form of title of ownership (Hill & Lindner, 2011). Therefore, although the land might have been illegally acquired or developed, it is not necessarily illegally occupied because of these policies as well as acknowledgement of customary or traditional lands (Kyessi & Furaha, 2010).

It is also important to note that in Dar es Salaam informal settlements are not limited to low income residents; they are spaces where middle to high-income residents have situated themselves (Kalabamu, 1992; Kironde, 2000). As Roy (2009) argues, informality is not necessarily always linked to poverty. Lupala (2002) suggests that in this sense, the legality of land ownership in Dar es Salaam is not as important as it may be in other contexts where policies view informal settlements negatively. Although this may have been the case in the past for Dar es Salaam, the extent and pervasiveness of informality as well as the diversity of informal areas brought about the shift to more positive and inclusive policies (Hill & Lindner, 2010).

Several scholars note the awareness of these issues at the national level by some of the policies which aim to include more diverse community voices in planning and

governance or formalize unplanned areas for more secure tenure and investment in residences (Dodman et al., 2011; Kiunsi, 2013; Kironde, 2006, Lupala, 2002). However, at the local level, these policies are argued to be not realized and not effective on a significant level (Congedo & Macchi, 2015; Dodman et al., 2011; Kiunsi, 2013; Kironde, 2006; Lupala, 2002). For example, providing licenses to informal developments is a difficult and lengthy process (Kironde, 2006) and has not been implemented extensively or consistently (Wehrmann, 2014). Furthermore, Rasmussen (2013) notes that although informal settlements house around a majority of the residents in Dar es Salaam, they are absent from the city's planning visions for 2030. Therefore, there are many factors at play in driving and managing urban growth in Dar es Salaam in ways that are conflicting, inequitable, and occur with insufficient knowledge of its population, environment, and processes. However, planning is not enough. Bissell (2011) argues that in Tanzania, neoliberal policies and political culture are greater barriers to sustainable development which cannot simply be managed by planning structure or intervention. An example is provided by Kironde (2006) drawing from McAuslan (1989) who suggests that planning in Dar es Salaam mostly favors the "political elite rather than those of the majority" (p.462).

1.4 Outline of chapters

The dissertation is structured as five chapters, with three chapters focusing on each broad question posed in the study, bound by an introduction and conclusion. The current introduction chapter lays out background information and the organization of the dissertation. The second chapter explores the scholarly literature to understand how urbanization, vulnerability, and planning in the urban context have been linked and

articulated specifically in Sub-Saharan Africa. It is a literature review which aims to distill the current state of knowledge of vulnerability and urban planning to outline challenges in the nexus of these fields as well as guide ways forward for research and future studies to strengthen the evidence bases. From the broader notions, the chapter introduces major sub-concepts between vulnerability and planning in the urban context, including governance, informal development, land use, and urban sprawl. Within these concepts and sub-concepts, theoretical paradigms are weaved in, such as the impact of colonial planning continuing to shape the postcolonial urban form, meanings of informality, and the fragmented state of vulnerability studies related to the urban.

The third chapter confronts the question of how to address the issues of limited availability of data, concentrating on Dar es Salaam as the case study area. Because land use is an essential urban planning concept, this chapter offers a quantitative methodology which estimates planned residential and informal settlement land uses within an urban boundary of Dar es Salaam, Tanzania. The method uses GIS and logistic regression analysis on various sets of multi-temporal data to provide reliable and more up-to-date (2014) land use data than current openly available land use data for the city, particularly of informal data. Thus, the study outlined in this chapter creates a dataset for further vulnerability and planning research for Dar es Salaam where previously data limitations existed. Although Dar es Salaam was the case study for this chapter, the methodology could be applied to other contexts as several openly-available global multi-temporal datasets were utilized.

The fourth chapter quantitatively tests the influence of planning on social vulnerability factors in Dar es Salaam integrating household as well as greater urban scale

variables. The study uses GIS and statistical techniques to develop two social vulnerability indices (quality of life and mobility) which incorporate planning-related variables (sprawl and land use) as well as social-economic and built environment factors. Separating the social vulnerability indices into quality of life and mobility enables a pointed analysis of the influence of planning factors on vulnerability. Several openly sourced datasets were utilized in this study as well, including geocoded household socio-economic survey data, roads data, and population density data at acceptable resolutions. Various datasets were merged owing to the availability of spatial data.

Lastly, the fifth chapter provides a conclusion and summarizes the findings, contributions, and ways forward for future studies building on the current study.

CHAPTER TWO: INTERSECTIONS OF URBAN PLANNING AND VULNERABILITY IN SUB-SAHARAN AFRICA – A LITERATURE REVIEW

2.1 Introduction

Rapid and unexpected changes in global climate and booming urbanization and urban development in the global south are bringing attention to conceptualizing and measuring urban vulnerabilities resulting from these activities and processes (Lankao & Qin, 2011). Urban built and social environment characteristics, such as densely concentrated populations and activities, complex socio-economic systems, and bases of major political and economic institutions, make the urban space a crucial center of analysis for vulnerability studies as increasing and concentrated vulnerabilities lead to greater disaster risk (Wamsler et al., 2013). Studies taking into consideration the urban setting in environmental or social vulnerability studies exist within the climate change or disaster and risk literature, however, newer trends are moving toward defining an 'urban vulnerability' in itself whereby the urban is the focal system within which urban-specific hazards and stressors are identified. The conceptualization of the urban as a system (Meerow et al., 2016) and not simply a study area is key in order to explore multiple urban stressors beyond climate hazards. Still, few comprehensive urban vulnerability frameworks are put forth without focusing on one specific climate hazard or social stressor such as poverty (Lankao & Qin, 2011; Xiu et al, 2016). Fewer studies explicitly account for urban

planning and governance influences on managing or mitigating vulnerabilities in urban settings and as a result of urban processes and activities, particularly in Sub-Saharan Africa, where urbanization is expected to increase substantially in secondary and intermediate cities and in distinct forms from other parts of the world (i.e. limited infrastructure investment and job creation) (Battersby & Watson, 2018).

This paper examines the current scholarly literature for (1) existing meanings of vulnerability in an urban environment, including 'urban vulnerability' as a concept and (2) roles of urban planning and planning-related factors in vulnerability studies in Sub-Saharan cities, especially where informal development dominates growth (World Bank, 2015). This knowledge may be important for planners and decision-makers to work toward mitigating or preventing harmful consequences of various urban social hazards before presenting ways forward. While formal urban planning in African cities arguably has been misdirected and ineffective (by evidence of proliferation of unplanned and informal developments) (Turok, 2016), it is still an active participant in many cities, contributing to the urban form and activities both directly and indirectly. Thus, the influence of urban planning in urban vulnerability is important to examine.

There are five main sections in this literature review. Section 2.2 introduces various meanings and presence of vulnerability broadly within the social science and climate change literature and summarizes how vulnerability has been operationalized. Section 2.3 examines urban planning and vulnerability associations specifically in Sub-Saharan Africa. It breaks down planning into sub-sections including governance, informal development, and urban land to unpack more dimensions of urban planning in vulnerability studies and

assessments. Section 2.4 discusses challenges in the urban planning and vulnerability nexus as well as directions for future work. The final section concludes the paper.

2.2 Vulnerability in an Urban Environment

Vulnerability has been defined, conceptualized, and theorized in numerous ways, with limited agreement on any one way to approach the topic (Wolf et al., 2013; Kienberger et al., 2013). It is not a static concept, but dynamic, multidimensional, and changing with time and space, and applicable to systems, populations, or other unit of analysis (Lee, 2014; St. Bernard, 2004). Scholars have noted the shifting meanings of vulnerability over time, especially utilized across disciplines including geography, economics, health, engineering, and anthropology, among others (Mavhura et al., 2017; Krellenberg et al., 2016; Eakin & Luers, 2006; Wolf et al., 2013; Xui et al., 2016). Differences in approach and conceptualization of vulnerability as well as the unclear connections to resilience make navigating the vulnerability literature and application to real world contexts difficult (Xiu et al, 2016).

Despite the variations, there are basic elements to understand vulnerability outlined by Wolf et al. (2013) which provide some universal foundation for the term. These elements include: (1) an entity (i.e. person, group, or system), (2) stimulus (i.e. hazard, event, stressor), (3) uncertain future evolution (i.e. capacity or difficulty to cope), and (4) the notion of harm (i.e. stress, loss, negative impact). Breaking down the basic elements of vulnerability focuses on important components of vulnerability and allows for various forms of application of the concept in different fields of interest.

Because of the extensive climate and hazard presence in the vulnerability literature, a widely accepted definition comes from the International Panel on Climate Change (IPCC)

vulnerability framework (Adger, 2006). Fundamental elements of the IPCC definition include climate-related hazard (i.e stimulus), susceptibility to harm (i.e. notion of harm), and adaptivity (i.e. uncertain future evolution) of a defined system or unit of analysis (i.e. entity) to cope with the hazard (IPCC, 2014). The IPCC definition thus contains the basic elements of vulnerability applied specifically to the climate change hazard framing. Although relevant for climate change studies, the sole focus on climate change bounds the application of the concept in the urban environment, as it restricts the significance of non-climate exposures in an urban system, such as the impacts of political-economic and environmental activities (Rasanen et al., 2016) as well as socioecological and socio-technical networks (Meerow et al., 2016).

2.2.1 Physical vs. Social vs. Urban Vulnerability

Apart from generalized notions of vulnerability, scholars have tended to focus on two types: physical and social vulnerability. Physical/environmental vulnerability is articulated in a number of ways, with scholars referring to vulnerability of the built environment, natural environment, or some combination of these. Physical entities in the built environment include buildings, land uses, infrastructures, and housing structures (Herslund et al., 2016; Xiu et al., 2016), while natural environment entities include ecosystems, green areas and some types of land uses (Herslund et al., 2016). Physical vulnerabilities are typically addressed through structural and engineering solutions such as creating flood walls, raising foundations of homes, and other interventions (Hambati & Gaston, 2015). However, nonstructural measures of enhancing building regulations, physical hazard warning systems, and community level adaptation practices, are also prevalent to mitigate physical vulnerabilities (Few, 2003).

Social vulnerability is arguably more fragmented, requiring further inquiry to build upon theories of this notion. The human-centered perspectives in vulnerability originated in political economy and political ecology disciplinary studies and have been applied in elsewhere within the social sciences, as well as within the risk and hazard perspectives (Eakin & Luers, 2006; St. Bernard, 2004; Cutter et al., 2009). In general, social vulnerability explores social, economic, cultural, political, and institutional predispositions which determine the capacity to deal with exposure to hazards or stimuli (Eakin & Luers, 2006; Ge et al., 2017a; Lee, 2014). Put in terms of the IPCC definition, social vulnerability represents the 'sensitivity' and 'capacity to cope' aspects of the broader vulnerability definition (Lee, 2014). In other words, it deals with the underlying contextual socioeconomic factors susceptible to harm and the capacity to respond to it (Cutter et al, 2009). The entities to which social vulnerability is measured ranges from individuals to societies (Ge et al., 2017a). Social vulnerability is found in the literature to be concentrated on environment/natural hazards such as floods, coastal areas, temperature related hazards, and a general grouping of environment hazards (Cutter et al., 2003). Alternatively, it has been specified to non-climate factors such as poverty, food insecurity, livelihood insecurity, and to assets or resources (Eakin & Luers, 2006; St. Bernard, 2004; Fang et al., 2016; Lourenco-Lindell, 2001). A wide range of social vulnerability conceptual frameworks exist depending on how it is defined and to what it is being measured. Common models include the Pressure and Release (PAR) model linking physical exposure with socioeconomic pressures, the Hazards of Place model (HOP) uniting biophysical and social vulnerability into a 'place' based vulnerability, and the Vulnerability Framework for Sustainability Science (VFSS) model combining multiple scales of human and

environment systems (Ge et al, 2017a). More recent approaches build upon these basic models by including more scalar features and additional factors (Masunungure & Shackleton, 2018; Rufat et al., 2015), or develop new pathways of understanding such as exploring flows of social vulnerability between cities (Ge et al., 2017b).

Along the lines of working toward comprehensive approaches of conceptualizing and assessing vulnerability is the notion of urban vulnerability (Fang et al., 2016). In climate change studies, incorporating climate as well as urbanization factors in vulnerability analyses (representing social and physical dimensions in an urban system) are a growing trend (Krellenberg et al., 2016). One major reason for this is the noticeable influence of urbanization factors in susceptibility and coping capacity outcomes, both in positive and negative ways (Krellenberg et al., 2016). For example, Congedo & Macchi (2015) cite urbanization and settlement patterns as non-climatic factors influencing vulnerability. Their study of household vulnerability links groundwater salinization to climate change and urban sprawl as a result of rapid urbanization in a coastal city in Tanzania. However, Archer & Bezdecny (2016) explore how vulnerability in cities can be minimized or prevented by effective management policies and human settlement characteristics. In this sense, the urban is more than a spatial scale, but an active participant with characteristics that may both positively and negatively influence vulnerability of units of analyses (Krellenberg et al., 2016).

Another reason urban vulnerability may be useful is the impact of hazards on populations grouped in densely populated spaces such as urban centers (Cho & Chang, 2017; Fang et al., 2016; Quarantelli, 2003). African urbanization is particularly important in this regard as Pauleit et al. (2002) argue, African cities urbanized differently from other

regions in the world. They suggest urbanization in Sub-Saharan Africa, unlike other places, was disconnected from economic development, and had institutional gaps which limited adaptive capacity and increased physical and social vulnerabilities. Although more recently Sub-Saharan cities are argued to be growing economically with increasing flows of foreign investment (Rogerson, 2017), many decades of economic stagnation and poor management in many cities made significant negative impacts in cities which continue to create vulnerabilities. The recent investments and growth have argued to be disproportionately benefiting a targeted group of the population, and not the vast majority, thus exacerbating inequalities (Rogerson, 2017).

Various urban vulnerability conceptual frameworks exist. For example, Fang et al. (2016) provide an urban vulnerability framework from the sustainability development perspective integrating four dimensions of vulnerability representing the coping capacity against various external and internal disturbances or exposures. These four dimensions are: resource, eco-environmental, economic, and social development, however, they are measured at national scale. Herslund et al. (2016) provide a more localized framework specific for Sub-Saharan Africa in which they identify four different dimensions of vulnerability: asset, institutional, attitudinal, and physical vulnerability, which affect and are affected by exposure, sensitivity, and adaptive capacity of a system at the community to individual levels. Another example is provided by Krellenberg et al. (2016) who merge external hazards, residential level vulnerability (susceptibility, coping capacity, and exposure), and what they refer to as 'spatial-structural fragmentation' dimensions at the urban scale. These fragmented dimensions include: social, economic, socio-cultural, political-administrative, and environmental dimensions in the climate change context.

As exemplified by the different frameworks, what constitutes the 'urban' varies across contexts (Laidley, 2015; Krellenberg et al., 2016). Conceptualizing urban vulnerability in different cities requires in-depth inquiry and analysis. Much like the struggle in defining the urban (Battersby & Watson, 2018), defining and theorizing urban vulnerability is also difficult (Fang et al., 2016). Some scholars pose urban vulnerability as a particularization of general vulnerability (Lankao & Qin, 2011; Salas & Yepes, 2018) however, this does not reduce its complexity and multidimensionality or nestle it as a smaller scale within the same general vulnerability framework. Urban vulnerability hosts another set of particular systemic and contextual conditions and processes requiring different frameworks and new methods of assessment. For instance, Mearns & Norton (2009) note relations between urbanization, inequality, and the built environment may lead to urban violence and human insecurity. They note how informal settlement areas where social institutions and effective government are likely lacking can enable or expose vulnerable groups to conflict, crime, and violence. These conditions may further exacerbate vulnerabilities or lead to the development of new ones, requiring new ways of thinking about vulnerability in more complex, evolving systems.

2.2.2 Vulnerability Operationalization

Operationalization of vulnerability has taken diverse forms over time depending on scales, methods, and contextual factors (Kienberger et al., 2013). Understanding how vulnerability is operationalized or assessed provides further substance for conceptualization. There are three main approaches to assess vulnerability: future, present, and combined approaches (Wolf et al., 2013). The approach to assess *future* vulnerability deals with a vulnerability outcome or endpoint result (Wolf et al., 2013). This type of

assessment comes from the broader discipline of risk and hazard disciplinary studies (Eakin & Luers, 2006). In this case, the impact of a risk or hazard on an ecosystem is the focus, including floods, heat waves, or other specific external hazards on a system. Future vulnerability approaches typically focus on physical and structural characteristics of the units of analyses. Researchers using this approach may create climate simulation models to anticipate or explore how hazards may affect systems at different units in defined future points. An example is provided by Kebede & Nicholls (2012) who developed future climate scenarios of coastal flooding to estimate potential asset and population losses leading to vulnerability in Dar es Salaam, Tanzania.

A second approach focuses on assessing the *present* state of the system or the current capacity to withstand stimuli (Wolf et al., 2013). These studies are also referred to as starting point studies and highlight the intrinsic state of the system preceding the disaster (Lee, 2014). In these cases, the stimuli or hazard may or may not be defined explicitly. This type of approach is typically aligned with social vulnerability, as the demographic and social-economic factors (representing context) impact on local populations are studied (Cutter et al., 2009).

Integrated or combined vulnerability assessments form a third approach in which scholars attempt to assess interactions and stimuli of human and biophysical systems (Wolf et al., 2013; Eakin & Luers, 2006), or coupled systems (Fang et al., 2016). This type of assessment is also referred to as comprehensive assessment in other studies (Coulibaly et al., 2015; Balica et al., 2012), but the notions are similar in that social, physical, and environmental factors are incorporated. Another branch of this approach is known as *place-based* vulnerability in which biophysical and social variables are included in vulnerability

assessment (Rygel et al., 2006). Place-based approaches are also present in social vulnerability studies but differ in the exposure aspect. In social vulnerability studies, place-based refers to *latent* exposure (inherent social and institutional factors) (Cutter et al., 2009), whereas integrated approaches additionally include *external* hazard exposures (Ge et al, 2017b).

Several scholars have attempted to conceptualize and theorize urban vulnerability in comprehensive ways (Fang et al., 2016; Krellenberg et al., 2016; Ge et al., 2017b; Bulkeley & Tuts, 2013). However, in application, many scholars tend to address specific hazards such as floods (Cho & Chang, 2017; Mansur et al., 2016; Rigillio & Cervelli, 2014; Salami et al; 2017). For instance, Mansur et al. (2016) assess urban flood vulnerability in the Amazon with factors such as flood exposure, socioeconomic sensitivity and infrastructural characteristics which determine adaptive capacity of populations in the area. The specification of vulnerability assessment to floods allows pointed analysis of the exposure of a specific hazard, reducing complexity of the comprehensive approach in application.

