Urban Infrastructure and Household Vulnerability to Food Insecurity in Maputo, Mozambique

by

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AUTHOR’S DECLARATION

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

ABSTRACT

Infrastructure is an important foundation for urban sustainability. Infrastructure includes both a system of institutions like banks and hospitals (known as social infrastructure) and a network of physical utilities like water and power grids (known as physical infrastructure). Social infrastructure allows households to access social services while physical infrastructure allows households to access physical resources. A lack of household access to either social or physical infrastructure can make a household vulnerable to poverty. Maputo provides one example of this relationship. The city is characterised by a dualistic split between a formal downtown core and informal peri-urban areas. The households in the formal areas of Maputo tend to have a greater access to both social and physical infrastructure, while households in the informal areas tend to have reduced access to both. In Maputo, a lack of household access to social and physical infrastructure also increases the odds that a household will be food insecure. This means that inconsistent infrastructure access seems to predispose a household to food insecurity.

Using household survey data collected from 2071 households in Maputo, this investigation applied binary logistic regression analysis to predict three measures of household food insecurity: the Household Dietary Diversity Score, the Household Food Insecurity Access Scale, and the Months of Adequate Household Food Provisioning. Two sets of independent variables were used in this analysis: inconsistent household access to physical and social infrastructure (measured by inconsistent access to water, electricity, medical care, and a cash income) and a set of social vulnerability indicators (the sex, education, and employment status of the household head, low household income, household size, dwelling informality, and the chronic illness of a household member).

The results demonstrate that households with inconsistent access to infrastructure have greater odds of being food insecure even while controlling for income level, the presence of chronic illness, household size, dwelling informality, or the gender of the household head. The relationship is also very reliable. Using only household access to water, electricity, medical care, and a cash income, it was possible predict whether a sampled household was food insecure with 75% accuracy (in the sampled population). This relationship has important implications for urban planning and municipal social policy. Households in areas with limited access to infrastructure are more likely to be food insecure even when low income is controlled for. Based on these findings, investment in urban infrastructure access may have a knock-on impact on household food insecurity in Maputo. These findings suggest a preliminary alternative intervention for household food security beyond complex and potentially confounding economic policy intervention.

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Chapter One: Introduction to the Problem Context

In November 2013, typhoon Haiyan swept inland in the Philippines and devastated the city of Tacloban (Ratha & Mahapatra, 2014). The typhoon disrupted all transportation into the port city, destroyed buildings, disrupted electricity, and debilitated major physical infrastructure services in the city (Merin, Kreiss, Lin, Pras, & Dagan, 2014). With all access to the outside world disrupted, the city experienced severe food and water shortages within a few short days. Drinking water was contaminated and the lack of electricity left few options for safely storing food (Dolhun, 2014). Residents were desperate for aid, evacuation, medical services, food and water. The arrival of help, however, was seriously delayed by the lack of effective transportation options available for delivering that aid. This story highlights one very important theme in urban environments: infrastructure plays a defining role in the vulnerability of a city to a food security crisis (the lack of access to sufficient nutritious and safe food by all people) (FAO, 2008). More specifically, Typhoon Haiyan taught us that disrupted infrastructure can significantly increase a city's vulnerability to a water and food security crisis within a matter of days.

The events in Tacloban raise serious concerns for our common future, particularly in regards to food security, for two reasons. First, humanity is going to become more vulnerable to these climatic hazards in the future (Godfray et al., 2010). Hazardous climatic events are going to become an increasingly frequent occurrence due to projected climate changes. This means that food shortages (resulting from variable temperature and precipitation) may become a more common occurrence in the future (Brown & Funk, 2008). This increase in the frequency of food shortages means that vulnerable populations will be at a greater risk of experiencing the impacts of such hazards, including food insecurity.

Second, the future of humanity appears to be increasingly urban (United Nations, 2014). In absolute numbers, the global urban population is estimated to have surpassed the global rural population around the year 2010. The rates of this urban growth have been geographically uneven, with almost exponential growth in many developing nations in the past few decades. Urban development in these areas has also been largely unplanned, resulting in the growth of massive sprawling informal settlements on the fringes of some of the largest cities in the developing world (Adelekan et al., 2015). Dense populations and reliance upon infrastructure for resource access also make urban environments vulnerable to the impacts of natural hazards (Wisner, Blaikie, Cannon, & Davis, 2004) as was demonstrated in the case of Tacloban.

These twin developments demonstrate a unique vulnerability that has the potential to predispose urban populations to food insecurity. This is especially true, given that the current climatic hazards which strain the global food system will increase in both frequency and intensity (Brown & Funk, 2008; Godfray et al., 2010). It is therefore essential to understand the intersection between urban vulnerability and food insecurity as a sustainability issue.

The unique vulnerabilities associated with urban environments present a sustainability challenge. Gibson (2005) highlighted the importance of maintaining human livelihoods as a part of sustainability assessment. In particular, Gibson (2005) notes the need to reduce gaps in livelihood sufficiency and opportunities between the poor and the wealthy. This recommendation highlights a defining sustainability challenge for urban poverty. Since the 1987 Brundtland report, a key principle of sustainable development has been both intergenerational equity (the distribution of resources across multiple generations) and intragenerational equity (the distribution of resources within the same generation) in access to opportunities and resources (Sneddon, Howarth, & Norgaard, 2006). One of the defining characteristics of urban poverty is the inequitable distribution of income and economic opportunities (Amis, 1995). Other urban resources are also inequitably distributed. In what may be a seminal article on the topic, Crush and Frayne (2011) investigated the spread of supermarkets in Southern African cities and demonstrated that supermarket availability was constrained to higher income neighbourhoods. As a result, informal food markets continued to spring up in the informal areas of the cities to support food access for residents in those areas. Inefficient and unavailable urban infrastructure also limits the extent to which livelihoods are equitably available to all urban households. Households situated in informal areas may be required to pay more for access to water and electricity (due to the post-hoc nature of this access where utility grids must first be extended into the informal area) and may be vulnerable to oppressive fee arrangements for those services when access is facilitated by informal utilities providers (Ahlers, Perez Güida, Rusca, & Schwartz, 2013; Baptista, 2013).