Even with the shift to comprehensive approaches, there is no standardization within or across disciplines (Busby et al., 2014). One reason is that social and institutional factors are not always agreed upon or easily quantifiable (Mavhura et al., 2017). Another reason is the variation in scales, which then require different forms of conceptualization and measurement, as well as produce different perceptions of the issues (Few, 2003). It is important to note that different types of data are more relevant and necessary at a local scale to determine local vulnerability than at larger scales (Kienberger et al., 2013). Mavhura et al. (2017) also suggest that variables important in determining local

vulnerability are ignored at the national level because they are context-specific, thus providing a different conceptualization and measurement of vulnerability. Furthermore, various forms of data (especially quantitative data) are more readily available at these higher levels.

2.2.3 Vulnerability, Resilience, and Sustainability

Associations between vulnerability and resilience are important to note because of shared attention to disturbances and adaptation in social-ecological systems (Adger, 2006). These terms are often considered to be inversely related, where vulnerability refers to susceptibility to harm and resilience refers to a positive adaptation to harm (Luthar et al., 2000). Lankao et al. (2012) and others articulate both resilience and vulnerability through a common concept of adaptation but differentiate vulnerability as the weak capacity to adapt or cope and resilience as actualized adaptation which can take place in the short and long-term time scales (Mutanga & Muiruki, 2013; Ge et al, 2017a). Resilience is often viewed as more positive, integrated in multiple systems, and more dynamic than 'not vulnerable' (Luthar et al, 2000; Meerow et al, 2016).

Still, there are definitional disagreements common in the literature and across disciplines (Arnold, 2014). Archer & Bezdecny (2016) note continued debate over resilience involving the notion of maintaining systemic equilibrium (return to status quo after a stimulus, or bounce-back) or if it involves change and transformation. Furthermore, Kelman et al. (2016) and other scholars suggest these concepts are not exactly on opposite ends of the spectrum and can exist at the same time (Cutter, 2016). In disaster risk literature, both vulnerability and resilience exist as components of risk, where lower vulnerability and higher resilience reduce risks for disaster in the face of hazards. For example, Leong et al.

(2007) provides an example of how the Vietnamese community in New Orleans, although recognized as socially vulnerable in terms of low income and non-English speaking, were able to recover from the effects of Hurricane Katrina and rebuild their community because of the strength of social capital and social networks. In this case, the residents were simultaneously vulnerable and resilient. This example provides some insight into the subtle differences in the concepts and their intersections.

Broader associations between vulnerability and resilience to sustainability also exist because of shared goals in addressing and unifying needs of human-environment systems (Eakin & Wehbe, 2009). Both vulnerability and resilience are suggested to be situated within an overarching sustainability science and guide sustainability practice (Turner II, 2010). For example, vulnerability provides information about human subsystem weaknesses and resilience informs of how populations or communities become adaptive and respond to disturbances (Turner II et al., 2003). In this way, vulnerability and resilience provide insights to strengthen understanding of systems (Turner II, 2010). However, scholars recognize these connections are complex and the connections have not been explored to a significant extent in the literature (Eakin & Wehbe, 2009).

2.3 Planning, development, and vulnerability in SSA cities

In addition to the various conceptualizations and approaches in vulnerability studies, factors which *influence* vulnerability vary as well. One particularly underrepresented set of factors in social and urban vulnerability are institutional factors related to urban planning and development (Cho & Chang, 2017). More representation of these factors is needed because the urban built environment, particularly in the global south countries, is suggested to be vulnerable due to activities such as settlements in hazard-

prone areas, inconsistencies in service provision, and limitations in planning and governance (Archer & Bezdecny, 2016). Also, urban development factors are important because they cannot be changed or reversed easily (Baker, 2012). The irreversibility aspect is one reason why proper planning and regulation is argued to be necessary, so that more efficient decisions on development can be made with minimal negative impacts in the long term. For example, in the US context, Simpson and Human's (2008) study concluded that even with limitations of data and methodology, vulnerability assessments were essential for local level planning and policy-making to ensure more efficient resource allocation and reduce losses. Similarly, Hove et al. (2013) posited strategic planning and municipal level management necessary to address inconsistent and missing service delivery leading to number of threats in African cities (e.g. pollution, human security, and other socio-economic issues). Other literatures move away from broader notions of vulnerability and focus on the role of planning as it relates to specific hazards. For example, Rigillio & Cervelli (2014) explore the role of planning in effectively dealing with seismic hazards in Santo Domingo, Dominican Republic. Not only is planning suggested to reduce vulnerabilities, but Salas & Yepes (2018) note that vulnerability analysis can in turn guide strategic urban planning in that it points out additional factors which should be included in future city plans for more resilient futures.

In many Sub-Saharan Africa cities, traditional as well as more recent paradigms of planning and development have contributed to the production of specific urban characteristics in the region (Kablan et al., 2017; Dodman et al., 2017). For example, the legacy of colonial planning shaped many African urban centers and continue to influence the urban form, population settlement patterns in cities, and promote segregated spaces

(Bissell, 2011; Briggs & Mwapfupe, 1999; Fekade, 2000; Kasala, 2015; Kironde, 2000). The result of colonial planning practices in African countries such as segregated spaces have been argued to affect unequal resource distribution and access, resulting in more vulnerable populations (Halla, 2007; Olvera et al., 2003; Williams et al., 2019). In recent years, Turok (2016) notes development in African cities have been geared toward growing middle class populations in the form of real estate projects, signifying growing economies for some segments of the population but not necessarily for all (Watson, 2014a). Meanwhile, socially just planning and management under more normative planning directions, Adelekan et al. (2015) note, is ineffective or absent. To unpack planning and development further, the following sections will examine the scholarly literature between urban governance, informal development, urban land use, and urban sprawl and vulnerability in Sub-Saharan Africa.

2.3.1 Governance

Pelling et al. (2018) list several governance limitations which they suggest contribute toward vulnerability in African cities and prevent change toward adaptation. Examples of governance limitations include weak governing institutions, partisan politics, lack of political will, economic instability, systemic corruption, lack of data on development parameters, and lack of hazard patterns to support inclusive and evidence-based planning. For example, Williams et al (2019) note the importance of political agendas in shaping development and for instance, how political actors in South Africa benefitted from resources meant for redistribution to more vulnerable segments of the population. The study showed stakeholders (i.e. municipal officials, scientists, NGO, and civil society members) regarded governance as having the greatest influence on flood risk

and vulnerability because of spatial and structural inequalities directly produced by the government policies and programs over time. Rogerson (2017) makes a similar argument for Mozambique suggesting neoliberalism and structural adjustment programs proliferated inequalities as well as opposition toward the informal economy, resulting in exclusion and marginalization - which inadvertently expanded the informal economy. Bissell (2011) and Kombe & Kreibich (2006) make similar arguments for Tanzania. In their book, Kombe & Kreibich (2006) also aimed in part to identify more specific reasons why government responses have been ineffective in Tanzania and pointed to deficiency of public resources, misplaced priorities, outdated legal frameworks, inappropriate norms and standards to inform planning responses, and strategic neglect of urban growth potential. Such inadequacies and mismanagement lead to vulnerable environments, which Hove et al. (2013) argue, threaten human security and peace.

Under normative planning paradigms, Watson (2002) suggests planners need a basis of understanding of social, spatial, and political processes to promote just and equitable outcomes, meaning the limitations in understanding of development activities and processes are barriers to effective planning and governance. Similarly, Medd & Mariam (2005) note that knowing and understanding challenges and limitations enables recognition of urban vulnerabilities, however, even with a basis of understanding, there are limited pathways to move forward effectively and difficulties in translating knowledge into practice. For example, governments in Tanzania implemented land regularization policies and programs to promote legal property rights and secure land tenure which saw some successes (Boshe, 2007), but overall failed to make meaningful impacts or benefitted much of the population (Kombe & Kreibich, 2006). Watson (2002) also notes economic

informalization in Sub-Saharan Africa cities in which the "the relationship between state and citizens, and between formal and informal actors, thus becomes under-codified and under-regulated" (p.39), further complicates matters. Alongside this, existing literature has tended to focus on higher level governance structures, not on local level governance with local attributes, actors, and processes (Wolf et al, 2018). Pelling et al. (2018) argue for innovative approaches between different levels of government and civil society groups or other stakeholders to work together to develop adaptive approaches and reduce vulnerabilities in African cities. Williams et al (2019) similarly argue for multiple actors including government actors to collaborate in effective governance to reduce vulnerability and improve resilience to hazards on African cities. In this sense, governance of urban spaces is not only limited to official government actors and agencies, but requires coordination of state, private sector, civil society, and other stakeholders in decision making and responding to vulnerabilities (Williams et al., 2019). Watson (2002), however, critiques this assumption of the ability of civil society groups to effect change in African cities and argues for clearer definitions of civil society groups and who they are benefitting, if at all. She questions the effectiveness of global north normative planning paradigms in the Sub-Saharan context (Watson, 2014b).

2.3.2 Informal Development

Urban planning and formal development through legal and government channels in African cities are not the only forces shaping cities and spatial form. Informal development and housing make up a significant part and often majority of the urban landscape and how populations access spaces or residence in Sub-Saharan cities. Globally, informal developments have been estimated to be growing at an average rate of 10% per year (UN

Habitat, 2010). The World Bank (2015) estimates 4.5 million new informal settlement residents per year in Sub-Saharan Africa. Although this does not specify urban or non-urban residents, the number of urban informal residents is significant as well. For example, in Dar es Salaam, Tanzania, informal areas are estimated to be 60-80% of all developments in the city (Kombe, 2005; UN Habitat, 2010). However, it is important to note the percent of informal developments varies from city to city (World Bank, 2015).

Informal pathways of urbanization or activities have often been simplified as being the opposite of formal or planned pathways or activities, however, on the ground and in the literature, informality is multifaceted, inconsistent, and not well understood (Boanada-Fuchs & Boanada Fuchs, 2018). For example, Boanada-Fuchs & Boanada Fuchs (2018) identify 112 characteristics of informality found in their sampling of literature ranging from economic, legal, technical, organizational, political, social, cultural dimensions. They argue since the 1970s, informality has increased in complexity, especially with relation to urban planning aspects of housing, planning practices, economy, land management, legal realms, and institutions. Although it originated in connection with developing contexts, Boanada-Fuchs & Boanada Fuchs (2018) argue that informality is a global concept and not limited to the developing world. Despite the ubiquity and significance, Mboga et al. (2017) and other scholars note a shortage of information and data, especially because of the diversity of characteristics of unplanned or informal developments (UN Habitat, 2010).

Causes for informal developments are viewed in diverse ways. Some scholars posit that formal practices and limitations/inefficiencies in planning *produce or stimulate* informal practices to compensate for lack of services requiring a negotiation for rights and services (Andreasen & Moller-Jenson, 2017; Boanada-Fuchs & Boanada Fuchs, 2018;

Porter, 2011). For example, Hsieh (2014) suggests urbanization in Sub-Saharan Africa paired with factors such as little or no economic growth led to the rise of slums and informal settlements as well as demand for services in these areas where infrastructure was lacking or nonexistent. Another view, however, posits informality as an active and united *opposition* to formal or modern practices (Boanada-Fuchs & Boanada Fuchs, 2018). This means practices before 'modern' influence (i.e. customary and tribal developments and practices) and a result of modern influence (i.e. spontaneous development and slums) are considered to be informal. Elate (2004), for instance, historically traces development of slums and informal settlements to the colonial period. Informality is also articulated as a bottom-up approach or *alternative* to planning in cities (Richmond et al, 2018).

In this sense informality can be seen as passive or active, and articulated as political or cultural, but typically with formal development as the established or starting reference point (Boanada-Fuchs & Boanada Fuchs, 2018). With these directions of conceptualization, informal development is compartmentalized in a dimension or spectrum of understanding. However, scholars note informality can exist simultaneously in multiple states and forms, even within formal institutions. For example, Roy's (2009) argument of India's informal planning regime and practice distorts boundaries between informality and formal planning. Similarly, Innes et al. (2007) present an argument of the USA context in which government and nongovernment collaborators deliberately set up an informal watershed management system to promote effective water management, thereby using informality as a planning tactic.

Despite these complexities and variations, scholars have nevertheless linked informal development and settlements with increased vulnerability (UN Habitat, 2015).

Likewise, scholars have linked planning with reducing vulnerability, particularly related to access and management of basic services such as water and sanitation (Richmond et al, 2018). However, the shifting or indistinct features of informality, the current state of the literature, as well as the dynamic nature of vulnerability do not allow for cohesive, comprehensive, and clear notions of relationships of informality, planning, and vulnerability to exist. Therefore, claims or assumptions of informal areas being more vulnerable are likely based on specific case studies and not to be generalized.

Examples of existing case studies linking informal developments and vulnerability in the Sub-Saharan context show mixed results based on specifics of spatial scales, methodology, selection of factors, and institutional factors of a place and population. Richmond et al.'s (2018) study of Kampala, Uganda explores drivers of vulnerability in informal communities and suggest participatory planning approaches to tackle the difficulties in assessing slum vulnerability and ways to reduce risks in these areas. Their qualitative study focused on food, water, energy, environment, livelihood, and health factors to assess vulnerability, which allowed for advocating planning as a pathway to reducing vulnerability. On the other hand, Andreasen & Moller-Jensen (2017) conducted a study in which they noted informal residents who were able to negotiate through their social networks for better services in informal areas of the periphery of Dar es Salaam, Tanzania were able to improve their own quality of life and reduce vulnerability within their communities and neighborhoods. Similarly, Lourenco-Lindell (2001) from their study in a west African city suggest social networks which aid in coping and adaptation in informal areas reduce vulnerabilities. Furthermore, Pharoah (2014) conducted a quantitative study in Cape Town, South Africa focusing on flooding hazards in which they

found formal state subsidized housing, not only informal settlements, were at high risk for flooding. In this case, the authors concluded that poverty was more of a key driver of flood vulnerability than formal or informal developments. Hence, claims of urban planning or formal directions of reducing vulnerability cannot be easily accepted. More investigation of the links between informal urban development and vulnerability in specific contexts are needed in Sub-Saharan cities.

2.3.3 Urban Land Use Management

One of the most important features of urban planning is land use (Kivell, 2002). Kivell (2002) notes that rather than viewing land as a "container" within which urban development or life occurs, it is "multifaceted" and "vital in explaining the shape, layout, growth of urban forms" as well as "influencing economic development, conferring power, and determining the relationships between different social groups and activities" (p.3). Similarly, Hubacek & Van den Bergh (2006) posit that land use can be an indicator of frictions between social and environmental processes. Hence, land use especially needs regulation and planning to be equitable, efficient, and reduce disaster risk (Baker, 2012).

Failures of the urban planning authorities and developers to administer and manage land related processes is significant in Sub-Saharan Africa (Cobbinah & Aboyage, 2017; Kironde, 2006). Planning agencies, as mentioned earlier, were and are often under-resourced to tackle the rapid growth or address land delivery and management (Cobbinah & Aboyage, 2017). What planning agencies plan for and what occurs on the ground differs significantly due in part to unrealistic planning, time lags in response and implementations, as well as uncoordinated decision-making (Kleemann et al., 2017; Dadi et al., 2016). Kalabamu (1992) provides the example of Dar es Salaam, in which he details the extensive

and drawn out process of formal urban land delivery arguing for its failures as a major factor in the proliferation of unplanned land development in the city. Therefore, access to land were significantly regulated through non-formal pathways such as local community social institutions in this city (Kombe, 2005). The informal land market also makes urban land use regulation particularly cumbersome and difficult, especially as its transactions occur "divorced from normative urban land use planning" and "self-managed" in the absence of a regulatory framework (Kombe, 2005, p.130). Furthermore, Kironde (2000) notes the continuation of colonial style administrative practices after independence in Dar es Salaam played a role in planning and regulation inefficiencies. In addition to the effect on the built environment, Williams et al. (2019) provide the example of Durban, South Africa and argue for effective land use management as critical for maintaining soil permeability and reducing runoff to decrease flood risks and vulnerability. Hence, the African urban context presents various relationships between urban land use and urban planning which are important to explore in relation to vulnerability. The following subsection further examines urban land systems and tenure relations with vulnerability.

2.3.3.1 Urban land systems and land tenure

Ghertner (2015) notes the concept of land tenure varies across contexts, which is relevant for many African cities. Different types of co-existing and spontaneous land systems complicate urban planning practices in the African context (Locke & Henley, 2016; Boamah & Walker, 2017). For one, the fragmented land systems create authoritative ambiguity, where responsibility for service provision, regulation, or tenure are muddled (Locke & Henley, 2016). Much like urban planning practice and development in general, several scholars argue against reducing African land tenure systems to legal/illegal or

formal/informal binary simplifications (McFarlane, 2012; Boamah & Walker, 2017). Boamah & Walker (2017) provide an example of what they refer to as Ghana's "legal pluralism" addressing the legal aspect of multiple land systems. They argue for a dismissal of viewing land systems as legal or illegal based on violation of customary or statutory legal land systems since there is complexity, unawareness, and conflicting processes which take place and disadvantage certain populations. The confusing landscape of land systems, land markets, legal systems, and challenges to access information prevent efficient and lawful practices (Boamah & Walker, 2017) and may lead to further challenges. For example, Fekade (2000) notes how land speculation practices where buyers purchase vast parcels of land create inaccessibility and scarcity create problems for lower income groups. These groups are left with few affordable options forcing them to locate to environmentally and socially hazardous areas, which create and reinforce vulnerabilities (Richmond et al, 2018).

In the absence of effective and transparent legal, regulatory, and planning systems, rights and security of urban land tenure in African cities has shown to rely on social relationships and 'negotiations' as alternatives to formal channels (Kombe & Kriebich, 2006; Magigi & Majani, 2006). Boanada-Fuchs & Boanada Fuchs (2018) suggest these arrangements are a "product of complex historical, cultural, and institutional processes" including existing customary land tenure as well as state-produced failures and absence of state and legal titles. In this sense, urban populations in many Sub-Saharan cities rely on *de facto* tenure security more than *de jure* tenure security (Sheuya & Burra, 2016; Boanada-Fuchs & Boanada Fuchs, 2018; Briggs & Mwapfupe, 1999). Baker (2012) note how tenure security impacts the level of investment in housing structures and services. Low income

groups in particular with insecure land or housing tenure have limited income and fewer incentives to invest in their homes, increasing their vulnerability status. On the other hand, Magigi & Majani (2006) in their study of informal communities show how certain neighborhoods in Dar es Salaam were able to change their hazardous land to regularized land through negotiation and resource mobilization strategies. Hence, urban populations regardless of tenure status in some cases are able to overcome risks and vulnerabilities depending on various contextual factors.

2.3.4 Urban Sprawl

The term 'sprawl' was first introduced in the literature in relation to urban spatial growth in 1937 by Earle Draper in the United States, describing an economically imprudent and socially negative form of urban growth (Nechyba & Walsh, 2004). From this definition, the term sprawl has been used in various ways in the scholarly literature, from the use of the term as noun (pattern), verb (process), to an adjective (Cutsinger et al., 2005). Therefore, the term does not have a universal definition and can have multiple varying interpretations depending on how a particular entity or scholar defines it (Gomez-Antonio et al, 2016).

In place of a precise definition, recent literature explains sprawl by its characteristics (Bhatta et al., 2010). Cutsinger et al. (2005) describe five dimensions of urban growth which can be used to determine urban sprawl: density, concentration, centrality, intra-use, proximity, and nuclearity. From these dimensions, low density development is the most common characteristic to describe sprawl in the literature, both in contiguous and non-contiguous urban development forms (Ewing, 2008; Nechyba & Walsh, 2004; Cobbinah & Amoako, 2012). Expanding on this characteristic, sprawl has

been related to low density growth which is also "awkward, uncontrolled, and haphazard" (p. 61) especially in peripheral areas or which follow the path of highways (Aguda & Adegboyega, 2013). Urban sprawl may also expressed as low density strip development, scattered or leapfrog patterns (Ewing 1997; Gomez-Antonio et al, 2016). Furthermore, Lv et al. (2012) provide an example of types of sprawl such as edge expansion sprawl, infilling sprawl, and outlying sprawl, in which each type of sprawl has different characteristics and forms based on location. These variations in characteristics are not uncommon in the literature and change according to context and author. Although much of the literature characterizes sprawl as a negative or not desirable form of urban growth as it restricts accessibility or destroys functional open space for example (Ewing, 1997), there are scholars who argue for the economic benefits (Glaeser, 2011; Brueckner & Fansler, 1983; Brueckner, 2000).

In general, there are several drivers of sprawl in the Sub-Saharan Africa region including development policies, insecure land tenure, lack of practical land use plans, and spillover effects from neighboring cities, among others (Dadi et al., 2016; Cobbinah & Aboyage, 2017). Kombe (2005) also argues for the role of poverty in driving changes in the built environment, which includes spatial expansion to meet housing needs (Andreasen & Moller-Jensen 2017; Mundia & Aniya, 2005; Briggs & Mwapfupe; Locke & Henley 2016). This type of context is different from that of western countries because residents of sprawled areas do not necessarily live in these areas out of choice or preferences, but because of the opposite reasons - a lack of choice in housing and lack of access in other areas closer to the urban center (Mkalawa, 2016). The unregulated land market does not follow laws and thus make land values difficult to predict (Cobbinah & Aboyage, 2017).

This occurs not only within the poverty context, but also as a result of a growing suburbanization and a rising demand and preference for single, detached housing in African cities (Mercer, 2017; Andreasen & Moller-Jensen, 2017). Therefore, sprawl occurs on the one hand because of reasons related to poverty and on the other, economic growth and increasing incomes. This however, is still a broad simplification of the drivers, but they are general trends found in the Sub-Saharan literature.

Locke & Henley (2016) suggest that "uncoordinated spatial growth can undermine sustained growth" (p.6), implying unplanned and informal sprawl is a concern in terms of sustainability and vulnerability. For example, Congedo & Macchi (2015) link urban sprawl and climate drivers to produce climate change vulnerability in cities, in which land development and sprawl affect consumption of natural resources and ecosystems negatively. Although negative environmental and biodiversity impacts of sprawl and relations to vulnerability exist (Congedo & Munafo, 2014; Congedo & Macchi, 2015; Neke & Du Plessis, 2004), not many studies in the African context explore the social impacts of urban sprawl and vulnerability. One example is Congedo et al. (2013) whose case study in Dar es Salaam suggested changes in land cover from natural to impervious surfaces caused by urban sprawl increased household vulnerability. They noted how sprawl residents' reliance on water boreholes facilitated saltwater intrusion and compromised household water sources.

2.4 The Direction of Future Vulnerability and Planning Research in SSA and Challenges

Many meanings and conceptualizations of vulnerability complicate already complex, overlapping, and ambiguous notions of the intersectional space of vulnerability and urban

planning, prompting a need for more work in this area. Because vulnerability and urban planning are broader concepts within which complex sub-concepts are layered and interconnected, these sub-concepts also need to be explored further in the literature. Examples of sub-concepts related to urban planning include local interactions of land, sprawl, informal or unplanned development, governance, and the role of actors and institutions. Also, more studies on specific urbanization processes and activities in African cities and how they are different from other parts of the world, amongst other African cities, and on smaller spatial scales, are necessary. As Fatemi et al. (2017) note, most vulnerability studies are in the USA context. Understanding these sub-conceptual nuances allow for more targeted approaches to reducing vulnerability and leveraging positive adaptive or resilient practices and planning in individual cities in Sub-Saharan Africa.

Along these lines, the connections and relationships between vulnerability and resilience must be clarified and strengthened. Scholars such as Cutter (2016) have noted the differences, however, it is still difficult to tease out in the existing literature, as the terms come across as interchangeable in certain studies. For example, vulnerability is defined as simply susceptibility to harm (Kelman, 2017) with capacity to cope or adapt (i.e. IPCC) in some studies, and resilience is defined as adaptation to harm or threats. The subtle difference between 'capacity to adapt' and actual 'adaptation' are not captured in studies clearly. It is important, therefore, for scholars to be keenly aware of the ways in which vulnerability and resilience are defined and operationalized in studies and assessments.

Another challenge in vulnerability studies in the urban context of Sub-Saharan Africa are critical data limitations, particularly of reliable or standardized data (Adelekan et al., 2015), in providing evidence of links to vulnerability at the local or urban level.

National level data in general are more widely available and accessible, however, local or urban level particularly of institutions, governance, planning, as well as other social and environmental data are lacking and/or non-existent, providing little direction for local level planning and vulnerability mitigation or adaptation. Local level data are important, as Turok (2016) notes, cities have unique spatial configurations even though there are broad similarities across cities. Therefore, specific contextual developments enable a better understanding of cities' unique vulnerabilities. Although still lacking, recognition of local level data limitations is not new, and there are data developments put forth to address this issue which are global, standardized, and available for researchers and scholars provided by institutions such as the World Bank, European Commission, and university databases. These developments however, do not necessarily allow for multi-temporal assessments, as historical data are difficult to reproduce or measure. A direction forward in this sense would be to utilize and test these open data sources for reliability and continue to produce data at the local level to meet data needs and improve the evidence base.

Lastly, exploring the conceptualization of urban vulnerability as a comprehensive approach to understanding vulnerability in urban contexts is a pathway for future vulnerability studies not limited to climate hazards. The approach distinguishes the urban as its own system with distinct stressors. It brings in variables and factors which are not necessarily present in current scholarship and new ways of thinking about vulnerability. For example, bringing in multi-scalar factors or stressors at the household and community scale as well as at the broader urban scale (e.g. planning, policies, history, and governance) allows for increased comprehensiveness within vulnerability studies, connecting the broader scale with the local within the distinct urban context of Sub-Saharan cities. These

types of factors and scales may point to not only recognizing failures of urban planning in Sub-Saharan cities, but how planning and governance *contributes* to vulnerability in different ways to direct more useful planning practices. Hence, continuing to form a more precise articulation and methodology can be a worthwhile path forward for urban planning as well as climate or disaster risk studies.

2.5 Conclusion

This paper reviewed the urban and climate change literature to develop an understanding of the current state and connections of vulnerability and urban planning in Sub-Saharan cities. There are ways forward to build upon urban planning and development research as it relates to vulnerability in cities. However, since vulnerability is a multifaceted and dynamic concept, the research and data must also be multifaceted, dynamic, robust, and relevant. Challenges of concept development and clarity, data limitations, and scalar issues are significant. The potential of the concept of urban vulnerability is a way forward, but it is still nascent. Even with gaps and limitations, however, it is important to continue to produce research to strengthen understanding of vulnerability and planning in the hope that Sub-Saharan populations have reduced risk and more equitable futures.

CHAPTER THREE: PHYSICAL DETERMINANTS OF PLANNED AND INFORMAL DEVELOPMENT IN DAR ES SALAAM — A REGRESSION APPROACH TO CONSTRUCT MULTI-TEMPORAL LAND USE DATA

3.1 Introduction

Increasing urbanization in Sub-Saharan Africa under conditions of resource restraints and poor land management has led to deficits in housing, especially affordable housing, resulting in urban land and housing development outside of the planned systems, which often lack proper sanitation, solid waste management, and other quality of life services and infrastructure (Kironde, 2000; Kironde 2006; Kombe, 2000). Unplanned or informal housing makes up a significant proportion of development and an estimated 61.7% of urban populations live in such neighborhoods in African cities (UN Habitat, 2015). Furthermore, a shortage of multi-temporal urban land use data has restricted urbanization research in Africa (Linard et al., 2013; Mkalawa, 2016). The urban land use data available is inadequate and in need of updating for an improved understanding of spatial urbanization patterns over time. Thus, it is imperative that informal data is available and reliable to understand urban land patterns more accurately and to support such important research in urban poverty, social justice, and urban vulnerability (Kironde, 1995; UN Habitat, 2015).

To address the gap of reliable urban data over time, this paper proposes a methodology to estimate urban land use data with informal settlements based on existing data. The existing data used is openly sourced and does not require the procurement of new remote sensing, satellite imagery, or other costly methods to determine current land use. It also does not require having to go through channels to procure data from sources which might be difficult, costly, unwilling, or unable to extract information.

Dar es Salaam is the case study to present a simple methodology to produce urban land use data with acceptable quality. Section 3.2 provides a review of related literature. Section 3.3 introduces the study area and explains the data collection process. Section 3.4 explores the relations between urban land use type and urban land use intensity, which is available in the global human settlement dataset (open source dataset). Section 3.5 presents a regression approach to estimate urban land use type based on various physical attributes. Section 3.6 assesses the quality of land use estimates. Section 3.7 concludes the paper and discusses several limitations of this research.

3.2 Literature Review

The East African region has been in a state of constantly changing land use, as Kiage et al. (2007) notes, caused by human activities as well as climate factors. Informal land development creates further challenges to detection and classification of land use, as there are multiple forms and definitions which make it difficult to define or characterize consistently (Mboga et al., 2017; Fekade, 2000). While informal settlements were initially described as ‘self-planned’ or ‘self-initiated’ housing (Fekade, 2000; Harrison, 1992) often characterized by sub-standard living conditions, the term has broadened to incorporate different aspects and conceptualizations of tenure security, planning, regulation, and

legality (Mboga et al., 2017; Boanada-Fuchs & Boanada Fuchs, 2018). The lack of consensus in defining the term as well as challenges in identifying informality (Acolin and Kim, 2017), has resulted in barriers to building up data and scholarship.

Remote sensing is one pathway toward measuring land cover changes and thus land use changes. High resolution satellite imagery is especially useful to detect land cover. Land cover describes physical attributes of the land, but not different urban land use activities (Kiage et al., 2007). Such data are often useful for studying natural habitations (Boyd & Danson, 2005), agriculture activities (Rojas et al., 2011), and environmental degradation (Wessels et al., 2004). It is also a good source of data to study urban sprawl and developed versus undeveloped land use changes (Mundia & Aniya, 2005; Montgomery, 2008; Linard et al., 2013).

However, a range of challenges exist with remote sensing, from obtaining cloud-free images, to determining classification methods which account for complex spatial and temporal scales of actual land changes (Jansen & Di Gregorio, 2002; Kiage et al., 2007; Mundia & Aniya, 2005; Lambin et al., 2003). More importantly, remote sensing land use data provide more detailed natural land uses than urban land uses. For instance, the U.S. National Land Cover Data classifies sixteen natural land covers, and only four urban land covers. These four urban land covers are classified based on the proportion land developed (USGS, nd).

Scholars have been able to recognize certain characteristics using remote sensing which differentiate informal housing from satellite images, such as roof color, level of vegetation, density of residences, proximity to road networks, building materials, and house size, among others (Hofmann, 2001; Mboga et al., 2017). Although these methods

are useful to an extent, there are complexities for instance, when characteristics of formal developments are mimicked in informal areas, and pockets of informal developments are found within formal developments (Hofmann, 2001). Furthermore, there is a general shortage of data tracking informal developments and measuring the extent of the impact on land use change over time (Mkalawa, 2016). Even if data are available with methodologies, they are often inconsistent, unclear, not available over multiple years, and/or reliant on outdated technologies (Mundia & Murayama, 2013).

With the spread of informal land use over the years, it has become important to recognize these developments, as they not only make up the majority land use type in some urban areas, but impact the city and residents. For example, informal residents suffer from marginalization and various social, spatial, and economic inequities, which require management and intervention (UN Habitat, 2015). Better quality data, methods, and measurements of informal developments can contribute to directing policymakers and planners toward managing growth and producing more equitable outcomes (Halla, 2007; Montgomery, 2008). Therefore, the aim of this study is to fill the data gap by contributing to the development of a multi-temporal urban land use dataset with informal development to understand urban land use changes over time as well as contribute to the broader goal of working toward equity and better quality of life for citizens in these regions.

3.3 Study Area and Data Collection

Dar es Salaam, Tanzania was selected as a case study for several reasons. First, this region has undergone rapid urbanization over the past few decades (UN Habitat, 2010). The urbanization rate in Dar es Salaam increased from 22.6% in 2002 to 29.1% in 2012, and the built up area increased by 133% from 2002 to 2011, placing it as one of the Africa's

fastest growing cities (Wenban-Smith, 2014; Gombe et al., 2017, Andreasen & Møller-Jensen, 2017). Second, the region has a significant portion of informally developed land, which has been increasing with rising urbanization rates since the 1960s (Kombe, 1994). An estimated 80% of the population live in informal developments in the city (Halla, 2007; UN Habitat, 2010). Lastly, the existence of multi-temporal datasets at the urban level for Dar es Salaam was a major reason for selection of this area.

3.3.1 Data Collection

Three sets of data were collected with the emphasis on selecting datasets which were reliable, openly available, and easily accessible on the internet. The first set of data is 1982, 1992, and 2002 land use data downloaded from the Socioeconomic Data and Application Center (SEDAC) website, affiliated with NASA and Columbia University. The 1982 and 1992 data are sourced from Šliužas (2004), who developed a land system classification system of five land use types: ocean and estuaries, vacant and agriculture, other urban, planned residential, and informal settlement. Ocean and estuaries as well as vacant and agricultural land are evident types. Other urban refers to industrial, commercial, transportation and recreational uses. Planned residential and informal settlement data classification were reliant on local knowledge from planners from the Dar es Salaam region who identified each planned and informal settlement within the study area on a land use map. The 2002 land use data builds upon Šliužas (2004) and were also estimated non-automatically based on aerial photographs and the existing land use (Hill & Lindner, 2011, p.171). The 2002 data was sourced from the SEDAC database covering the same extent and with the same classification system as the other datasets. The classification system for these land use datasets forms the basis of this study's land use classification as well.

The second set of data is built up area in raster format from the European Commission's Global Human Settlement (GHS) initiative, which began in efforts not only to produce an integrated, open, and free global dataset of human settlements, but also with the goal to support disaster risk reduction research and crisis management (Pesaresi et al, 2015). The GHS initiative developed built up area data as well as population data to produce a final dataset layer depicting global human presence in the form of settlements, which includes temporary settlements. The 1990, 2000, and 2014 data were downloaded at 250m resolution. These datasets are built upon satellite images and consistently measured globally. Each cell has a float (decimal) value from 0 to 1, which indicates the proportion of built up area in each cell. The validation of the built up area data was calculated to be more than 90% accurate by developers of the data (Pesaresi et al., 2013).

In addition to these two major datasets, road and elevation data were collected. Road data was sourced from an independent firm (Mapcruzin) which derived 2014 road data from openstreetmap.org. The web-based data of openstreetmap is openly available and created by a network of mappers, GIS professionals, and engineers, and supported by institutions such as University College London, Bytemark Hosting, and Imperial College London, among others[1]. There are 18 different types of roads in the dataset. For this study, the types of roads and streets were reduced to three in order to make the data more

[1] The use of collaborative sources such as openstreetmap.org (OSM) in which the data is user-generated and managed by a group of volunteers has both advantages and drawbacks. The availability of the data because of the efforts of the community of contributors and collaborators provides a solution to existing barriers of access of spatial data in many parts of the world. As noted by Haklay & Weber (2008), although there is reliance on a combination of experts and non-experts in generating the data, the use of tools such as GPS receivers and organization workshops for the OSM community mappers provide some consistency and credibility to the dataset. However, issues and errors arise, for instance in naming, identification, and misinterpreting satellite imagery from on-the-ground mapping, among others. In this paper, only major roads were selected for analysis to take advantage of the open dataset as well as circumvent issues with more detailed road data.

manageable. Appendix 1 notes the road types, definitions of road types, and the number of data points for that particular road type in the dataset.

Elevation data was downloaded from the Center for Tropical Agriculture (CIAT) website which featured data from the USGS/NASA STRM source (Jarvis et al., 2008). The dataset contains global raster data at the 90m level with missing data filled in by interpolation methods. The elevation data is useful because slope can be calculated, which would assist in differentiating planned from unplanned spaces. For example, Maklawa (2016) notes unplanned housing developments have been found to be in areas with steeper slopes.

3.3.2 Study Area

The study area boundary was created from administrative urban ward boundaries available in a shapefile through the Tanzania National Bureau of Statistics for 2002. The goal of this research was to develop a reliable method to estimate formal and informal land use, which are concentrated in the urban boundary. Almost all areas outside of the study area were vacant or ocean. Therefore, the urban boundary was used as the study area for further analyses. See Figure 3.1 for a map of the Dar es Salaam regional administrative boundary, coverage of the land use datasets, and the urban boundary overlapping.