Gibson (2005) also noted the importance of efficient resource use to sustainability by illustrating the need to "provide a larger base for ensuring sustainable livelihoods for all while reducing threats to the long-term integrity of socio-ecological systems by reducing extractive damage, avoiding waste and cutting overall material and energy use per unit of benefit" (Appendix 3). Gibson emphasizes the need to ensure that resources are used as efficiently as possible by minimizing costs for a maximum gain (in both ecological and social terms). In light of this statement, urban dietary trends have demonstrated an unsettling shift. Diets in many urban centres are shifting from a predominantly grain and vegetable diet to a diet of dairy and meat, which are more agriculturally intensive to produce and potentially less sustainable to maintain (Dixon et al., 2007; Cohen and Garrett, 2010; Godfray et al., 2010). The energy costs of developing and maintaining livestock is significantly higher than the costs associated with grain and vegetable farming. Livestock rearing can also require costlier inputs. The area of land required for livestock rearing can put significant strain on food systems (Galloway et al., 2007; Hoekstra & Wiedmann, 2014). This dietary shift may be linked with urbanization, where urban households may change their diet as their access to global and industrialized food systems is facilitated by the spread of globalized supermarkets in cities of the developing world (Popkin, 1993; Dixon et al., 2007; Cohen and Garrett, 2010; Godfray et al., 2010).

Cities are also vulnerable due to high population density and reliance upon infrastructure for resource access (Godschalk, 2003; Wisner et al., 2004). High population density can facilitate the spread of contagious diseases that rely upon human vectors and also exacerbate the impact of natural disasters on human populations when the impacts are localized within cities (Wisner et al., 2004). As demonstrated by the Tacloban case, infrastructure damage can disrupt access to key resources required for human survival. Urban vulnerability also appears to be defined by multi-dimensional interactions (social and ecological) and multi-scalar interactions (interactions across a hierarchy of variables) between urban human populations and urban environments (Comfort, 2006). These observations indicate the unique pressures which form urban vulnerability and under these complex pressures, poverty can predispose urban households to food insecurity (Vatsa, 2004). That said, this discussion requires a logical framework which can explain how urban environments can become vulnerable needs to be clearly articulated. The concept of social vulnerability provides a means of articulating those relationships.

In the Disaster Risk Reduction (DRR) literature, social vulnerability is defined by both coping (the degree to which humans can adapt to mitigate hazard impacts) and sensitivity (the susceptibility of humans to hazard impacts) (Birkmann, 2006). This definition of social vulnerability developed as a result of successive paradigms in the DRR field. The concept of vulnerability began in the DRR field with the realization that the risk of a hazard is mediated by human behaviours which increase or decrease the risk of a hazard. This approach was amended in 1970 when researchers found that the risk of hazards was higher in Less Developed Countries (LDCs) than in More Developed Countries (MDCs). The greater risk of hazards in LDCs was assumed to demonstrate that hazard risk is determined by the social and political context in addition to human behaviour. This development of academic approaches led to the vulnerability approach which defined vulnerability as any human condition that increases human sensitivity to a hazard as a result of the interaction between multiple systems (social, economic, and ecological) and across multiple scales of analysis (Smith and Petley, 2009). In a case study of how cities can become vulnerable, Comfort (2006) demonstrated that the impact of Hurricane Katrina on New Orleans was accentuated by both dilapidated flood levees (hard infrastructure) and municipal economic downturn over the previous decades (soft infrastructure).

There are a few lessons we can learn from the historical development of the social vulnerability concept. First, no hazard impact is exclusively natural. While it is true that a hazard must be present, the impact of that hazard on a human population is mediated by the vulnerability of the population (which is determined in part by the social characteristics of the population) (Smith and Petley, 2009). Second, the vulnerability concept is only made significant in relation to hazards. Vulnerability must be understood because it is a predisposing factor which can facilitate the impact of a hazard. In theory, then, vulnerability does not exist without the possibility of a hazard impact. In summary of these two points, all hazard impacts are both social and natural and the relationships between natural hazards and social vulnerabilities are symbiotic in the sense that both elements must be present for the definition of either term. Thus, the analysis of vulnerability really is a socio-ecological investigation at least at the conceptual level. Given these lessons, the unique vulnerability of urban households to food insecurity in developing nations is compounded by growing hazards associated with the global food system (Clapp, 2011).

The current state of that global food system depicts a troubling picture. Climate change impacts in the form of increasing temperature and variable precipitation are projected to limit agricultural productivity (and therefore food supply) (Godfray et al., 2010), potentially resulting in rising food prices and widespread food insecurity in the future (Brown & Funk, 2008). These pressures on agricultural productivity are compounded by the fact that 30% of global food production is wasted (never utilized) and most of this waste occurs at the level of the consumer (Godfray et al., 2010). As previously described, and in addition to the challenges of maintaining agricultural productivity and reducing food waste, global dietary preferences have continued to shift to greater dairy and meat consumption which requires more intensive farming and increases the cost of agricultural inputs (Tilman et al., 2002; Clapp, 2011; Godfray et al., 2010).

As a result, food security is becoming a growing sustainability concern. In the FAO conceptualization, food security is based on three variables (food availability, food access, and nutrition) and one dimension (stability over time) (FAO, 2008). It is important to note that food availability (conceptualizing food supply) is only one part of food security in this definition. In other words, there are factors which determine food insecurity vulnerability beyond the supply of food. Urban food security, as an exclusive focus on food security in cities, is a relatively new research focus (Crush & Frayne, 2011). Urban environments present unique challenges to household food security, stemming from the various unique vulnerabilities associated with urban environments (as were reviewed earlier). These vulnerabilities suggest that urban and rural food security should differ significantly.