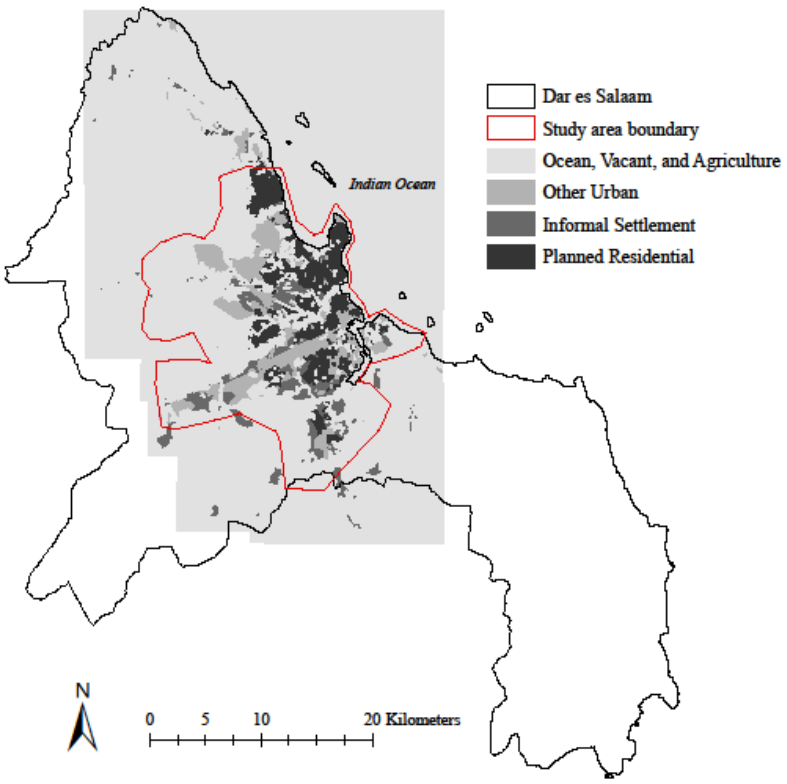

Figure 3.1: Study area with 1992 land use

3.3.3 Basic Land Use Information

Table 3.1 shows information on each land use dataset in terms of area coverage, percent of total area, and percent change of each land use type within the dataset and within the study area. It is important to note that ocean and estuaries were combined with vacant and agriculture land uses for this study because they were not the focus of the study. Hence, for simplification purposes, these land uses were combined so there were a total of four land use types.

It is clear from Table 3.1 vacant lands decreased the most over the three decade period and informal settlements increased the most. Informal settlements also increasingly constituted a larger percent of the total area over the years, while other land uses either

decreased or increased at slower rates (other urban and planned residential). The growth rate of informal land was consistently faster than the rate of planned land. This strengthens the argument for the importance of an inclusion of informal land uses for understanding urban growth and land use changes in the city.

Table 3.1: **Area by land use type**

Land use type	Area (sq km)			Percent of total area			Percent change area 1982-1992	Percent change area 1992-2002
	1982	1992	2002	1982	1992	2002		
Ocean/vacant	263.25	221.89	155.39	63.96	53.91	37.76	-8.53	-17.63
Other urban	65.59	71.72	72.61	15.94	17.43	17.64	4.46	0.62
Informal	40.66	61.76	119.84	9.88	15.01	29.12	20.60	31.98
Planned	42.06	56.19	63.72	10.22	13.65	15.48	14.38	6.28

Figure 3.2 shows maps of 1982, 1992, and 2002 land use within the study area. A general increase over time in informal settlements is most noticeable, with growth of planned residential area visible mostly from 1982 to 1992. The spatial growth of informal settlements extends from the central areas of the city to the peripheral areas over time, converting large expanses of agricultural and vacant land to informal residential use. Planned areas have tended to remain central, however, from 1992, new developments can be seen in the northern urban areas as well as visible expansion around existing fringe planned residential areas. Some growth of other urban areas can be detected in the peripheral areas as well, but the changes are the least significant among the other land use types. In general, the land use types in the central urban areas have remained mostly the same over time, with growth occurring in the outer areas of the city, where agricultural and vacant land are converted to urban land uses. The growth over 1992-2002 is much faster

than over 1982-1992 and is dominated by informal development. This is consistent with the findings in Table 3.1.

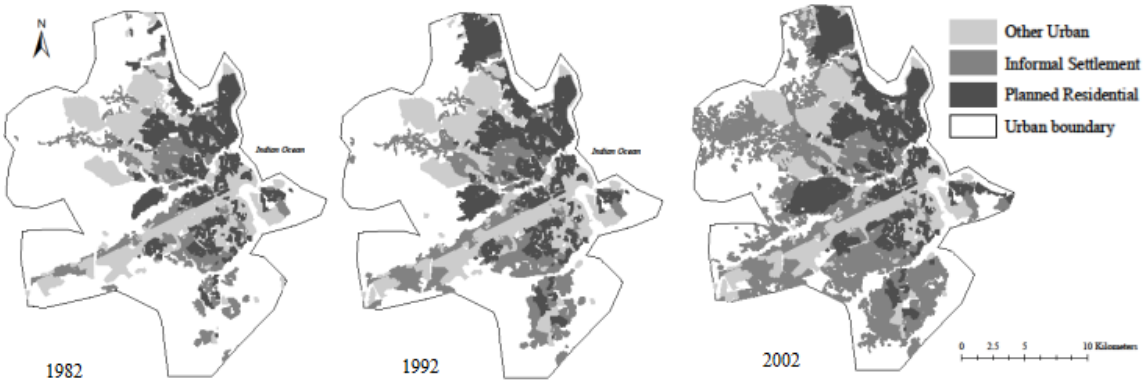

Figure 3.2: **1982, 1992, and 2002 land use**

3.4 Relations between Land Use and Built Up Area Data

A land use dataset has specific urban land use information useful for policy makers, planners, and researchers, but such data is not consistently available over time and across cities. Raster data of built up area is available over time and for all cities but lacks detailed land use information. Therefore, it was hypothesized that if a stable relation exists between the two sets of data, a consistent set of land use data could be built based on raster image data.

Figure 3.3 explores the relation between 1992 land use data and 1990 built up area grid value. Grid value indicates proportion of land developed, i.e. land use intensity. The box plot suggests this grid value can be a useful variable to identify land use, especially for planned and informal land use versus undeveloped land use (i.e. ocean and vacant). From the figure it was determined that ocean, vacant, and planned land use types have more

compact ranges of built up area, whereas other urban and informal land uses have greater variability in terms of built up area. These results were expected because the types of activities which fall under the other urban classification are varied and there are different forms of informal growth which vary spatially and in density. Therefore, there are a wider range of built up areas associated with these land use types.

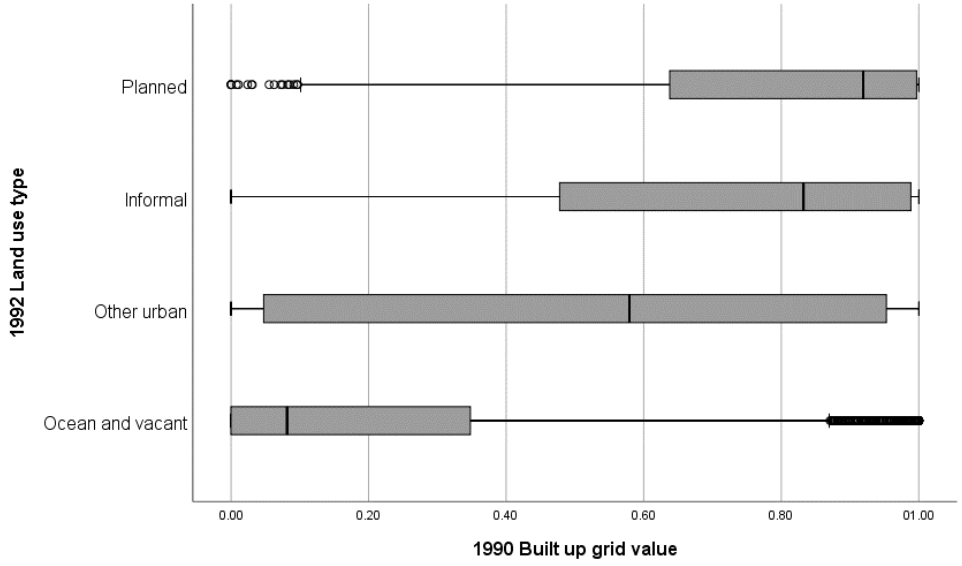

Figure 3.3: Box plot for data at the 95% confidence interval

The notion behind the confidence interval method was to determine a specific value range of built up area for each land use type. Certain land use types were more densely built up than others and there was a distinct relationship between land use type and built up area. For example, ocean and vacant lands would have the least amount of built up area, whereas planned spaces were likely to have the most built up area. Therefore, by isolating a range of built up values specific to each land use type, future land use type could be estimated. Table 3.2 shows ranges of the built up grid value means for each land use type.

Based on the mean bounds and the full range of built up values, a distinct range was determined for each land use type. The determined ranges are in Table 3.3. Although these ranges were not fully inclusive of all the built up area values within each land use type (i.e. other urban values span the entire range), they generally followed the most likely range based on the information available and the author's discretion.

Table 3.2: Confidence interval analysis

Confidence Interval		Ocean/Vacant	Other urban	Informal	Planned
95%	Lower bound	0.214	0.498	0.696	0.771
	Upper bound	0.234	0.545	0.734	0.805
97%	Lower bound	0.213	0.495	0.694	0.769
	Upper bound	0.235	0.547	0.736	0.807
99%	Lower bound	0.211	0.491	0.690	0.765
	Upper bound	0.237	0.552	0.740	0.814

Table 3.3: Estimated ranges based on confidence intervals for each land use type

Land use type	Built up grid value range
Ocean and vacant	$0 \geq X \leq 0.3$
Other urban	$0.30 > X \leq 0.6$
Informal	$0.60 > X \leq 0.75$
Planned	$0.75 > X \leq 1$

These specified ranges were used to recode the built up area values and determine new land use types associated with the value using statistical software. The newly estimated land use types were compared to the actual existing land use type for quality assessment measurement. Table 3.4 presents the quality assessment, suggesting that the overall confidence interval method yielded a 41.18% accuracy level. This means that less than half of all the records were estimated correctly.

Table 3.4: Quality assessment of 1992 estimated land use based on Table 3.3

Land use type	Number of records	Number of correct estimates	Percent correct
Ocean and vacant	3176	1855	58.41%
Other urban	1161	193	16.62%
Informal	998	86	8.62%
Planned	911	438	48.08%
Total	6246	2572	41.18%

When broken down by land use type, the accuracy rates varied widely. As expected, ocean, vacant, and planned land uses were estimated more correctly than other urban and informal settlement land uses. Although the full range of other urban uses was the greatest, informal settlement had the lowest accuracy. This suggests that a significant amount of informal settlement land uses were likely at the lower or higher ends of built up area range, which were cut off by the selected range. Hence, the overlaps in built up area values between land use types were inferred to be too high to produce accurate estimations of land use types with this approach.

3.5 The Regression Approach

The confidence intervals were established based on the relations between land use type and land use intensity (i.e. grid value). The quality of the land use data estimated based on these confidence intervals is very limited, especially for informal development. In this section, a regression approach is introduced that yields more reliable land use estimates. The specific goal was to derive reliable 2014 land use data with informal and planned residential areas in Dar es Salaam, which is not available, based on existing openly sourced data and past land-use data of 1992.

3.5.1 Methodology

Figure 3.4 presents the overall methodology. The approach involved converting built up area raster data to point format for the year 1990. Converting it to point format allowed the 1992 land use data to be spatially joined with a 1990 built up area. The 1992 land use type could be statistically modelled, using 1990 built up area grid value and other variables as explanatory variables. The relation is used to estimate 1992 and 2002 land use types, and quality of these estimates assessed. If this regression approach produced land uses data with acceptable quality, then this methodology could be applied to estimate 2014 land use data.

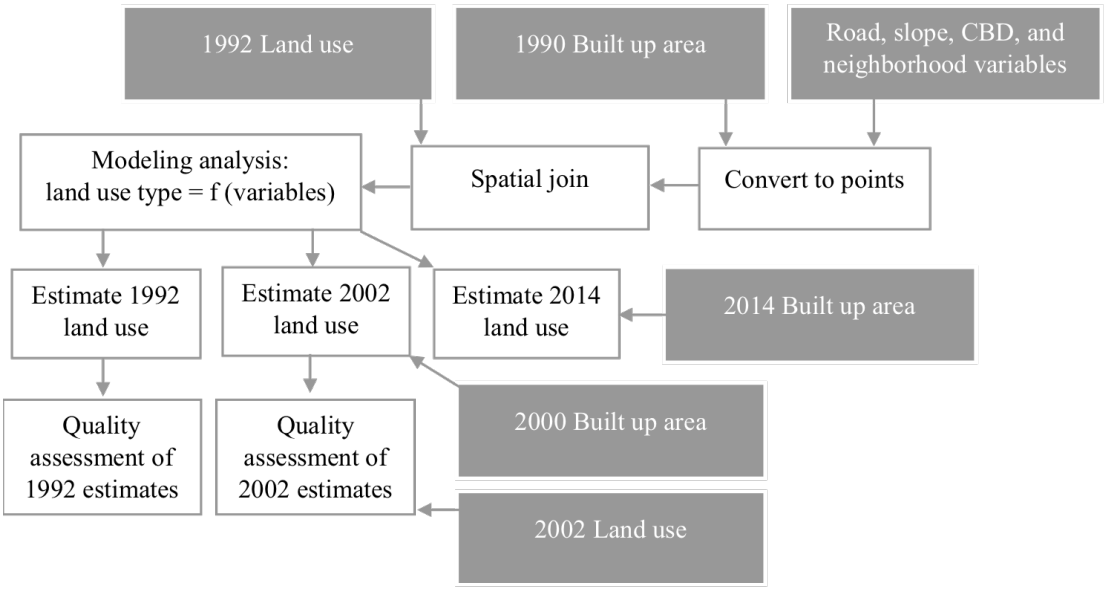

Figure 3.4: Simplified diagram of land use estimation model method and data inputs

3.5.2 Variables

The dependent variable is land use type at time t, LUt. Table 3 suggests that land use intensity increases from ocean/vacant, to other urban, to informal, and to planned.

Therefore, LUt takes the value of 1 for vacant or ocean, 2 for other urban, 3 for informal, and 4 for formal. LUt is an ordinal categorical variable. Table 3.5 summarizes the independent variables. All these variables describe physical attributes of a grid or location and were either directly obtained from or calculated from various openly source data.

Table 3.5: Independent variables

Variable	Code	Explanation
	GRID	The grid value of every 250m cell, indicating proportion of land developed
Road Density	RDENPS	Primary and secondary roads combined length in 1000m neighborhood;
	RDENT	Tertiary road length in 1000m neighborhood;
	RDENR	Residential road length in 1000m neighborhood;
Distance to road	RDISTPS	Shortest distance to primary and secondary roads combined from grid point;
	RDISTT	Shortest distance to tertiary roads from grid point;
	RDISTR	Shortest distance to residential road from grid point;
	DISTC	Distance to the CBD
Past land use	LUP_V	Dummy variable indicating whether a location is vacant in past
	LUP_U	Dummy variable indicating whether a location is other urban in past
	LUP_I	Dummy variable indicating whether a location is informal in past
	LUP_P	Dummy variable indicating whether a location is planned in past
Past neighbor-hood	NIP_V	Dummy variable indicating that vacant land dominate the neighborhood in the past
	NIP_U	Dummy variable indicating that other urban land dominate the neighborhood in the past
	NIP_I	Dummy variable indicating that informal land dominate the neighborhood in the past
	NIP_P	Dummy variable indicating that planned land dominate the neighborhood in the past
	S	Slope

Grid code (GRID) is the first independent variable to estimate land use type. It is the proportion of land developed at a location. Higher GRID values are expected to reduce

the probability of a location to be vacant but increases the probability of this location to be developed (informal, formal, or other urban).

Road density variables for different roads was calculated within a 1000m neighborhood of a location. Primary roads cover large areas of the city, spanning from the central areas to the peripheries. Secondary roads include roads which connect "medium sized places", according to the openstreetmap guidelines for classification. Primary and secondary roads were joined into one category for the analysis because they constitute the major roads in the city.

Tertiary roads link smaller towns and larger villages. They were described as through roads and wide enough for two vehicles to fit. These roads were considered important for local access and travel between urban and rural residential land uses. Residential roads, as the name implies, make up roads and streets in residential areas. Residential roads in the dataset have the greatest number of inputs and cover smaller areas such as neighborhoods, as opposed to other roads types which stretch across the city or between towns. Assuming no other coverage than residential, they were useful to pinpoint extents of residential neighborhoods.

It was hypothesized that the level of road density coincided with a type of land use. For example, planned residential areas were expected to have a higher residential road density as compared to ocean and vacant land uses. The line density tool was used to determine the densities of roads within a 1km radius buffer zone of each built up area point. Therefore, the sum of the lengths of the selected road types were calculated within this radius, representing density. Since the outputs were in raster format, the rasters were converted to points and spatially joined with the built up area grid points.

Shortest distance to road variables were calculated in ArcGIS. In the literature, planned areas have better access to roads because these areas are designed for better access to transportation networks in and around the city (Olvera et al., 2003). However, it should be noted that informal growth has been observed to occur along stretches of highways in Dar es Salaam (Gombe et al., 2017). Therefore, this set of distance variables was considered useful for estimating land use type.

Distance to the CBD (DISTC) measures the distance from each data point to the central business district. Planned residences were likely to be closer to the central business district than informal or vacant lands. Also, it was likely that other urban land uses would be closer to the CBD since other urban land use includes commercial and business activities. Therefore, this variable would be a useful component in determining future land uses. The location of the central business district was determined by identifying Dar es Salaam's city center and business district using google maps and associating that location to the built up area grid in ArcGIS. A particular built up area point within the district was decided by selecting the closest point to the middle of the district area. Once identified as a point in the built up area grid, the near tool in the ArcGIS toolbox was used to calculate the distances between that center point and every other built up area point.

Past land use type variables were considered for this study as an indicator of land use to be expected in the future. For instance, a location with planned development was expected to continue to be planned development in the next period. Past land use data allowed us to calculate for past dominant neighborhood land use as well.

Past dominant neighborhood land use variables also indicate the type of land uses to be expected in the future. The neighborhood point statistics tool available in ArcGIS

allowed calculations of the majority land use type within a specified radius or neighborhood of a selected point. Because it was unclear which neighborhood radius would provide the most accurate results for the model, a variety of neighborhood radii were tested to produce the most accurate estimates. Neighborhood circle radii at 250m, 500m, and 1000m were calculated around each grid point. The best neighborhood size was determined by running the full model for each different neighborhood radius. The 250m neighborhood produced the greatest number of correct data estimates in the final model.