There has been limited research, however, which might suggest whether the characteristics of household food security differ between urban and rural environments. Some research has demonstrated that urban environments are associated with greater inequality in household food security (in particular, regarding the proportion of household income taken up by food purchases) (Morgan & Sonnino, 2010). Food security also may be more spatially stratified within cities than in rural areas. Poor urban neighbourhoods (particularly in informal areas) tend to be associated with higher levels of household food insecurity, while more affluent urban neighbourhoods are associated greater household food security (Frayne et al., 2010). Cities also appear to be more tightly integrated into global food trade, potentially explaining the hypothesis that cities can be more vulnerable to the impacts of international food price volatility (as was observed in the 2008 food price crisis) (Ruel & Garrett, 2010). Urban food security appears to be sensitive to differences in total household income and the consistency of household access to infrastructure (Frayne & McCordic, 2015). In addition, recent research suggests that informality may be a determining variable of urban household food security. Urban households situated in informal areas (areas not formally planned as residential) have limited land tenure security and are generally not integrated into utility grids (Crush & Frayne, 2010). As such, these households are exposed to higher utilities costs (due to a lack of access to utilities grids), which can limit access to food under the additional pressures of limited income.

The determinants of urban household food security offer a window into understanding the vulnerabilities of urban household food security. This is because changes in these determinants should produce a change in the food security status of an urban household. For example, if a household were to go without an income source, we would expect that household to become food insecure. If this were to happen, we would consider income to be both a determinant of household food security and vulnerability of households to food insecurity since reduced household income will increase the chances of household food insecurity. It is important to note that the determinants of household food security may be multi-scalar, multi-dimensional, and, in the case of some determinants, outside the control of a given household. For example, economically, urban household food security may be vulnerable to monetary inflation, food price vulnerability, food market collapse, a lack of government fiscal responsibility, and income inequality (Amendah, Buigut, & Mohamed, 2014; Timmer, 2000). Socially, urban household food security may be vulnerable to population density, disease, conflict, and political corruption (Jenkins & Scanlan, 2001). Poor urban households may suffer from a lack of access to food, dietary diversity, and long term food provisioning due to the inability to command entitlements (resources and rights that a household can use to gain access to other resources) and food price (Ruel & Garrett, 2010; Sen, 1980). Given the importance of infrastructure for urban resource access, inconsistent infrastructure access (as is observed in many informal settlements of the developing world) may also impact urban household food security (Comfort, 2006). These vulnerabilities are suggested by the current literature on the subject, but have not yet been empirically demonstrated.

Attempting to make sense of the link between infrastructure and food insecurity vulnerability can be challenging. Conceptually, urban households are made vulnerable by their sensitivity to hazard impacts (the combination of contextual factors which increase the likelihood that a household will experience food insecurity) and their lack of coping capacity (a household's ability to effectively respond and adapt to food insecurity) (Weichselgartner, 2001). One specific concept in the Disaster Risk Reduction literature which has relevance to this discussion is the concept of built-in resilience. Built-in resilience refers to the capacity of physical infrastructure to withstand the impact of a hazard (although it should be noted that the resilience concept refers to a much broader set of variables than just infrastructure). Built-in resilience begins with a holistic urban planning vision that integrates both soft infrastructure (e.g. land tenure) and hard infrastructure (e.g. the structural integrity of a building) in an attempt to reduce a household's vulnerability to the impact of a natural disaster (Doberstein & Stager, 2013). Built-in resilience is meant to maximize a household's ability to increase and maintain assets (Bosher & Dainty, 2011). As an example, a sustainable food system design could mitigate food supply shocks due to drought and increase household food access. Or, alternatively, the efficient and cheap supply of infrastructural services such as water, fuel, and electricity can limit household expenditure and increase a household's ability to access food. Social and physical infrastructure (the structures that support the supply of physical utilities and social services) may play a role in determining household food security. Inconsistent infrastructure access appears to mitigate the equity of household food access across the city and may mitigate the impact of climatic hazards due to climate change. While there is theoretical and statistical evidence to suggest that infrastructure development has the potential to reduce urban poverty (Ogun, 2010), there is limited empirical evidence as yet that clearly demonstrates that infrastructure has an impact on urban food security.

Given the unique characteristics of urban environments, inconsistent infrastructure access is likely an important determinant of urban household vulnerability to food insecurity. That said, there is little research to demonstrate this relationship and very limited research from which the relative contribution of infrastructure to household food security can be compared to other indicators of social vulnerability. The multidimensional nature of food security also suggests that infrastructure may play a different role in determining different aspects of household food security. In other words, inconsistent infrastructure access may play a greater role in determining household food access than in determining household dietary diversity. However, there is limited scholarly literature with which a substantive answer can be provided to these questions. There is also limited theoretical research devoted to explaining how or why infrastructure would play a primary role in determining urban food security. Together these observations demonstrate that the influence of inconsistent infrastructure access on urban household food insecurity is a needed area of research.

Problem Statement

In summary, humanity's future appears to be increasingly urban. While becoming a more urban global population has benefits, urban living also comes with unique vulnerabilities. One of those vulnerabilities is household food insecurity, a prospect which is likely to become more common as food shortage hazards become more frequent due to climate change. Inconsistent household access to infrastructure in cities mediates a household's access to resources and may also influence the household's access to food. Using this logic, inconsistent household access to infrastructure may increase a household's vulnerability to food insecurity.

Research Gap

That said, the impact of inconsistent infrastructure access on household vulnerability to food insecurity has not been extensively researched, representing a gap in the literature. The most recent publication on the topic (Frayne & McCordic, 2015) was drawn from an analysis of survey data from 2008 across 11 Southern African cities. This analysis, however, did not comprehensively account for the impact of other social vulnerability variables and did not test this relationship in relation to household dietary diversity. In addition, this topic may be inferred from research on the association between infrastructure and poverty (Canning and Pedroni , 2004), however this research did not address food insecurity.

Research Objectives

In response to this gap in the literature, this investigation will attempt to determine the role of inconsistent household infrastructure access in household vulnerability to food insecurity in Maputo, a city associated with stark differences in household infrastructure access.

Research Methods

In order to effectively investigate the role of inconsistent infrastructure access in household vulnerability to food insecurity, I will present a review of the literature which is relevant to this investigation. The relevant concepts to this investigation will be drawn from the literature on food insecurity, poverty, urban infrastructure, and a review of frameworks from the social vulnerability literature in particular (drawn from the field of Disaster Risk Reduction). This review will provide the necessary concepts and relationships to inform a coherent theoretical framework through which empirical work on this topic can be interpreted. This theoretical framework will then be explained and demonstrated using cases of food insecurity. The framework will then be used to interpret empirical findings from a case study of household food insecurity vulnerability in a case study of Maputo. The analyses performed in this case study will also test the extent to which this theoretical framework is a helpful model for explaining urban household food insecurity.

Chapter Two: Conceptualizing Food Insecurity Vulnerability via Literature Review and Theory Building

In order to clearly interpret the findings of this investigation, this chapter will design a theoretical framework to conceptualize urban household vulnerability to food insecurity. In doing so, this framework will demonstrate the relationship between household variables and household food insecurity. The conceptualization of this relationship must lend itself to operationalization in order to empirically test this theoretical framework. The extent to which urban household vulnerability to food insecurity can be operationalized, however, rests upon the definitions of food insecurity, infrastructure, and vulnerability used to construct this framework. This framework will therefore develop from a review of the relevant literature touched on by this investigation. In this case, the framework will develop from a review of the food security literature, its relationship with poverty, urban infrastructure, and social vulnerability.

Conceptualization of Food Insecurity

The idea of food security has seen substantial development over the past century. When the term was originally introduced in the 1970's, the world was faced with both a global food crisis as well as the ongoing Cold War (Clapp, 2015). As such, food security was primarily a political concern in regards to maintaining national self-sufficiency and limiting reliance upon global markets. The concept of food insecurity, however, seems to have been in use in various forms before this time. More specifically, the concept of food insecurity seems to have progressed through at least two (possibly three) generations of paradigms. While these paradigms build upon, and respond to, each other in succession, all of these paradigms are still in use in food security research. The first generation of food security paradigms provided a supply oriented definition of food security that framed hunger as the result of a disruption in the supply of food (Barrett, 2002; Jenkins and Scanlan, 2001). This disruption in supply was established via nationally aggregated measures of food supply (Barrett, 2010). As such, the paradigm relied largely upon macroeconomic trends in the supply and demand for food (Barrett, 2002).

This view of food security is still widely held but was challenged in seminal work on famines published by the welfare economist Amartya Sen in 1980. Sen (1980) established what was to be the second generation of food security paradigms. Sen pointed out that the supply of domestic food was in fact not coupled with food security. Instead, Sen suggested that food insecurity was the result of poor access, where households were not able to access food due to insufficient entitlements. Entitlements are resources at a household's disposal which can be used to access food. Sen (1981) outlined four types of entitlements: trade-based entitlements (a household is entitled to own what was legally traded for), production-based entitlement (a household is entitled to own what they produce), own-labour entitlement (a household is entitled to own and trade their labour), and inheritance or transfer entitlements (a household is entitled to transfer, or receive transfers, of legally owned resources). Sen (1981) noted that a lack of entitlements was a root cause in the Ethiopian famine and the Bengali famine in which nationally aggregated measures of food supply remained stable or increased while the domestic population was in famine. In the Bengali famine, entitlements held limited value due to rising inflation, and were limited due to war-time taxation and the prohibition of cereal export (which would have provided an alternative income stream for agents). This situation was exacerbated by the rising price of rice and sudden, large speculative withdrawals from banks which exacerbated the famine and created administrative chaos. The Ethiopian famine, which primarily affected Wollo pastoralists, was exacerbated by a reduction in the value of livestock and the late reception of foreign aid, effectively cutting out the entitlement base of those pastoralists. In both of these examples, food security rested on the individual's ability to command entitlements in order to access food.

Sen (1980) also noted that nationally aggregated measures were insufficient to capture the phenomenon of food security. Instead, Sen suggested that these measures should be taken at the scale of the individual due to the observation that national averages can mask contextually relevant poverty characteristics. In essence, Sen was offering a microeconomic approach to a concept which had been previously conceptualized as a macroeconomic phenomenon. In addition, Sen (1980) noted the important influence of context in mediating food access and the interaction of multiple systems in determining food access.

While there has not been a single founder of the third generation of food security paradigms, there is agreement among some academics around a new conceptualization of food security which may gain popularity in food security research (Barrett, 2002; Ecker and Breisinger, 2012). This third generation of food security paradigms assumes that food security exists within a larger external system of risk, at different scales, that influences the ongoing stability of a household's food security and capacity to mitigate that risk. As such, this generation of food security paradigms frames development as a means of increasing the resilience of food systems to the impact of system perturbations (e.g. income shocks, price shocks, or natural disasters) (Ecker and Breisinger, 2012). In addition, this generation of food security paradigms notes that food security should be measured at the individual level (Barrett, 2002). This is because an individual's food security is influenced by characteristics at multiple scales (e.g. household income, municipal food economy, and national agricultural productivity). Barrett (2002), in particular, notes that the distribution of food within a household can still be preferential to certain members based on their role in the household. While previous generations of food security paradigms have relied upon economic theory (both microeconomic and macroeconomic), this new generation of food security appears to be informed by a complex systems approach. Holland

(1992) describes complex adaptive systems by their evolution (gradual or punctuated transformations over time), aggregate behaviour (macro-level patterns which "emerge" from micro-level behaviours), and anticipation (susceptible to adaptive feedback loops). In other words, these systems represent the aggregated behaviour of decentralized agent behaviour which is dynamic and susceptible to feedback loops (cyclical information exchanges that either catalyze or inhibit process in two systems). As such, the future of food security research may be required to increasingly adapt to these potentially complex characteristics.