Slope (S) was calculated in ArcGIS using the slope tool on elevation data. Slope presents a barrier for the layout of a development project. This variable was expected to have a negative impact on planned residential land use.

3.5.3 Logistic Analyses

Logistic regression was utilized in this study because the dependent variable (land use type) was categorical and the relationship between the dependent and independent variable (built up area) was nonlinear. Both ordinal logistic regression and binomial logistic regression methods were tested. Binary logistic regression yielded better results to provide more reliable land use estimates. Hence, only binomial logistic regression analyses are reported in this chapter.

To run binomial analyses, the ordinal land use variable (LU) was converted into the following four land use dummy variables:

LUV = 1, if current land use type is vacant or ocean, =0, otherwise;

LUU = 1, if current land use type is other urban, =0, otherwise;

LUI = 1, if current land use type is informal, =0, otherwise; and

LUP = 1, if current land use type is planned, =0, otherwise.

The following four sets of binomial logistic regression analyses were run to explain the probability of a location to be vacant/ocean, other urban, informal, and formal, respectively:

$$P(LUV = 1) = \frac{1}{1 + \exp(-\alpha_0 + \alpha \boldsymbol{X})},$$

$$P(LUU = 1) = \frac{1}{1 + \exp(-\beta_0 + \beta \boldsymbol{X})},$$

$$P(LUI = 1) = \frac{1}{1 + \exp(-\gamma_0 + \gamma \boldsymbol{X})}, \text{ and}$$

$$P(LUP = 1) = \frac{1}{1 + \exp(-\delta_0 + \delta \boldsymbol{X})},$$

where $\boldsymbol{X}$ is a set of explanatory variables, as presented in Table 5.

Tables 3.6 and 3.7 present the regression results for 1992 and 2002 land use, respectively. Table 6 presents some important information on the relationships between the independent variables and 1992 land use. Consistent with expectation, the 1990 grid value (GRID) had significant, but opposite impacts in developed (other urban, informal, and planned) versus undeveloped (ocean/vacant) models. The increasing impact from GRID in the other urban, informal, and planned models is consistent with the confidence interval analysis results in Table 3.2.

Distance to primary and secondary road (RDISTPS) provided some significant relationships with land uses. Ocean/vacant and informal settlements results indicated a higher probability of proximity to primary and secondary roads. Planned settlements were likely to be farther away from primary and secondary roads. Distance to primary and secondary road results align with expectations of closer proximity to vacant and informal settlements and not to planned residences, since primary and secondary roads are for inter-

regional travel and not as important for local travel. As noted in the literature, growth of new informal settlements was observed along the major highways (corresponding to primary and secondary roads) in Dar es Salaam, hence, results of closer proximity to these roads make sense. Tertiary (RDISTT) and residential roads (RDISTR) distance were not significant to any land use estimates.

Distance to the central business district (DISTC) for the 1992 model had a positive relationship with other urban and informal settlements, indicating probability of distance from the CBD. Ocean and vacant lands had a negative relationship in both models, indicating probability of proximity to the CBD. These results were not in line with expectations since most vacant lands are outside of the urban areas. The 2002 model had similar results except other urban probability changed to proximity to the CBD.

Road density variables provided meaningful inputs to estimate land use types. In the 1992 model, higher density of primary and secondary roads (RDENPS) decreased the probability of a location to be vacant and increased the probability to be other urban or informal. However, in the 2002 model, areas with higher density of primary and secondary roads were less likely to be informal settlements and more likely to be vacant and other urban. Density of tertiary roads (RDENT) is not significant for the ocean/vacant and other urban models because of lack of presence of tertiary road in such areas. It is interesting that this variable has significance for both the 1992 and 2002 only in the informal areas. Denser tertiary roads were expected be in planned neighborhoods, but not informal neighborhoods, indicating better access to infrastructure in planned neighborhoods than in informal neighborhoods. Lastly, whereas residential road density (RDENR) in the 1992 model was

more likely for planned settlements, the 2002 model results indicated a positive relationship with residential road density in informal areas as well.

Percent slope (S) probability was lower in planned and other urban land uses, high in vacant, and not significant for estimating informal settlements in both models. This is consistent with expectation that hilly areas are not suitable for development and will remain vacant. It is worth to point out this variable does not have a significant impact in the informal model, but a strong negative impact on planned development. This could be explained by the importance of planning in planned versus in informal development, and/or a lack of ability of people who reside at informal neighborhoods in choosing a suitable site.

The two 1982 neighborhood variables (NIP_IF_82 and NIP_P_82) exert significant, but opposite impacts in the informal and planned 1992 model. A location within an informal or planned neighborhood in 1982 was more likely to be informal or planned. However, a location within a planned neighborhood in 1982 was less likely to be informal in the next time period. This indicates a possible segregation between planned and informal development. Similar trends are in the 2002 model for 1992 neighborhood variables (NIP_IF_92 and NIP_P_92).

Table 3.6: 1992 land use model results

	Ocean/Vacant		Other Urban		Informal		Planned	
	Est.	p-value	Est.	p-value	Est.	p-value	Est.	p-value
Constant	-2.936	0.000	-5.153	0.000	-3.874	0.000	-5.072	0.000
GRID_90	-3.347	0.000	0.736	0.029	2.448	0.000	3.726	0.000
RDISTPS	-0.549	0.000			-0.602	0.000	1.195	0.000
DISTC	-0.120	0.000	0.082	0.005	0.075	0.000		
RDENPS	-1.344	0.000	1.696	0.000	0.364	0.001		
RDENR					-0.236	0.000	0.249	0.000
RDENT					-0.446	0.026		
S	0.155	0.000	-0.161	0.001			-0.269	0.000
LUP_V_82	7.310	0.000						
LUP_U_82			8.369	0.000				
LUP_I_82					5.821	0.000		
LUP_F_82							7.346	0.000
NIP_U_82			-0.113	0.730	-2.877	0.000	-2.520	0.000
NIP_IF_82			-1.619	0.000			-2.432	0.000
NIP_P_82	0.822	0.037	-2.795	0.000	-2.529	0.000	-1.169	0.001
n	6246		6246		6246		6246	
-2 Log likelihood	2634.323		1104.964		2359.384		1304.915	

Table 3.7: 2002 land use model results

	Ocean/Vacant		Other Urban		Informal		Planned	
	Est.	p-value	Est.	p-value	Est.	p-value	Est.	p-value
Constant	-2.901	0.000	-3.526	0.000	-3.240	0.000	-4.168	0.000
GRID_00	-2.872	0.000	-0.889	0.002	2.764	0.000	3.256	0.000
RDISTPS	-0.280	0.000			0.035	0.577	0.212	0.045
DISTC	-0.044	0.001	-0.006	0.813	0.099	0.000		
RDENPS	0.422	0.000	0.339	0.009	-0.762	0.000		
RDENR					0.060	0.007	0.065	0.055
RDENT					-0.625	0.000		
S	0.089	0.000	-0.197	0.000			-0.397	0.000
LUP_V_92	4.378	0.000						
LUP_U_92			5.068	0.000				
LUP_I_92					4.236	0.000		
LUP_F_92							5.569	0.000
NIP_U_92			2.117	0.000	-1.684	0.000	-1.635	0.000
NIP_IF_92			0.759	0.004			-2.216	0.000
NIP_P_92	-0.231	0.471	0.913	0.001	-3.411	0.000		
n	6246		6246		6246			6246
-2 Log likelihood	4058.771		1449.097		4270.043		1405.316	

3.6 Land Use Estimates and Quality Assessment

Following the regression results in Tables 3.6 and 3.7, probabilities were calculated the predicted of a location to be ocean/vacant, other urban, informal, and planned. The estimated land use values were determined by selecting the highest predicted probability among all four regressions (or category of land use) for each record. Based on the relations estimated in Table 3.6, 1992 land use and 2002 land use were estimated. Based on the relations in Table 3.7, 2002 land use were estimated.

These sets of estimated land use values were compared to the actual land use values for quality assessment of the model. Table 3.8 presents the quality assessment of 1992 and 2002 land use based on the 1992 land use model. Results for the model show significant correct number of land use estimates, with an overall 89.69% accuracy. The least accurate land use type, as expected, were informal land uses.

Table 3.8: Quality assessment of 1992 and 2002 land use estimates based on the 1992 land use model

	1992			2002		
Land use type	**Number of records**	**Correct estimates**	**Percent correct**	**Number of records**	**Correct estimates**	**Percent correct**
Ocean/vacant	3176	3116	98.11%	2126	2049	96.38%
Other urban	1161	1049	90.35%	1164	1072	92.10%
Informal	998	667	66.83%	1936	981	50.67%
Planned	911	770	84.52%	1020	875	85.78%
Total	6246	5602	89.69%	6246	4977	79.68%

The accuracy of the 1992 model decreased when applied to estimate land use ten years later (2002) from 89.69% to 79.68%. The maps in Figure 3.5 provide a visual of the incorrect estimated land use points for planned and informal settlements. From the figure,

the incorrect estimates are generally toward the periphery, indicating the limitations of the model to predict peripheral growth, especially for informal areas. There are several reasons why this could be the case. The first is that the built up area input is for two years prior to the land use, so it does not include the extra two years of built up area growth (from 2000 to 2002). A second reason might be that the peripheral growth in these outer areas is at a greater rate than the previous years modeled, therefore, the extent of growth and growth rates for the later decades are not captured by the 1992 model. Lastly, the impact of planning, political, and economic directions could have changed relationships with land over time, thus altering growth patterns which the model does not consider (Halla, 2007).

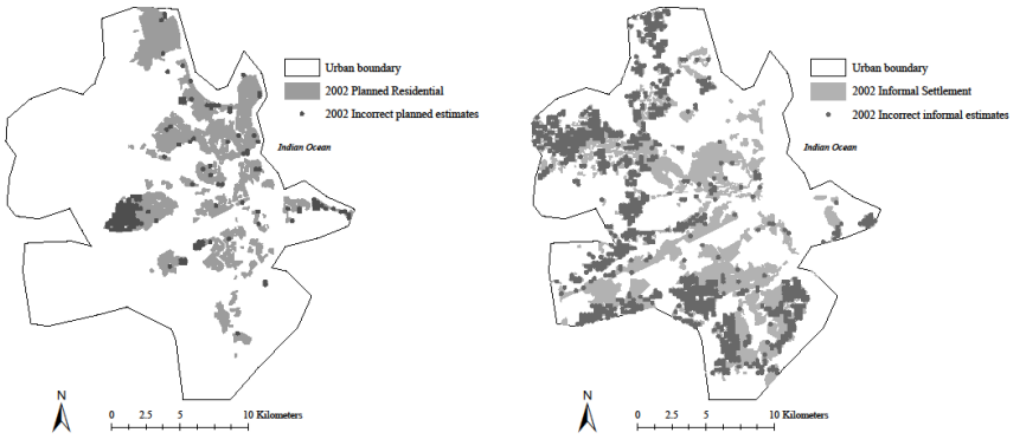

Figure 3.5: Incorrect estimates of the 2002 planned and informal land use based on the 1992 regression model within the defined urban boundary.

Table 3.9 shows the quality assessment of 2002 estimated land use with actual 2002 data based on the 2002 model. Although the quality assessment level of the 2002 model was not as high as the 1992 model, it represents a more recent and accurate informal growth land use from which to base estimations of 2014 land use. Despite the lack of confirmation of the 2002 model's prediction accuracy for future land uses (compared to the 1992 model),

it was considered to be useful. Since the model was tested with 1992 data and the results of the predictions were about 10% less accurate, it was inferred that the 2002 model would also produce predictions around that range of decreased accuracy for 2014 land use. This was a major assumption, but the success of the 1992 model provided some reassurance of the usefulness of the model in general. The final figure 6 shows predictions of 2014 land uses based on the 2002 land use model.

Table 3.9: Quality assessment of 2002 estimated land use based on 2002 land use model

Land use type	Number of records	Correct estimates	Percent correct
Ocean/vacant	2126	1963	92.33%
Other urban	1164	1069	91.84%
Informal	1936	1212	69.60%
Planned	1020	872	85.49%
Total	6246	5116	81.91%

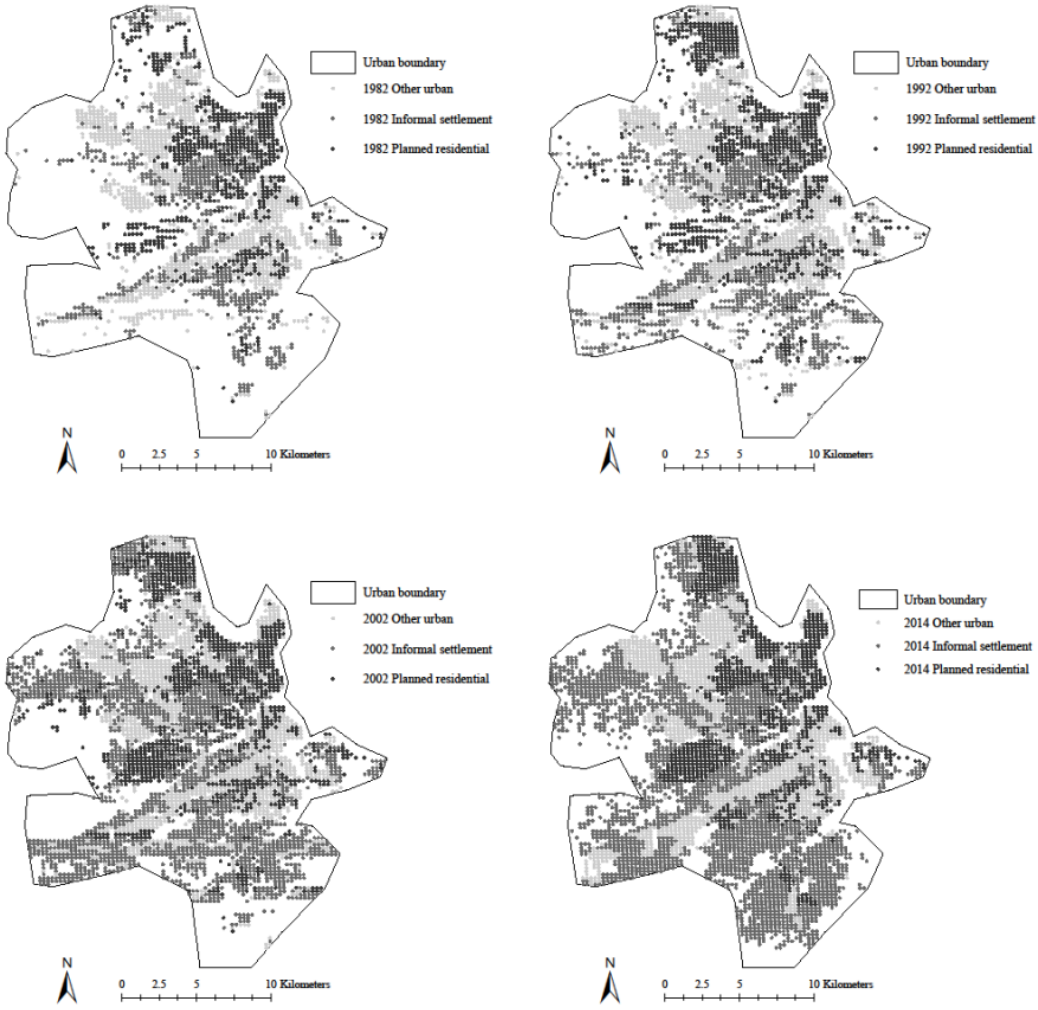

Figure 3.6: Land use from 1982, 1992 and 2002, with 2014 land use estimates based on the 2002 land use binary regression model.

The main contributors to the accuracy rates of the land use model were built up area and the previous decade's existing land use dataset according to the model. Clearly, with more recent land use datasets to work with, estimates would likely have been improved since the literature points to significant increases in rate of urbanization and built up area growth after 2002. Road distance and proximity, distance to the CBD, and percent slope also contributed to results, but were of minor influence. It is also the case that the most

influential variables were those which had multi-temporal data. For example, the street network did not change in the model and in the predictions over time. For one, the mutli-temporal data were not available, only more recent road data were available. It is inferred that with more accurate road coverage available at the time of the land uses datasets, the model and thus accuracy could have been marginally improved.

3.7 Conclusions

In contexts with data and data availability limitations, it is sometimes necessary to use existing data with innovative methods and new technologies to estimate, predict, or model urban land use and urbanization processes. For this study, with limitations in obtaining more recent urban land use data, it was necessary to produce an estimation of 2014 urban land use in order to conduct further analysis for future studies on urban land use trends in Dar es Salaam over time.

Selection of existing datasets were based on open availability (especially multi-temporal data), but also on reliability of data using the most accurately available technology. Another important aspect of the selected datasets (especially the land use and built up area data) is that they were not developed with a focus on administrative boundaries. This is useful because data determined by administrative boundaries are not necessarily the most representative of neighborhood boundaries on the ground. However, administrative boundaries were valuable in determining the urban boundary which allowed the study to be more focused on urban land use instead of the greater Dar es Salaam region. Furthermore, a major benefit was the existence of multi-temporal urban land use data which were developed using the same methodology and with the consistent classification system. This eliminated the need to reconcile various land use datasets with different

methods and classification systems, which could have compromised the quality and utility of the data or introduced additional biases.

The results of the study show simple regression models can be useful in estimating future land uses, especially if good quality multi-temporal existing urban land use data and multi-temporal built up area data are available. The multi-temporal GHS data were particularly useful in this case and can be used for other studies since it is a global dataset. The results also show the model provides acceptable results even in settings undergoing unplanned growth. However, despite the significant results of the model, the informal residential land uses were, as expected, the most difficult to predict out of the land use categories in this study. It is also important to note, the other land uses did not change significantly over time, allowing the future predictions to be at a high accuracy overall.

Considering Dar es Salaam's urbanization rates over the past three decades, the rates of urbanization and population growth have changed with each passing decade. For example, the rate of urbanization from the 1980s to the early 2000s have shown to be lower than from the 2002 onward. Therefore, the relationships between urbanization and land use changes have also likely changed, leading to probable decreased accuracy of the 2002 model to predict 2014 land use change in Dar es Salaam.

The main limitations of this study are related to the existing datasets as well as the lack of quality assessment of the final 2014 land use estimations. A benefit of the different datasets is the close alignment of the data time periods. Although the years did not match exactly (i.e. 1990 built up area and 1992 land use), they were close to each other to be acceptable for analysis. However, a limitation with the data is the difference in technologies when the datasets were created. For example, the land use data was developed with aerial

photography interpretation, whereas the built up area satellite imagery come from more advanced technologies, methodologies and remotely sensed data. Therefore, there can be differences in accuracy even though the time periods are closely aligned. Lastly, the model did not allow for certain areas or land use types to be controlled for. For example, reserved park areas or land uses which perhaps were unable to be converted to residential land uses were not controlled. In spite of these limitations, these datasets and methods were considered to be sufficient for estimation of land use data for 2014.