Over the course of this paradigm evolution, four concepts have come to define food security. These concepts include food availability, utilization, access, and food stability. Food availability refers to the supply of food via food production (Barrett, 2010). Sen (1980) suggested that the decline of food availability has commonly been held responsible for the onset of famines. That said, while food availability is a necessary condition for food security, it is not a sufficient condition (Jenkins & Scanlan, 2001). Food supply can therefore be thought of as a necessary precondition for the remaining pillars of food security discussed here.

Food access refers to the ability of an individual to command entitlements to secure food (Sen, 1980). While scholars have often cited economic factors as the primary determinants of food accessibility, there are other intermediary factors which can disrupt food access as well. As an example, Coveney and O'Dwyer (2009) suggested that a lack of access to transportation can disrupt food access. The FAO (2008) also suggests that the entitlements necessary to secure food access can be provided by social, legal or political arrangements. In summary, food access is an important aspect of food security and it is determined by factors in addition to economic activity.

Food utilization is a much more difficult concept to operationalize. Food utilization refers to all factors that impact the nutritional well-being of an individual (FAO, 2008). These factors mediate the relationship between an individual's consumption of food and the nutritional well-being of that individual. The FAO (2008) suggests that these factors include (but are not limited to) clean water, dietary diversity, and medical care. In some respects, food utilization really acts as a catch-all for all factors influencing food security and are not better accounted for by food availability, access, and stability. Given the comprehensive nature of this variable, it will be easy to interpret some of the independent variables in this investigation as being a proxy for food utilization. That said, the sum of these independent variables do not comprehensively account for food utilization. In addition, the dependent variables in this investigation are only composed of validated measures of specific aspects or pillars of food security as opposed to comprehensive tests of food security (none of which include a comprehensive test of food utilization). Given these arguments, it is unlikely that there is a confounding relationship between any of the independent variables which are partial measures of food utilization and the dependent variables in this investigation.

Food stability refers to the stability of food access over the long-term (FAO, 2008). This aspect of food insecurity is a reference to the potential shocks that can disrupt household food access. The potential shocks that can disrupt food security may be stochastic or seasonal and cross multiple domains (social, economic, climatic, etc.). The core aspect of this pillar of food security is maintaining continuous food access under the pressure of all stressors over the long-term. Together these four concepts (or pillars) provide a means of understanding how food insecurity is characterized. Given this definition of food insecurity, it is important to distinguish hunger from food insecurity as the relationship between food insecurity and hunger can appear to overlap. Lappe et al. (2013) suggested that hunger is narrowly defined by caloric intake and may demonstrate the impact of severe food insecurity. While the validity of this definition is being debated, the definition does allow for a clearer distinction of hunger from the definition of food insecurity while at the same time representing the link between the two concepts. Similar to hunger, the relationship between food insecurity and poverty is also nuanced and challenging to explain.

The Relationship between Poverty and Food Insecurity

While the relationship between poverty and food insecurity may appear to be intuitive, the relationship is remarkably difficult to define. The challenge begins with defining poverty. Hagenaars and De Vos (1988) suggest that poverty is defined by having less than an absolute amount, having less than others, or the perception of not having enough to survive. More generally, Ravallion (1992) suggests that poverty is defined by not having attained some level of well-being. Defining both the concept of well-being and the thresholds of well-being necessary to constitute poverty has been a challenge for economists. Economists have attempted to use various measures of income and consumption as a proxy for well-being, however, this approach has remained a challenging endeavor. In a seminal work on the topic, Sen (1976) set out the requirement that any poverty measure must be sensitive to all reductions in, or transfers of, a poor household's income. Foster, Greer, and Thorbreck (1984) added to Sen's (1976) approach by demonstrating that a parametric measure of poverty should still be decomposable and sufficiently measure relative poverty (and demonstrated a mathematical means of making such a measurement). In other words, this addition to Sen's work recommends that a poverty measure should be applicable to multiple scales of aggregation (municipal, national, regional for example) while still being able to capture the distribution of income at lower scales. In 1981, Sen expanded his contribution to welfare economics by articulating his theory that poverty is also determined by capabilities and the use of entitlements (rights and resources which an individual can exchange for access to needed resources). In spite of these advances, however, Atkinson (1987) suggested that poverty measures were still failing to capture the conceptual and empirical complexity of the phenomenon. The complexity of poverty is justified by some of the challenging confounds which have arisen from observations of the nature of poverty by scholars.

Green and Hulme (2005) suggest that poverty is a social construct which is defined differently in different places and at different times, making it difficult to present a definition that is applicable to all experiences of deprivation. Poverty is also multi-causal, can be chronic, and is ultimately an individual experience of deprivation. For example, chronic poverty is the individual experience of the intransient deprivation of capabilities necessary to maintain livelihoods over an extended duration (Hulme & Shepherd, 2003). One defining feature of chronic poverty is that the experience cannot be measured at the aggregate level due to the importance of individual context in determining the nature of an experience of chronic poverty. Chronic poverty is often multi-generational as well. Aliber (2003) suggests that "chronic poverty is often conceptualized as poverty that is transmitted from one generation to the next, usually meaning that children from poor households are likely to become poor adults, whose children will in turn risk remaining in poverty, and so on" (p. 472). In a review of poor urban communities in Southern Africa, Aliber (2003) found that chronic poverty could be transmitted across generations by limiting the opportunities available to the younger generations in poor urban families. Aliber provided the example of poor multigenerational households living in informal areas in South Africa inadvertently constricting the infrastructure services available to household members belonging to the younger generation simply due to the location of the household.

Households can fall into the kind of chronic poverty described by Aliber under the pressure of a poverty trap. Poverty traps refer to conditions in which household asset levels evolve over time to draw a household into poverty or keep a household in a state of poverty (Barrett & Carter, 2013). Barrett and Carter (2013) argue that poverty trap mechanisms can result from the interaction between the characteristics of the household with the household's social environment. As an example, a household member with a disability living among a stigmatizing population may, as a result of social exclusion and discrimination, fall into poverty. Barrett and Carter (2013) point out that poverty traps can also result from the ineffectiveness of urban infrastructure in enhancing the well-being of households, necessitating higher household expenditures to maintain a household's quality of life. The vulnerability of households to shocks is another important determinant of household poverty that also confounds poverty measurement. Shocks are defined as sudden changes in household assets resulting from factors external to that household. These external factors may be economic, social, or environmental. Moser (1998) defined vulnerability as sensitivity (the magnitude of the impact that external economic changes have on a household) and resilience (the speed with which a household can recover from a shock). Moser (1998) suggested that urban households are particularly vulnerable to the impact of market failures and environmental hazards.

Within the complexity of poverty definitions and paradigms, food insecurity is often treated as either a characteristic or an outcome of poverty (Barrett, 2010). Households are either considered to be food insecure as a part of their overall impoverishment or are considered to have become food insecure as a result of poverty. Barrett (2010) suggested that "most food insecurity is associated not with catastrophes, but rather with chronic poverty" (p. 827), demonstrating the intertwined nature of poverty and food insecurity. Given the propensity to use income as a poverty measure (as demonstrated by the efforts of Sen and others to measure poverty), it is then understandable how the causal mechanism of "low income leading to food insecurity" can be cemented in poverty research. While this mechanism has been repeatedly validated by empirical research, it may be possible that another route to food insecurity exists. Recent research has suggested that the mechanisms involved in producing poverty may be similar to the mechanisms that produce food insecurity. For example, similar to the topic of this dissertation, Sekkat (2013) found that infrastructure (in the form of paved roads) did minimize the impact of urban concentration on urban poverty in a series of computational simulations and estimations. The similarities between poverty research and food insecurity research also extend to conceptual themes. Moser's (1998) definition of vulnerability is actually very similar to the vulnerability framework that will be developed in this dissertation and it may be possible to interpret the results of this investigation according to Barrett and Carter's (2013) conceptualization of poverty traps.

So, while poverty is an overarching paradigm that can explain the mechanisms by which a household can become food insecure, the use of poverty as an over-arching explanation has limited utility in this investigation. This is because an overarching poverty framework would not necessarily be able to explain the relationships between household vulnerabilities and food insecurity (as these relationships are not necessarily causal), nor would such a framework be able to explain the relative importance of different vulnerabilities to household food insecurity (without incorporating a social vulnerability framework). Moreover, defining these relationships by impoverishment gives the false impression that these relationships are only applicable to low-income households (a notion that will be disputed later in this dissertation). These kinds of definitions can give the false impression that vulnerability to food insecurity in cities is not defined along multiple lines of deprivation which, in and of themselves, may not be sufficient to categorize a household as poor. In other words, using general labels like “poor households” may mask these underlying vulnerabilities carried by a larger segment of the population. All of that said, food insecurity and poverty remain related and, at times, intertwined topics of investigation. As such, many of the contextual factors which predispose a household to poverty may also be involved in determining household food insecurity.

This investigation also makes use of social vulnerability to explain the underlying mechanisms which predispose households to food insecurity. While it is true that the poverty mechanisms reviewed here (such as chronic poverty) could be used to interpret the results of this investigation, the constraints of the data and the statistical analyses used in this investigation limit the ability of this dissertation to comprehensively test the explanatory validity of these mechanisms. In other words, the lack of longitudinal data and computational simulations as an analysis option limits the testability of these mechanisms in this dissertation (given the inherent nature of feedback loops in maintaining chronic household poverty). Instead, this investigation will devise an operationalized definition of vulnerability informed by the literature on social vulnerability while remaining amenable to statistical analysis. For these reasons, this dissertation will focus in specifically on the impact of urban infrastructure on household vulnerability to food insecurity.

Given this review, it is evident that there is a clear and valid relationship between poverty and food insecurity (where food insecurity either acts as an outcome or a characteristic of poverty). In addition, given the breadth of the definitions provided here for poverty, it is evident that all of the variables included in this investigation could be viewed as a proxy for poverty measurement (across both the independent and dependent variables in this analysis). So it is clear that (based on the definition taken to conceptualize poverty) poverty may be the causal origin for any of the conditions measured here.

All of that said, each of the variables in this investigation appears to have different impacts on a household's odds of food insecurity within the household sample. In other words, there appears to be a ranked degree of impact which each of these variables appears to have on the odds of a household being categorized as food insecure. The challenge is this: while poverty could hypothetically cause any one of the dependent and independent variables in this investigation, a poverty framework alone would be insufficient to explain the differences in these impacts. Given the thesis of this investigation, the variables related to consistent infrastructure access may have a greater impact on the odds of households becoming food insecure when compared to other, empirically established, household social vulnerability characteristics. As such, consistent infrastructure access may have a greater impact on household odds of being food insecure. That said, defining infrastructure, like poverty, remains problematic.

Conceptualization of Urban Infrastructure

There is no standard definition of infrastructure that is universally accepted. Many approaches to defining infrastructure have attempted to capture the economic value of infrastructural outputs. One seminal example of this approach is provided by Jochimsen (1966), who defined infrastructure as "the sum of material, institutional and personal facilities and data which are available to the economic agents and which contribute to realizing the equalization of the remuneration of comparable inputs in the case of a suitable allocation of resources, that is complete integration and maximum level of economic activities" (as cited in Buhr, 2003, p. 1). In other words, infrastructure exists to both optimize inputs in relation to economic outputs while also supporting the equality of comparable inputs in relation to their comparable outputs.