Although there are limitations, the opportunities presented by the existence and availability of these datasets are important in that they allow for evidence-based and transparent scholarship. With the use of openly available data and the presented methodology, this study aimed to test the reliability and applicability of available datasets and use them to produce estimates of current land use data. It also aimed to promote open scholarship to build upon and strengthen understanding of urbanization, especially informal development, in Sub-Saharan Africa. Future studies can be conducted based on improving the methodology outlined in this study, in terms of developing different types of models using the openly sourced datasets, or improving the current model using additional datasets or variables. Also, a more detailed set of land use classifications can be especially valuable to move beyond binary conceptualization and measurement of informal and planned residential data. Lastly, studies could use the estimated 2014 land use dataset developed in this study for further investigation on land use changes over time or to have an idea of current informal growth in the Dar es Salaam region (with consideration of the limitations of the estimations).

CHAPTER FOUR: DO URBAN PLANNING AND SPRAWL AFFECT SOCIAL VULNERABILITY? AN ASSESSMENT OF QUALITY OF LIFE AND MOBILITY IN DAR ES SALAAM, TANZANIA

4.1 Introduction

It is well established that a majority of the global population now lives in cities, with urbanization, particularly in developing nations, continuing to increase and intensify (United Nations, 2015). In this regard, urban populations and spaces are important subjects of interest to scholars, especially where high rates of urbanization magnify existing or introduce new inefficient, inequitable, and vulnerable outcomes. One pathway of vulnerability studies in urban areas is to measure inequities amongst urban populations and identify vulnerable groups. Scholars have observed multifaceted relationships between urban areas and vulnerabilities, whereby urban processes and activities have been suggested to accelerate, maintain, and/or reduce defined vulnerabilities of populations and in cities (Adelekan et al., 2016; Krellenberg et al., 2016). These multifaceted relationships between the urban, urbanization, and vulnerability require pointed inquiry in specific contexts in order to determine what urban processes and activities affect which populations, by what factors, in what spaces and scales, and to what (or how) they are vulnerable. Specifying the dimensions is inferred to improve understanding of distinct contextual

processes and enable targeted approaches to improve equitable outcomes and mitigate defined vulnerabilities in cities, particularly those cities which are still urbanizing.

Current impacts of formal urban planning and governance institutions tasked with addressing vulnerabilities and equitable planning are unclear in many Sub-Saharan cities. For example, these institutions often struggle with administrative and resource inconsistencies (Kironde, 2000; Adelekan et al., 2015; UN Habitat, 2010), as well as data collection and data availability limitations (Borel-Saladin et al., 2018). Also, the existence of multiple, overlapping, and multi-scalar formal and informal development activities and systems further complicate the urban landscape (Boamah & Walker, 2017; Locke & Henley, 2016; UN Habitat, 2010). The influence of formal urban planning and vulnerability in Sub-Saharan cities are thus difficult to measure and express.

This paper focuses specifically on the social aspect of vulnerability and aims to investigate the influence of formal planning and sprawling to quality of life and mobility at the urban scale. Dar es Salaam, Tanzania is the selected case study area. Using quantitative methods such as principal component analysis (PCA), statistical regressions, and spatial mapping techniques, the paper also aims to provide new pathways to assessing the concept of social vulnerability in an urban environment. Dar es Salaam's particular context of high percentage of informal residents and rate of urbanization make the city an interesting area for this type of study. Furthermore, the availability of reliable open data sources for Dar es Salaam allowed for the analysis, as other parts of the Sub-Saharan region typically face challenges from limited data availability and access, and/or lack of reliable data which distinguish informally developed areas.

The paper is organized as follows. Section 4.2 explores the concept of social vulnerability and its measurement in an urban environment. This section also presents the research hypotheses about the relations between urban planning, sprawl, and social vulnerability. Section 4.3 introduces the study area and explains the data collection process. Section 4.4 uses the principle component analysis method to construct two indices (Quality of Life and Mobility) for social vulnerability. Section 4.5 presents the descriptive results. Section 4.6 further offers regression analyses of two social vulnerability variables. Section 4.7 concludes the paper.

4.2 Social Vulnerability

4.2.1 Vulnerability, Urban Vulnerability, and Social Vulnerability

Vulnerability as a basic term is defined as a system's susceptibility to harm (Kelman et al., 2016). Initially stemming from natural disaster studies, it has been further developed in diverse ways over time across professions, with early vulnerability studies focusing on natural systems, later transitioning to human dimensions of vulnerability (i.e. social and economic), and more recently focusing on coupled socio-environmental systems and comprehensive sustainable development directions (Cho & Chang, 2017; Fang et al., 2016). Reconfigured conceptualizations of vulnerability across different disciplines have resulted in limited consensus (Salami et al, 2017), as well as a lack of agreement on operationalization (Wolf et al., 2013). The IPCC (Intergovernmental Panel on Climate Change) notion of vulnerability is a commonly referenced framework in climate change studies (Salas & Yepes, 2018). The definition merges not only susceptibility of systems, but also exposure of external hazards and adaptive capacity or coping of systems.

Urban vulnerability is a relatively new notion in the literature, evolving much like the concept of the urban itself (Krellenberg et al., 2016). Urbanization factors have been linked to increasing vulnerability in cities and amongst populations, particularly the urban poor, prompting a focus on urban contexts in recent years (Baker, 2012; Salami et al., 2017). Urbanization processes and the urban context provide additional facets through which complex and integrated interactions can be explored to understand, explain, and measure vulnerability in various spatial-temporal dimensions. Fang et al. (2016) define urban vulnerability as the "coping capacity to resist multiple aspects of disturbances from various internal and external natural and human factors," (p.156) and incorporate resource, eco-environmental, economic, and social vulnerabilities of the urban context within its conceptualization. This definition offers a multi-dimensional approach to understand vulnerability involving stressors, which are not limited to biophysical or climate-related hazards (Räsänen et al, 2016).

Guided by this definition, two broad dimensions nested within urban vulnerability can be differentiated: environmental and social vulnerability. Environmental vulnerability, also referred to as biophysical vulnerability in some studies (Kelly & Adger, 2000), deals with the coping capacity to natural disturbances, and social vulnerability evaluates the different coping capacity caused by the society operation. Many studies related to economic and political inequality (Richmond et al., 2018; Fang et al., 2016; Heinrichs et al., 2013) address different groups' coping capacity with the same urban environment and can be included into the social vulnerability literature.

A rich set of literature is available in exploring how the urbanization process affects environmental vulnerability (Garschagen & Romero-Lankao, 2015; Krellenberg et al.,

2016), however, the study on social vulnerability is more fragmented. In general, social vulnerability acknowledges the impact of external exposures, but emphasizes the roles of social, political, economic, and institutional contextual factors on various spatial and temporal scales (Eriksen et al., 2008). Similar to the IPCC definition, social vulnerability often includes the aspect of capacity to cope with and adapt to the urban environment (Lee, 2014). Therefore, the factors which influence social vulnerability can work to reduce or increase vulnerability depending on coping or adaptation capacities of systems. Along these lines, social vulnerability can be argued to be the humanistic dimension of urban vulnerability in the same way as it constitutes more general forms of vulnerability.

Figure 4.1 presents a simple representation of the relationships between urban, environmental, and social vulnerability and the factors which influence them. Urban vulnerability is a broader concept for analyzing urban dynamics caused by both external and internal factors, while social vulnerability represents a subset of urban vulnerability and emphasizes different social units' (e.g. population, community, or household) coping capacities within the same social-economic structure. For example, factors such as institutions can work in different ways to enable coping and adaptation or intensify and activate vulnerability for different social units. It is important to note that social, environmental, urban vulnerability are not dependent on multiple isolated factors but linked by complex and variegated interactions between multiple factors.

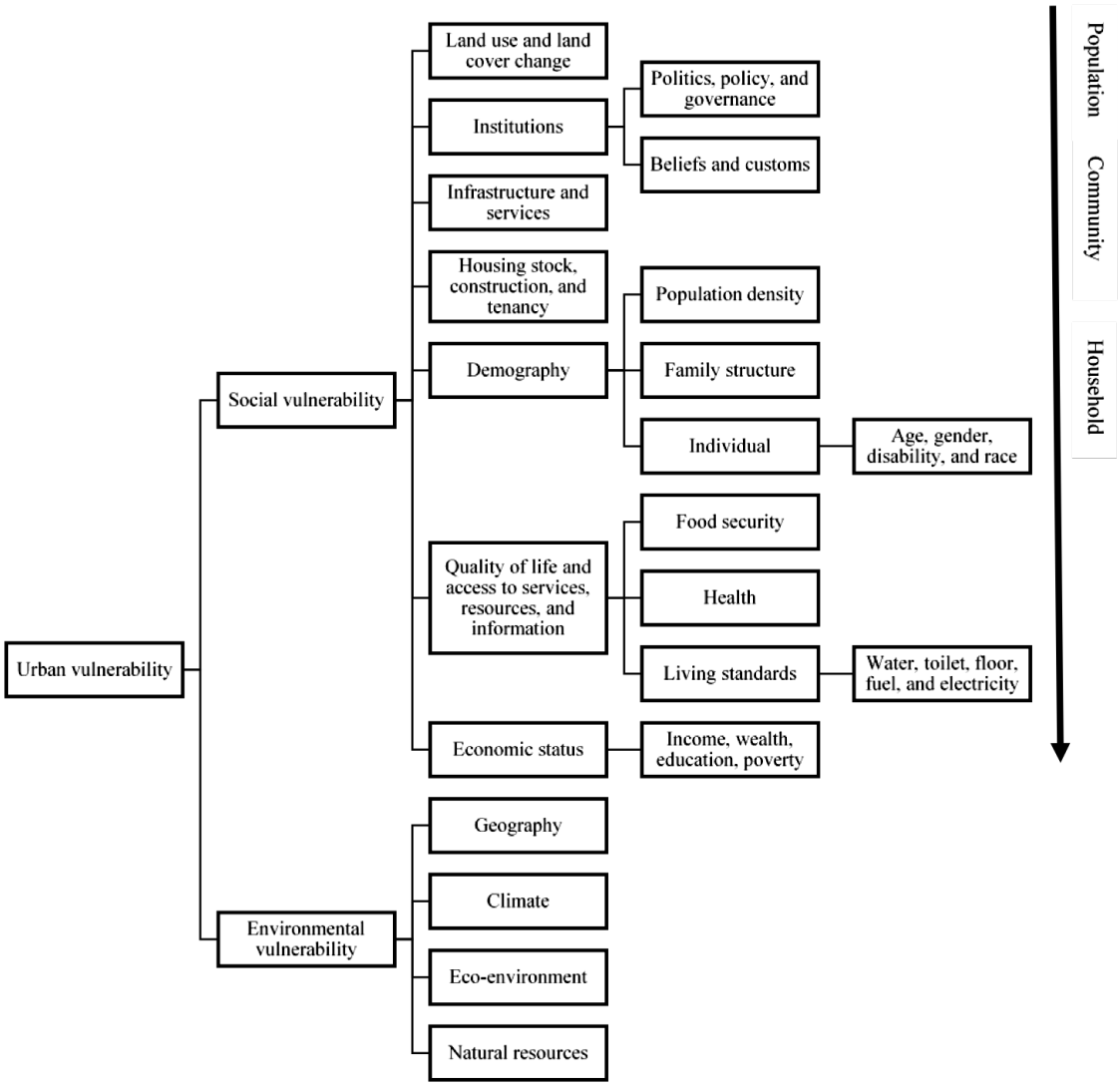

Figure 4.1: Urban vulnerability vs. environmental vulnerability vs. social vulnerability

4.2.2 Factors Related to Social Vulnerability

The commonly referenced paper by Cutter et al. (2003), which operationalizes social vulnerability factors to environmental hazards, serves as a starting point to explore factors related to social vulnerability in the urban system. Categories of factors outlined in the paper include (1) demographic factors such as gender, age, race, (2) socio-economic

status such as income, political power, personal wealth, (3) housing quality and tenancy, (4) density of the built environment, and (5) infrastructure dependence and access to services, among others. Land use, population growth and density, access to property, and urban governance are additional factors emerging from the notion of urban vulnerability (Krellenberg et al., 2016).

Although demographic factors such as age, gender, and race are suggested to influence social vulnerability, results from vulnerability studies are not straightforward. For example, women and children are generally considered to be a vulnerable demographic (Quarantelli, 2003). Dodman et al. (2017) suggest women may face more challenges such as gender norms or differences in rural/urban culture of women's rights, earn less than males (Cutter et al., 2003; Beyer et al., 2016) and have greater family care responsibilities (Fernandez et al., 2016). Blumenberg (2004) also finds that low-income females are more vulnerable in U.S. cities. Females likely have to commute in a suburbanized city with a lack of public transit service, work in an economy with gendered differences in occupation and income, and live in a society where women are still expected for their home responsibilities. However, some empirical studies suggest female heads of household show no impacts on vulnerability, especially if they are of middle to upper class economic status (Rufat et al., 2015). Therefore, demographic factors alone are not necessarily sufficient to indicate social vulnerability.

Socio-economic characteristics are widely accepted individual and household level social vulnerability factors (Pelling, 2002), however, also depend on other factors. For example, low-income households with certain demographic characteristics, such as high number of family members and high number of children are linked to greater vulnerability

(Dodman et al., 2011; UN Habitat, 2015; Beyer et al., 2016; Fernandez et al., 2016). Low-income households could lead to low or no education of children (Beyer et al., 2016). Wealthy households likely have better access to resources, including food, water, transportation, and education (Eriksen et al., 2008; Beyer et al., 2016; Rufat et al., 2015; Dodman et al., 2017; Lupala, 2002; Lawal & Arokoyu, 2015; Ebert et al., 2009). At the same time, not all poor populations are vulnerable to food insecurity (Bohle et al., 1994). Moser (1996) suggests the possession of tangible and intangible assets (labor, human capital, productive assets, household relations, and social capital) as well as the "ability to transform those assets into food, or other basic necessities" (p.2) are a form of resilience to vulnerability and reduce the effects of threats.

Furthermore, at the household level, Tipple (2005) suggests quality of housing construction and infrastructure, location (slope), and regulation, linked with affordable and available land supply, are factors impacting social vulnerability. Wealthier populations are able to afford better constructed homes with sturdy material to withstand environmental hazards (Flanagan et al., 2011; Cutter et al., 2003). Although poor populations are often cited as the most vulnerable in terms of housing construction (Baker, 2012; Few, 2003; Nuwagaba, 2003), scholars have noted they are not always the most vulnerable groups when faced with hazards (Eriksen et al., 2008; Pelling, 2002) due to strong social networks as well as development of adaptation and coping methods from experiences. More importantly, wealthy households may be more attracted to housing in environmentally unstable areas (e.g. coastal) (Bagstad et al., 2007).

Community level characteristics are also commonly referenced aspects of vulnerability. Population density can play a role in producing social vulnerabilities (Abson

et al., 2012). For example, although more dense areas are likely to have infrastructure and services because of high demand, at the same time, traffic and crowding can reduce mobility, especially in situations in which evacuation is required (Dodman et al., 2017). Crowding has also been linked to reduced quality of life (Lawal & Arokoyu, 2015). Depending on context and other economic, social, and physical factors, population density may or may not be an indicator of greater urban vulnerability.

At a broader scale, several factors are proposed to influence vulnerability in the literature, such as politics, governance, and cultural institutions, as well as built environment characteristics. Institutional factors may contribute to positive adaptation ability of societies or intensify vulnerability and lack of coping or adaptation (Kelly & Adger, 2000; Tipple, 2005; Eriksen et al., 2008; Krellenberg et al., 2016). For example, urban development policies and programs shape urban settlement patterns, guide aspects of tenure security, economic development, infrastructure development, and service provision in cities (Porio, 2011). On the other hand, the legacy of colonial institutions, for instance, have been shown to produce vulnerable marginalized communities and populations with reduced coping capacity (Kironde, 2000). Civil society groups have also shown to aid or influence coping or adaptation of population groups to hazards (Herslund et al., 2016).

Lastly, land use and land cover changes are considered a broad scale factor of urban vulnerability (Krellenberg et al., 2016; Congedo et al., 2013). Particularly in the Sub-Saharan urban context, informal land use raises added challenges in vulnerability studies, especially within conditions of rapid urbanization in African cities. For example, informal housing in urban areas has been observed to be located in hazardous areas and linked to

poverty and limited coping (Pauleit et al., 2002) as well as urban violence (Mearns & Norton, 2009). Populations in urban areas tend to suffer the consequences of variations in quality or lack of infrastructure. In informally developed areas, basic services and transportation costs are higher as well as the lack of formal tenure security reduces investment in spaces (Hill & Linder, 2011). Furthermore, enforcement of adaptive policies to hazards or risks are a challenge in informal or unplanned urban areas in sub-Saharan cities (Mutanga & Mwiruki, 2013; Kiunsi, 2013).

4.2.3 Social Vulnerability Index

Quantifying indicators or factors has been a significant challenge in assessment of social vulnerability (Mavhura et al, 2017). A common approach is the construction of a social vulnerability index. There are three main types of indices: deductive, hierarchical, and inductive (Tate, 2012; De Sherbinin et al., 2015; Coulibaly et al., 2015; Reckien, 2018). To create a deductive index, selected indicators are normalized and aggregated with or without weighting variables (Eguaroje et al., 2015; Danumah et al., 2016; Ebert et al., 2009). A hierarchical index is a large system consisting with many sub-indices of different categories. An inductive index is produced by a principle component analysis approach to reduce a large group of correlated factors. Although there are recognized issues and limitations with the index approaches (Fernandez et al., 2016; Lankao & Qin, 2011), as well as with the aggregation of the indicators into a composite index (Jones & Andrey, 2007), indices are commonly utilized and can be readily interpreted by policy makers and decision makers.