Drawing from Jochimsen's (1966) work, Buhr (2003) takes a very broad approach to defining infrastructure by including personal, material, and institutional infrastructure. According to this conceptualization, personal infrastructure refers to human capital or all determinants of the economic output of individuals (for example, the birth rate, migration, education, and willingness to work of a working population). Material infrastructure refers to capital goods and services. Torrisi (2009) explains that material infrastructure "can be defined as goods and services able to satisfy those wants of economic agents originating from physical and social requirements of human beings" (p. 12). This form of infrastructure refers to networks or systems of physical goods and social services that ameliorate a need for a human population. Finally, institutional infrastructure refers to the codified rules and regulations that govern humans as well as the means by which those rules and regulations are enforced (Buhr, 2003).

As noted by Jochimsen (1966) and Buhr (2003), infrastructure access and availability can play a significant role in economic development. In a case study of China, Démurger (2001) found that infrastructure availability played a significant role in determining the regional differences in economic development within the country. In a panel regression analysis of 43-67 countries, Canning and Pedroni (2004) found that the provision of material infrastructure (in the form of electricity, paved roads, and telecommunications for example) from 1950 to 1992 did predict long-term economic growth.

Within this dissertation, infrastructure will refer specifically to material infrastructure with one additional distinction (which will be helpful in the analysis of the results). This dissertation will make the distinction between material infrastructure that provides an output which is primarily a physical good (such as water and electricity), and infrastructure linked to a social service (such as medical care or a cash-based income). This distinction is helpful in order to interpret the unique impacts of each of these infrastructure categories on household food security. In order to illustrate the definitions of infrastructure used in this dissertation, the provisioning of water, electricity, cash incomes, and medical care will be explained as infrastructure below.

The provisioning of water within a city represents an essential resource. The disruption of the networks providing water within the city can disrupt resources for human life as well as economic activity within the city (Chang, 2004). Water treatment plants, pumps, piping, and water access points are necessary components to supply water throughout a city (Boyle et al., 2010). The provisioning of water within a city therefore requires extensive material infrastructure and represents an important aspect of urban infrastructure.

Similar to the provisioning of water, electricity also represents a key resource for human life within urban areas (Chang, 2004). Also similar to water provisioning, electricity requires a network of power generation plants in addition to a supply grid. As with water infrastructure, this description focuses exclusively on material infrastructure units and avoids the institutional infrastructure components necessary to govern and administrate the supply and distribution of electricity. Both of these infrastructure resources are considered in this dissertation to be examples of physical infrastructure in that both kinds of infrastructure are designed for the purpose of supply a physical (tangible) good to be consumed by the end consumers.

The provisioning of cash-based incomes can be conceptualized as a form of financial infrastructure service (Torrisi, 2009). It can be argued that a cash-based currency can only be maintained by a system of institutions which secure the printing, distribution, and value of currency (determined by the manipulation of the market by central banks in addition to other factors). In other words, financial infrastructure exists to maintain the flow and value of cash.

Merton and Bodie (1995) suggest that "financial infrastructure consists of the legal and accounting procedures, the organization of trading and clearing facilities, and the regulatory structures that govern the relations among the users of the financial system" (p. 18). Biagio et al. (2003) define financial infrastructure as codified regulations, supervisory systems, infrastructure of information, exchange and clearing systems, liquidity, and the institutions and rules which govern financial corporations. Similarly, Rosengren and Jordan (2000) define financial infrastructure as being composed of "legal systems, accounting systems, banking sectors, and securities markets" (p. 2). Gray (2002) summarizes these definitions by proposing that "financial infrastructure includes both the skill of people involved in the sector and the formal (statutes) and informal (recognized precedents and culture) institutions" (p. 182). Given these definitions, financial infrastructure appears to include the human services and assets involved in the production of, and in supporting the distribution of, cash currency in its various forms and derived from its various sources by households.

Within these definitions, cash can be considered an output (resource or service) of a financial infrastructure. This approach is not unfounded in the literature. Gertler (1988) reviewed the different theories linking the function of a financial infrastructure with economic development and suggested that financial infrastructure supported the flow of cash in an economy. This assertion is supported by other scholars. Leyshon and Thrift (1994) proposed that a lack of access to financial services (like credit or loans) demonstrated a lack of access to products of a financial infrastructure. Allen et al.'s (2006) overview of financial infrastructure included payment settlements and transfers as products of a financial infrastructure (an assertion validated by Dale et al., 2000). Lindley (2009) suggested that cash remittance services are a part of a broader financial infrastructure which supported access to remitted cash. Another theory, proposed by Honohan (2004), is that financial infrastructure allows financial users to pool their risk and that the development of financial infrastructure also increases the use of debt as a financial service. Pixley (2009) also proposed that the value of money (and trust in the stability of that value) was based on the functionality of an entire financial infrastructure which manipulated the market value of money (and therefore influenced the ultimate use of money in an economy). Together these studies validate Gertler's (1988) theory proposing that financial infrastructure supports economic development by fostering cash flow in an economy. This theory has also been used to explain the impact of Kenya's digital cash infrastructure in mending the gaps in the country's financial infrastructure (Cracknell, 2012). The World Bank's (2012) report on the use of mobile technology to support cash transfers corroborates this interpretation that access to cash remittances is a product of a financial infrastructure and that mobile transfers make up a growing characteristic of financial infrastructure in developing nations.

This point is made especially poignant when some means of employment in Maputo offer only in-kind rather than cash based remuneration, a distinction which limits the exchangeability and value of that remuneration for the purpose of purchasing goods. Access to a cash-based income therefore represents the ability of a household to access the specific services of a financial infrastructure.