4.2.4 The African Context and Research Questions

Social vulnerability assessments using diverse approaches are present in the African context and literature. Kablan et al. (2017) adapted a European framework (known as MOVE) to Cote D'ivoire, in West Africa. Pauleit et al. (2002) and Nomdo et al. (2002) have attempted to create Africa-specific vulnerability assessment frameworks. However, few studies have incorporated the informal or unplanned aspect of African urbanization into the social vulnerability assessment. Institutional factors such as planning and governance also have low representation in the urban vulnerability literature (Cho & Chang, 2017). The complexities of informal urban development are important but poorly understood in the scholarly literature (Kombe & Kriebich, 2006). Due to limited informal settlement data (Osuteye et al., 2017) there is a significant lack of local-scale social vulnerability analysis inclusive of unplanned or informal areas (Kebede & Nicholls, 2012; Dodman et al., 2011).

This study aims to address the limitations and provide a social vulnerability assessment which incorporates urban planning related processes (i.e. land use, informal development) as well as social and economic factors in the Sub-Saharan African context. In other words, it aims to quantitatively determine whether urban planning factors contribute to or influence social vulnerability in African cities. Two main research questions frame the study: (1) does urban planning reduce social vulnerability and (2) does urban sprawl contribute to social vulnerability? Three hypotheses stem from these research questions.

Hypothesis 1*: Planned urban areas are less socially vulnerable than informally developed urban areas*. This hypothesis proposes that urban planning is an important factor

which reduces social vulnerability and unplanned or informal areas are more socially vulnerable. Urban planning activities are expected to optimize infrastructure and service land uses, and planned areas are also more likely to have tenure security and better housing structure (Richmond et al., 2018). Therefore, the variable of planning encompasses multidimensional factors useful for social vulnerability assessment in the African urban context.

Hypothesis 2: *Sprawled areas have higher social vulnerability than non-sprawled areas, i.e. urban sprawl intensifies social vulnerability.* This second hypothesis draws from the literature which argues that sprawl has costs, including the destruction of the natural environment and agricultural land, various forms of pollution, poor sanitation and decreased services, increased commuting, traffic congestion, and low density housing. Economically, sprawl has been suggested to contribute to high energy consumption and increasing energy costs, land market inefficiencies, high costs of services, high transportation costs, and increases in land prices and land speculation (Cobbinah & Amoako, 2012). Furthermore, in the African context, sprawled areas are likely to be areas where poorer populations live (Dodman et al., 2017). In this sense, urban sprawl, like urban planning, encompasses various social, spatial, and economic factors within this one indicator, and may be a useful multi-dimensional indicator of social vulnerability.

Hypothesis 3: *Planned sprawl areas are less socially vulnerable than informally developed sprawl areas.* The third hypothesis essentially posits that planned urban sprawl is less vulnerable than unplanned urban sprawl. The difference between this hypothesis and the previous one is the results of this hypothesis allow for a more specific analysis of urban sprawl contributions to social vulnerability. Whereas urban sprawl and urban planning

measured separately may be useful indicators of social vulnerability, the combination of informal development and sprawl may provide some insights into compounding negative effects.

4.3 Study Area and Data Collection

Dar es Salaam, Tanzania was selected for this study because of its location as a growing coastal city in the sub-Saharan Africa region as well as the availability of openly sourced data such as urban land use with informal settlement data. It is a city urbanizing faster than planning and has kept up in terms of influx of rural-urban migrants, population growth, as well as spatial expansion of the urban areas over the past 40 years (Hambati & Gaston, 2015). Figure 4.2 presents the selected urban study area within the greater city administrative boundary. The urban study area (urban boundary) is consolidated based 2002 administrative ward unit boundaries where social-economic data is available.

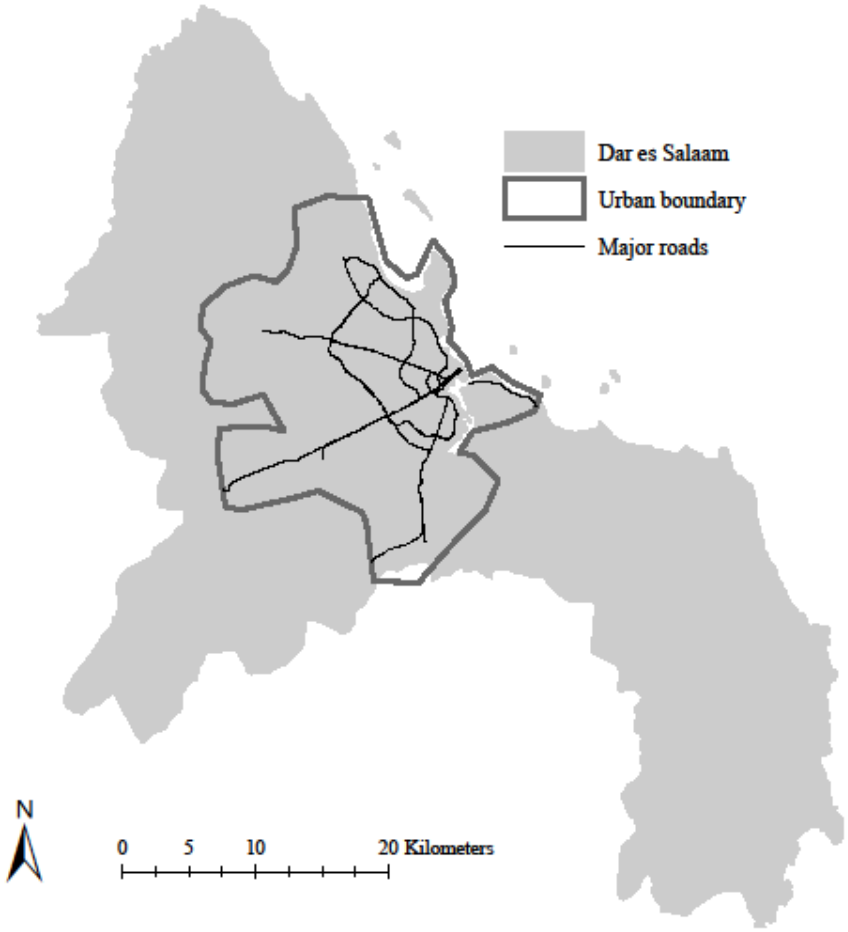

Figure 4.2: Study area

Social, demographic, and economic data at the household level were obtained from the 2015-16 Tanzania Demographic and Health Survey and Malaria Indicator Survey (2015-16 TDHS-MIS). Each household in the survey was associated with a spatial cluster consisting of up to 22 households per cluster (31 clusters total in the study area). Along with survey data, GPS data of the survey clusters were provided for download, which allowed for spatial analysis and mapping.

For population data, the Global Human Settlements (GHS) program of the European Commission population raster data were downloaded for Dar es Salaam at the 250m scale

for the year 2015 (Pesaresi et al, 2013). Road data were downloaded as a shapefile from mapcruzin.com in order to assess a measure of access to transportation and a road network. The mapcruzin data is based off road data from openstreetmap.org, a collective web-based mapping network supported by various institutions and organizations, including several universities. It is important to note the downloaded roads were not as comprehensive as the source openstreetmap.org but were deemed sufficient for the analysis.

Urban land use data with informal settlements as well as planned residential areas for the years 1982, 1992, and 2002 were downloaded from the Socioeconomic Data and Application Center (SEDAC) website, affiliated with Columbia University and NASA (Šliužas, 2004). The 2014 urban land use data were estimated based on previous land use, built up area proportion, road distance and density, as well as slope, among others. This estimation approach has been tested as reliable (see Chapter Three).

The central business district (CBD) in Dar es Salaam is considered in this paper to be the city center, which is selected. To measure sprawl, the central business district (CBD) point was selected and mapped in order to measure distance from each data point in the study area to the CBD. Since there was no predefined central business district point to base the measurement from, an arbitrary point in the center of the area identified as the greater business district by google maps was selected and mapped.

Guided by Figure 4.1, Table 4.1 presents a final list of the indicators/variables selected and calculated from the above data sources for further social vulnerability analyses. Variables created from the 2015-16 TDHS-MIS survey were grouped into three categories: quality of life, economic status, and demographic attributes. These variables are at the household scale. Quality of life variables include living standard factors, food

security and access to services and resources. Due to limited economic variables available in survey data, two proxy variables were selected: education level and bank account. A household with a bank account indicates potentiality to secure a loan and considered to be less vulnerable than storing cash at home (Tipple, 2005). Similarly, a household with higher and education level usually indicates a higher level of economic status (Lawal & Arokoyu, 2015; Rufat et al., 2015). In terms of demographic variables, number of children under the age of 5, number of household members, gender of the head of household, and age of the head of the household were selected.

In addition, four urban planning and built environment variables – population density, distance to roads, sprawl, and planning dummy variables were calculated in ArcGIS as factors which influence social vulnerability on the larger urban scale. Population density was calculated as the number of people within a $250m^2$ cell averaged by cluster of the study area. Distances to roads were the distances from each data point to the closest major road within a 1km radius and averaged by cluster. Urban planned residential areas were calculated and coded as 0 if the majority of a cluster had unplanned residential land use and 1 if the majority of a cluster had planned residential land use. Lastly, a sprawl dummy was calculated based on the distance to the CBD for each observation in relation to the median distance. For each ward unit, if the distance to the CBD was greater than the median distance of all wards, it was considered sprawled and coded as 1. All other points within the median distance were considered to be part of the main city and coded 0.

Table 4.1: Variable dictionary

Variable		Explanation	Source
Household Characteristics			
Quality of life and access to resources and services	WATER	=0 if other drinking water sources; =1 if unimproved; =2 if improved; =3 if piped neighbor; =4 if bottled; =5 if piped yard; and =6 if piped plot	2015-2016 TDHS-MIS
	ELEC	=1 with access to electricity service; =0, otherwise	
	SANI	=0 if unimproved sanitation facility; =1 if pit with slab; =2 if VIP; =3 if flush with pit; =4 if flush septic; and =5 with piped flush	
	FLOOR	=0 if other floor material; =1 if earth; =2 if cement; =3 if carpet; and =4 if ceramic tile flooring	
	FOOD	=0 if always problem meeting food needs; =1 if often; =2 if sometimes; =3 if seldom; =4 if never	
	PHONE	=1 if owns mobile phone and/or landline; =0 otherwise	
	AUTO	=1 if owns automobile; =0 otherwise	
	BIKE	=1 if owns bicycle; =0 otherwise	
	RADIO	=1 if owns radio; =0 otherwise	
Economic status	BANK	=1 if has a bank account; =0 otherwise	
	EDU	=0 if don't know; =1 if no education; =2 if primary; =3 if secondary; and =4 if higher education	
Demographic	HHN	Number of household members	
	CHILD5	Number of children 5 and under in the household	
	GENDER	=0 if male; =1 if female (head of the household)	
	AGE	Age of the head of the household	
Urban Planning and Built Environment			
	DEN	Number persons per 250m^2 area averaged per cluster	GHS
	DISR	Access to major roads within 1km radius averaged per cluster	Calculated in ArcGIS
	PLAN	=1, if majority of a cluster's residential activities are planned; =0 otherwise	
	S	=1, if greater than median distance to CBD, =0 otherwise	

4.4 Principal Component Analyses

The household social variables were expected to be highly correlated. This presented a challenge for further regression analyses. In addition, it was more difficult to provide meaningful interpretations if all the variables were directly used in regression analyses. Therefore, principal component analyses (PCA) were performed in SPSS to reduce the number of social variables. Table 4.2 presents the results. The variables within these components were recoded from the original survey to be in the form of most to least vulnerable for ease of interpretation before the PCA. For instance, the lower scale of source of drinking water were unimproved sources such as unprotected surface water and the higher end sources were piped water in the yard or home. In this sense, a higher value meant less vulnerable.

Table 4.2: PCA results of social variables

	Variable	Component (QOL)	Component (MOB)
Quality of life and access to resources and services	WATER	0.418	
	ELEC	0.633	
	SANI	0.647	
	FLOOR	0.687	
	FOOD	0.400	
Mobility and Connectivity	PHONE		0.508
	AUTO		0.634
	BIKE		0.558
	RADIO		0.617
% of Variance Explained		32.524	33.809

The first component indicated general quality of life (QOL). It was heavily loaded by variables related to a household's basic needs such as clean water, sanitation, food security, electricity, and sturdy housing structure. All the variables were positively loaded into this component, with higher QOL value indicating better sources of drinking water,

electricity, sanitation facility, housing floor material, and food security, i.e. better quality of life.

The second component was positively loaded by variables related to mobility and connectivity, and constituted a household's mobility (MOB) component. It indicated the ability of individuals within the household to physically move around the city (bicycle and automobile) as well as have access to information and resources which would enable mobility (phone and radio). Higher MOB values were associated with higher level of mobility and lower social vulnerability.

4.5 Descriptive Statistics

Descriptive statistics for the complete set of variables are in Table 4.3. The household social vulnerability variables (QOL and MOB) were normalized by the PCA. The mean of the PLAN dummy was 0.188, indicating that only 18.8% of the development are planned and majority were unplanned or informal.

Table 4.3: Descriptive statistics of all variables

Variables	N	Min	Max	Mean	Median	Std. Dev.
QOL	584	-2.676	2.842	0.000	-0.006	1.000
MOB	584	-2.278	5.105	0.000	-0.033	1.000
EDU	584	0.000	4.000	2.457	2.000	0.704
BANK	584	0.000	1.000	0.790	1.000	0.404
CHILD5	584	0.000	4.000	0.637	0.000	0.785
HHN	584	1.000	15.000	4.182	4.000	2.570
GENDER	584	0.000	1.000	0.200	0.000	0.401
AGE	584	18.000	83.000	40.500	38.000	13.175
DEN	584	115.427	2810.097	987.723	0.942	637.933
DISR	584	0.038	0.611	0.054	0.041	0.084
PLAN	584	0.000	1.000	0.188	0.000	0.391
S	584	0.000	1.000	0.4966	0.000	0.5004

Table 4.4 presents correlation coefficients between variables. Correlations between the PCA component variables (QOL and MOB) and economic status (EDU and BANK) are positive and significant at the 1% significance level. This is in line with the literature linking dimensions of accessibility (mobility), housing quality (quality of life), and socioeconomic status with social vulnerability in similarly associated patterns (Lawal & Arokoyu, 2015; Rufat et al., 2015). The strongest correlations for quality of life (QOL) were mobility (MOB), education (EDU), bank account (BANK), population density (DEN) and distance to roads (DISR). For mobility (MOB), the strongest correlations were education (EDU), bank account (BANK), and population density (DEN).

No significant correlations resulted from the urban sprawl variable (S) with each of the social variables. This suggested sprawl as a variable on its own did not significantly correlate with social vulnerability variables, however, there was a chance it would be a useful variable when other factors were present. For the urban planning variable (PLAN) there was a significant relation (at the 5% significance level) only with quality of life (QOL) but not mobility (MOB). The significant positive relationship suggested planning may contribute to improved quality of life. This supported the first hypothesis, however, further analysis was required to understand the relationships between all selected variables.

Table 4.4: Correlation coefficients

Variable	QOL	MOB
MOB	0.370**	
EDU	0.349**	0.328**
BANK	0.121**	0.159**
CHILD5	0.000	0.046
HHN	0.202**	0.274**
GENDER	-0.023	-0.113*
AGE	0.072	0.149*
DEN	-0.147**	-0.128**
DISR	0.126**	0.048
PLAN	0.094*	-0.004
S	0.032	0.024

**Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed).

4.6 The Regression Analyses

Further regression analyses of QOL and MOB were utilized to explore the hypotheses. Two simple linear regression models were set up, as:

$$QOL = \text{f}(X, PLAN, S, PLAN*S, IFOR*S),$$

$$MOB = \text{f}(Y, PLAN, S, PLAN*S, IFOR*S),$$

where X, Y were two sets of control variables. *IFOR* is an informal dummy variable, with IFOR =1 for informal development and =0 otherwise. The *PLAN* dummy was used to assess Hypothesis 1 about whether planning helps in reducing social vulnerability. The dummy variable *S* was to assess the role of urban sprawl, i.e. Hypothesis 2. The two interaction variables (*PLAN*S*, *IFOR*S*) were to assess how urban sprawl interacts with planned and informal development, and to address Hypothesis 3.

Regression results are shown in Table 4.5. Planning and sprawl, as well as the interaction variables, were the variables of interest to address the hypothesis. Additional economic, demographic, and infrastructure variables were used as control variables.

Table 4.5: Final linear regression models for quality of life and mobility

Variables		QOL		MOB	
		Est.	p-value	Est.	p-value
Constant		-1.077	0.000	-1.391	0.000
Economic	EDU	0.380	0.000	0.375	0.000
	BANK	0.084	0.373	0.177	0.062
Demographic	CHILD5	-0.111	0.046		
	HHN	0.080	0.000	0.073	0.000
	GENDER	0.015	0.878	-0.188	0.050
	AGE			0.007	0.032
	DEN	-0.250	0.001	-0.196	0.007
Infrastructure	DISR	0.778	0.089	-0.315	0.492
Planning	PLAN	0.503	0.000	0.311	0.024
Sprawl	S	-0.108	0.263	-0.046	0.631
Planned Sprawl	PLAN*S	0.396	0.145	0.095	0.728
Informal Sprawl	IFOR*S	-0.939	0.001	-0.728	0.008
N		584		584	
R-squared		0.212		0.212	

The estimates of control variables generally align with expectations. Greater level of education (proxy for economic status) have significant and positive impacts on both quality of life and mobility, suggesting that education helps in increasing the accessibility to infrastructure, services, and resources and therefore, is linked with decreased social vulnerability. This is consistent with the available empirical evidences of better economic status factors related to better life quality and mobility, while the poor in Dar es Salaam generally have more difficulty in accessing basic services (Olvera et al., 2003). Having a bank account is positive but not significant for either model.

For demographic variables, number of household members (HHN) have a significantly positive value in both models, implying more members are related to better quality of life and mobility. However, having fewer young children in the household (CHILD5) is linked with better quality of life. The mobility model suggests that households with older heads (AGE) have greater mobility. Households with male heads (GENDER)

are significantly linked with better mobility, but not quality of life. This result supports existing observations in Dar es Salaam of men being more mobile than women, as women tend to be responsible for household duties (Olvera et al., 2003). Both higher quality of life and better mobility are significantly related to a lower population density, suggesting lower population density is linked with reduced social vulnerability, as expected.

Distance to primary and secondary roads (DISR) has a negative association in the mobility model, suggesting the closer to the road network, the higher the mobility. However, this association is not significant. The quality of life model suggests that the farther away from major roads, the higher the quality of life, and this effect is significant at the 10% level. This makes sense, because local roads or local means of travel (walking/public transportation), rather than major roads, are more relevant for residents' daily life (Mkalawa & Haixiao, 2014). Furthermore, Mkalawa (2016) notes that most people in Dar es Salaam do not own vehicles and the problematic transportation system has not kept up with urban population growth, even in wealthy areas (Olvera et al., 2003). In this sense, adjacency to this major transportation infrastructure may not improve quality of life for most urban residents.

Table 4.6 summarizes the factors that significantly affect quality of life and mobility, including the hypothesized variables. For the results of the first hypothesis (urban planning), the models suggest planned development in Dar es Salaam significantly improves quality of life and mobility. Relationships between quality of life and availability of urban planned infrastructure and services are supported in the literature (Andreasen, & Møller-Jensen, 2017). Because major aspects of planning include infrastructure and service

provision, connections between planning and quality to basic services, food security, and mobility are fitting.

Table 4.6: Factors significantly affecting quality of life and mobility

QOL	MOB
↑ Education (EDU) ***	↑ Education (EDU) ***
↓ Children 5 and under (CHILD5) **	↑ Bank Account (BANK) *
↑ Number HH members (HHN) ***	↑ Number HH members (HHN) ***
↓ Population density (DEN) ***	↓ Gender (female) (GENDER) **
↑ Planning (PLAN) ***	↑ Age of head of HH (AGE) **
↑ Distance to major roads (DISR) *	↓ Population density (DEN) ***
↓Sprawled informal development (IFOR*S) ***	↑ Planning (PLAN) **
	↓ Sprawled informal development (IFOR*S) ***

***Significant at the 0.01 level.
** Significant at the 0.05 level.
* Significant at the 0.1 level.

As for the second hypothesis about whether sprawl affects quality of life and mobility, the sprawl dummy variable (*S*) has a negative, but insignificant impact in both models. Nevertheless, the two interaction variables reveal that sprawl interacts differently with planned and informal development. Planned sprawl (PLAN*S) has a positive, but not significant impact on quality of life and mobility. Informal sprawl (IFOR*S) has a significant and negative impact, supporting the third hypothesis. Informally developed sprawl areas have lower quality of life and mobility. This can be explained by the known limitations in infrastructure and services in peripheral areas of Dar es Salaam (Dodman et al., 2011).

4.7 Conclusions

This study proposed three hypotheses related to urban social vulnerability incorporating urban planning factors (land use and sprawl) in social vulnerability assessment. The study also aimed to enhance social vulnerability measurement by

including reliable existing open data sources in scholarly research when data is often difficult to source or obtain from other channels. Also, separating social vulnerability into two models (quality of life and mobility) guided by the PCA allowed for more targeted assessment of variable influence.

Results suggest that in Dar es Salaam, planning is a significant predictor for the aspect of quality of life and mobility, while sprawl itself is not a significant predictor for both. However, sprawl interacts with informal and planned development in different ways to affect urban residents' quality of life and mobility. Areas with informally developed sprawl are linked with lower quality of life and mobility, meaning greater social vulnerability. Another crucial result is the strength of the interrelations between the main social vulnerability factors (quality of life and mobility) and economic status, suggesting these major characteristics are important for improving social vulnerability, regardless of planning, sprawl, or any other factors.

Planning and sprawl could be important variables to incorporate in future urban social vulnerability assessments in other contexts. Dar es Salaam was a particularly relevant study area because of the significant informal land use development, sprawl, and dataset availability to test the impact of these variables. It is unclear whether urban sprawl and planning may be important for all urban social vulnerability assessments, however, in cities similar to Dar es Salaam, these variables and indicators are useful to explore and offer results which can be examined more deeply to tease out contextual nuances.

CHAPTER FIVE: CONCLUSION

This study focused on three main questions to understand how distinct Sub-Saharan urbanization and urban planning factors influence vulnerability at the urban scale. These questions are important because vulnerabilities are linked to inequities and increase risk for disasters in cities. Urban planners are usually tasked with minimizing inequities and risks in cities, however, the roles and influence of planners in Sub-Saharan cities are unclear and data to explore these intersections are limited. The three questions were laid out in three chapters and formed the main body of this dissertation.

The first question (second chapter) asked: what are the current known connections between distinct urbanization, urban planning, and vulnerability studies within Sub-Saharan cities in the scholarly literature? The purpose of this question was to form a basis of understanding of how links between planning, development, and vulnerabilities have been articulated thus far in Sub-Saharan Africa. Reviewing the existing literature highlighted knowledge gaps, challenges, and ways forward, and laid the foundation for the rest of this study. Findings from the review of literature indicated several limitations in the knowledge and understanding of Sub-Saharan urbanization, fragmented meanings of vulnerability in the urban context, as well as overlapping and contradicting influences of governance, land use, and informality. Furthermore, the review revealed a critical lack of data overall in the Sub-Saharan context, preventing understanding of urban processes and

activities relating to vulnerabilities, and hindering informed action from planners and policy-makers.

The second question (third chapter) asked: how to overcome data deficiencies related to urbanization and planning in Sub-Saharan cities? The purpose of this question was to explore ways to build the evidence base using resourceful methods to work around data limitations. This study used the city of Dar es Salaam, Tanzania as a case study area to develop and test a land use data estimation methodology which differentiated planned and informally developed areas. The study results produced a reliable dataset in a Sub-Saharan city featuring land use data useful for further study of planning and vulnerability intersections.

The third question (fourth chapter) asked: do planning factors (land use and sprawl) influence vulnerability of populations in Sub-Saharan Africa? The purpose of this question was to determine the influence of planning on vulnerability in order to build the evidence base of the specific planning-vulnerability nexus of Sub-Saharan cities. The study once again centered on Dar es Salaam, Tanzania. A quantitative vulnerability assessment methodology using linear regression analysis was used to develop two vulnerability indices, focusing on social vulnerability. The indices were quality of life and mobility. Planning factors were land use (planned and informal), roads representing infrastructure, sprawl, and interactions between planning and sprawl. Results suggested significant positive impacts of planning associated with quality of life and mobility, no impacts of sprawl or planned sprawl, and negative impacts of informal sprawl. Hence, planned areas of Dar es Salaam were associated with lower social vulnerability and informal sprawl was linked to greater social vulnerability. These results put planning in a positive light in that

residents of planned areas are likely to be better off than those in the informal areas and periphery. The breaking down of planning concepts and vulnerability indices allowed for more nuanced results and understandings of the impacts at the urban level.

The results of the overall study provided two main contributions: methodological and theoretical. The first main contribution (methodological) is the development of reproducible methodologies which quantify planning-related factors and statistically test impacts on specific vulnerabilities at the urban scale. For example, the estimation of land use data for 2014 based on older multi-temporal datasets is important for several reasons. The first is the applicability to other similar contexts owing to the access to consistent global datasets. The second is the aspect of using openly available data to develop new data. Promoting open datasets was considered important to circumvent access barriers as well as inexplicit methods of data production in studies.

The second main contribution (theoretical) is guidance for future studies to build upon re-conceptualizing notions of vulnerability and vulnerability assessment in the Sub-Saharan context, incorporating distinct features of urban planning and urbanization. The literature review pinpointed key gaps and challenges in the scholarship which if addressed, could improve understanding of the broader dimensions of factors affecting vulnerabilities of urban populations in Sub-Saharan cities. The fourth chapter also introduced a conceptual map situating social vulnerability of urban systems within the framing of urban vulnerability and offered a distillation of major social vulnerability factors at various urban scales (household, community, and population level). This conceptualization of urban vulnerability is a theoretical contribution which can be further strengthened and expanded upon in future studies.

Similarly, in Dar es Salaam, the land use estimation dataset could lead ways forward to improve understanding of the urban context in terms of further spatial analysis. The predicted results from the estimations could be verified with on-the-ground investigation of land uses to determine the reliability of the method. Smaller scale mapping and more community scale planned and informal developments can also improve the results. It may also be a useful template to test on similar cities. The social vulnerability assessment similarly provides a methodology to work with and build upon, as well as to use as a template for other urban contexts to test specific planning related features of urban areas in Sub-Saharan cities. For example, environmental factors, if available, could provide a more comprehensive urban vulnerability assessment. It may also be useful to verify the results from the study with on-the-ground observation to test the reliability of the model. This study may have value beyond this dissertation. For example, identifying vulnerability in the city allows for planners and stakeholders to be better informed for guiding policies and for developing clearer objectives to reduce urban vulnerability and work toward more equitable and sustainable futures.

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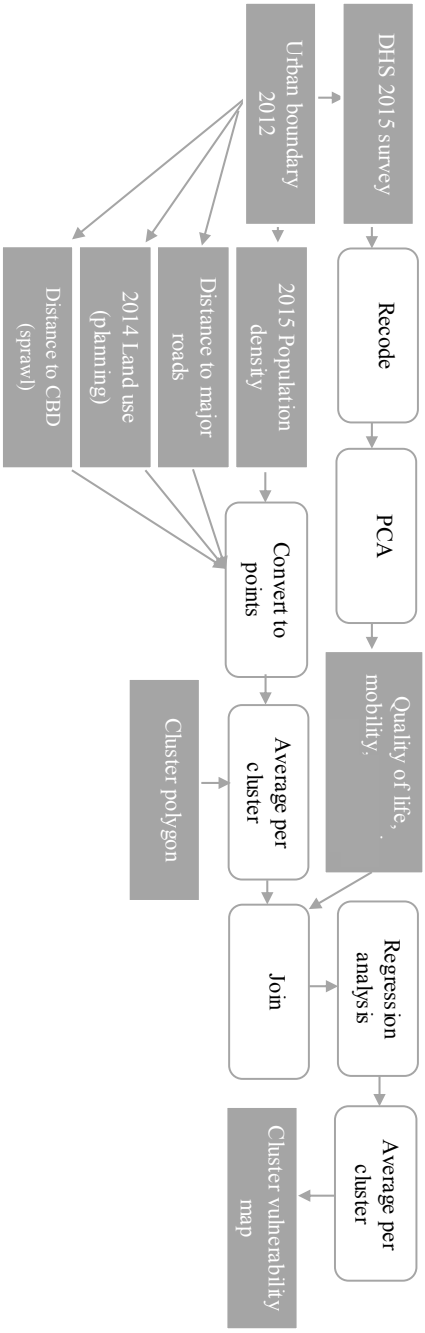
APPENDIX 1: ROAD TYPES

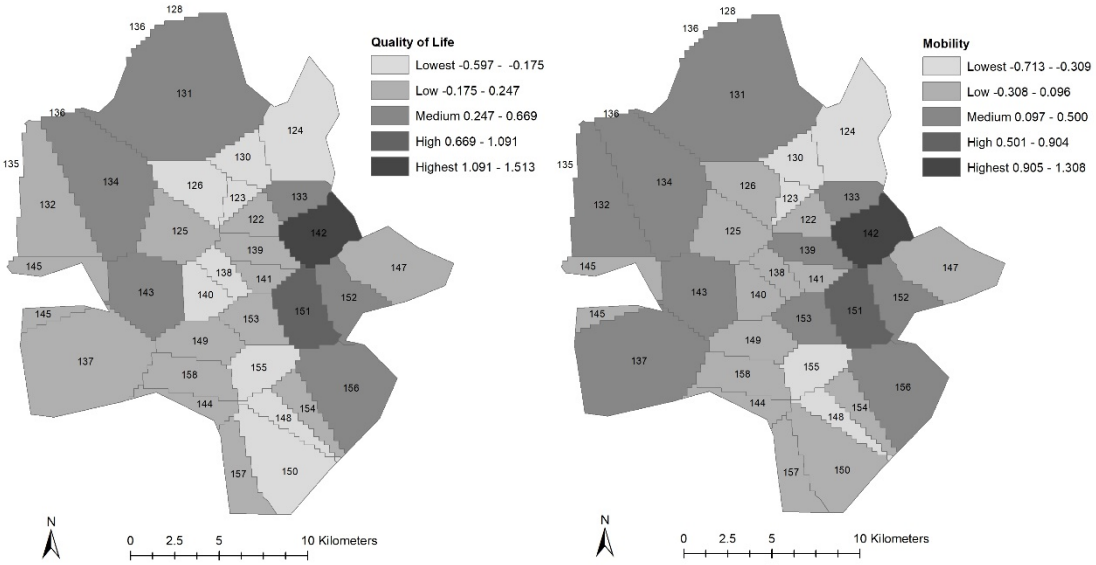
	Road type	Data points	Tagging guidelines from open street map	Reclassified roads
1	Footway	808	For pedestrian only where they can sometimes be separated from another parallel highway for vehicles; most probably unpaved	
2	Living Street	3	*Not in guidelines*	
3	Path	30	Paths are usually impassable for motorised vehicles. (However, African motorcyclists can sometimes do the most improbable stunts.) Not for unpaved residential areas!	
4	Pedestrial	2	*Not in guidelines*	
5	Primary	90	National roads connect the most important cities/towns in a country. In most countries, these roads will usually be tarmaced and show centre markings.	Primary
6	Primary Link	6	*Not in guidelines*	
7	Proposed	4	*Not in guidelines*	
8	Residential	2275	This tag is used only in urban areas and only on roads which serve no other purpose than residential.	Residential
9	Road	31	*Not in guidelines*	
10	Secondary	78	They are the second most important roads in a country's transport system. They typically link medium-sized places. Might be tarmaced in some countries, but many times they are not.	Primary
11	Secondary Link	2	*Not in guidelines*	
12	Service	272	This tag is used for driveways, carpark entrance roads, private roads, etc (most often in urban areas, but may exist in rural areas too, such as driveways to gas stations or service roads in mining sites or waste recycling sites)	
13	Steps	3	*Not in guidelines*	
14	Tertiary	117	These are busy through roads that link smaller towns and larger villages. More often	Tertiary

			than not, these roads will be unpaved. However, this tag should be used only on roads wide enough to allow two cars to pass safely.
15	Tertiary Link	66	*Not in guidelines*
16	Track	119	This tag is usually used for roads providing access to agricultural or forestry facilities. In Africa, roads within National Parks mostly qualify as tracks too. Never use track to mark an unpaved or unsealed road in built-up areas.
17	Trunk	13	Multiple lane roads; These roads have a motorway-like layout with no junctions, no traffic lights, and usually ramps for access. Their surface is always tarmaced.
18	Unclassified	991	Link small villages. These roads are usually unpaved and are only wide enough for one vehicle. This tag is primarily used in rural areas and outside of inhabited places, though unclassified roads can be used to link suburbs in a city or town.

APPENDIX 2: PROCESS OF THE STUDY (CHAPTER FOUR)



APPENDIX 3: MAPS OF STUDY AREA CLUSTERS WITH AVERAGE QUALITY OF LIFE AND MOBILITY PREDICTED VALUES



CURRICULUM VITA

Sheliza Bhanjee

Phone: +1 (502) 337-8564
Email: sheliza.bhanjee@louisville.edu

Education

2019	Ph.D. in Urban and Public Affairs, University of Louisville
2010	M.S. in Earth and Atmospheric Sciences, Georgia Institute of Technology
2009	B.S. in Earth and Atmospheric Sciences, Georgia Institute of Technology

Publications

Peer-reviewed journal article
Bhanjee, S. & Zhang, C. H. (2018). Mapping Latest Patterns of Urban Sprawl in Dar es Salaam, Tanzania. *Papers in Applied Geography*, 1-13.

Research & Professional Experience (selected)

2015 – 2019	Graduate Research Assistant University of Louisville, Louisville, Kentucky Urban and Public Affairs, Dr. Sumei Zhang (2018-19) Urban and Public Affairs, Dr. Lisa Bjorkman (2015-18)
2013 – 2015	Research Associate and Program Manager East African Institute, Aga Khan University, Nairobi, Kenya
2012 – 2015	Program Coordinator Faculty of Health Sciences, Aga Khan University, Nairobi, Kenya

2009	Policy Intern United States Environmental Protection Agency (EPA), Region 4,
2008	Policy Analyst Intern Georgia Tech Research Institute, Office of Policy Analysis and Research, Atlanta, Georgia
2007 – 2009	Undergraduate Research Assistant Georgia Tech, Atlanta, Georgia Geochemistry laboratory, Dr. Martial Taillefert, Earth and Atmospheric Sciences (2009) Risk and natural hazard management, Dr. Yi Deng, Earth and Atmospheric Sciences (2008) Psychometrics research laboratory, Dr. James Roberts, School of Psychology (2007)

Invited Talks & Presentations

2019	Paper presentation, Association of American Geographers (AAG) Annual Conference, Washington, D.C., USA
2018	Poster presentation, Association of American Geographers (AAG) Annual Conference, New Orleans, USA
2016	Invited talk, Center for Asian Democracy at the University of Louisville, Louisville, Kentucky, USA
2015	Research presentation, University of British Columbia and CEPT University, Ahmedabad, India
	Research presentation, Sustainable Food Systems conference, University of Fraser Valley, Abbotsford, Canada

Fieldwork & International Experiences

2015	Ahmedabad, India: Intensive 2-week urban planning course and field research project, CEPT University and University of British Columbia
	Abbotsford, Canada: Urban planning studio course, University of Fraser Valley
	Kampala, Uganda: Regional youth survey, East African Institute, Aga Khan University

	Mwanza, Tanzania: Regional youth survey, East African Institute, Aga Khan University
2014	Nairobi, Kenya: Regional youth survey; East African Institute, Aga Khan University

Teaching Experience

	Instructor
Spring 2019	Comparative Urban Politics, University of Louisville
	Teaching Assistant
Spring 2018	Sustainable Built Environment, University of Louisville
	Lab Instructor
Spring 2010	Habitable Planet, Georgia Tech
Fall 2009	Introduction to Earth Sciences, Georgia Tech

Awards

2019	Doctoral dissertation completion award, School of Interdisciplinary and Graduate Studies, University of Louisville
2018/2019	Doctoral student conference presentation award, Department of Urban and Public Affairs, University of Louisville
2015	International travel award to Ahmedabad, India, Center for Asian Democracy, University of Louisville
2015 – 2019	Graduate research assistantship, University of Louisville
2009 – 2010	Graduate teaching assistantship, Georgia Tech
2007	Academic achievement grant, Georgia Tech
2005 – 2009	Full tuition HOPE Scholarship, Georgia Tech

Service

2019	Referee: Development Southern Africa
2018	Referee: The Review of Regional Studies Journal
2012 – 2013	Tutor, Tutorial Assistance Program (TAP) for secondary students, Nairobi, Kenya
2011	Teacher, Hawker's Market Girls School, Nairobi, Kenya

Professional Membership

Association of American Geographers (AAG)
American Planning Association (APA)
Kentucky Science Academy

Professional Development

Mediation training (40 hours), University of Louisville
Grant Writing Academy (14 hours), University of Louisville

Software

ArcGIS; SPSS; basic experience with MATLAB, Python, and Vensim