The provisioning of medical care can also be conceptualized as an infrastructure service (Buhr, 2003). Medical care can only be provided if supported by a network of hospitals, clinics, labs, and pharmaceutical supply chains. This service is also supported by the provisioning of education for the purpose of training medical practitioners (not to mention the administrative and regulatory bodies governing the practice of medicine). As such, the provisioning of medical care is only possible when supported by a network of institutions and services and is an example of material infrastructure within the city.

A specific point should be made here to qualify both medical care and a cash-based income as a social service rather than a physical good. After all, isn't a 20 dollar note a physical product that is being produced and distributed among a population like any other physical good? If that 20-dollar note were to be judged solely by its intrinsic utility (as one might judge the utility of water or electricity) the note would be worth the same amount as any piece of paper of that quality and size. The value of the note is actually largely determined by a system of financial institutions and services manipulating the market value of that piece of paper by printing or purchasing money, setting interest rates, and engaging in other market manipulations. As such, the value of the 20-dollar note is determined by a social service. In addition, the utility of that 20-dollar note is only helpful if there is a market available through which that note can be exchanged for goods or services. Thus, access to a cash income represents access to the entire infrastructure supporting the value and trade of currency. The same argument can be applied to medical care. The value of medical care cannot be judged solely by the value of physical products like pills, sutures, or bandages because there is a necessary service component requiring the engagement of both a medical practitioner and the consumer. This service component (which makes use of pills, sutures, and bandages) creates the value of medical care and is supported by a network of institutions involved in medical training, medical practice, and medical administration. These arguments underline one of the fundamental qualities of a social service, which is the intangibility of its value. While the value of a physical good can be measured by the labour and parts involved in its production, the value of a service is much more difficult to measure because of the intangible resources which make up that service.

In this dissertation, infrastructure will be defined as the sum of goods and services specifically provided by systems of interacting human agents and physical assets that are administrated for the concerted purpose of facilitating the supply of those goods and services to fulfill human needs. This definition is based on the broad definition of infrastructure provided by Jochimsen (1966) and overlaps more specifically with the definition of material infrastructure provided by Buhr (2003). This definition does not assume the free distribution of infrastructure goods and services and allows for the influence of both market pressures and social policy in both the provision of infrastructure goods and services and in the means by which those infrastructure goods and services are accessed. For example, a household's access to electricity and water may be maintained by both a fee for service model and a subsidized rate for low income households. A household's access to medical care may be determined by a fee for service model, medical insurance, subsidized healthcare or universal healthcare. A household's access to cash may be determined by household member employment, access to credit or government social grants.

Conceptualization of Vulnerability

Depending on which field of literature you read, vulnerability is either defined as a characteristic of humans, the interaction between humans and the surrounding environment, or of the environment itself (Birkmann, 2006; Weichselgartner, 2001). There is some agreement that vulnerability represents the interaction of phenomena across scales, geography, and time. Demonstrating these variables comprehensively and empirically is not possible within the scope of this investigation. The challenge that lies in this section is this: first, how can vulnerability be conceptualized in such a way that accounts sufficiently for the complexity of the phenomena, and second, how can that concept be simplified into an operationalized hypothesis while accounting for as much of that complexity as possible?

In order to answer these challenges, this section will first review some of the models of social vulnerability that have been developed in the field of Disaster Risk Reduction. This will not represent a comprehensive review of all models of social vulnerability, but this review will touch on models having some relationship to the measurement of urban household vulnerability to food insecurity. Accordingly, this review may include models which were designed to measure other variables (such as disaster risk) but also conceptualize vulnerability in their design. As such, any models that are at an inappropriate scale (are not applicable to the household scale and only apply to municipal, national, or global scales), are not geographically applicable to urban environments (given the focus of this research), and are not thematically linked to urban food security (strictly ecological models, for example) will not be included in this review. Once that review is completed, a model will be designed and operationalized for use in answering the research question of this investigation. This model will then be tested against cases of urban food insecurity in order to determine the explanatory value of the model.

Birkmann (2006) offers two definitions of vulnerability: The United Nations International Strategy for Disaster Reduction (UNISDR) definition: “the conditions determined by physical, social, economic, and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards” and the United Nations Development Programme (UNDP) definition: “a human condition or process resulting in physical, social economic and environmental factors, which determine the likelihood and scale of damage from the impact of a given hazard” (p.4). As can be determined by these definitions, vulnerability has multiple dimensions (differentiated across contexts), which are differentiated by scale (the spatial and temporal scale of measurement), and are dynamic (the influences and determinants of vulnerability can change over time) (Birkmann, 2006). In addition, however, both definitions support the idea that vulnerability is a characteristic of a human population in relation to a hazard.

The complexity of the vulnerability term can confound the operationalization of the term, making empirical investigation difficult. In order to provide a reliable measure of vulnerability, the theoretical framework being constructed here will need to be catered to answering the research question in this investigation. To provide potential elements for that framework, I will present a cursory review of some DRR models including: the Pressure and Release Model, the Access Model, the Holistic Model, the Onion Framework, the BBC Model, Turner's Vulnerability Framework, and the Sustainable Livelihoods Framework.

The Pressure and Release Model

One of the earliest models of DRR (The Pressure and Release model) defines disaster risk according to the interaction of hazards and vulnerabilities (Risk= Hazard x Vulnerability) (Birkmann, 2006). In particular, this model suggests that disaster impacts are the result of the confluence of root causes, dynamic pressures and unsafe conditions (Wisner et al., 2004). Root causes can be social, political, economic, or environmental factors, while the dynamic pressures represent the activities or processes allowing root causes to create unsafe conditions or hazards (Smith and Petley, 2009). This model would assume that household vulnerability to food insecurity develops from the confluence of root causes (such as limited access to power or the influence of ideologies), the formation of dynamic pressures (such as urbanization, public or private investment, or population growth) and unsafe conditions (households residing in dangerous locations, having limited access to infrastructure, or limited capacity to develop assets) (Wisner et al., 2004). This confluence of vulnerability characteristics can leave a household sensitive to food insecurity (Birkmann, 2006).

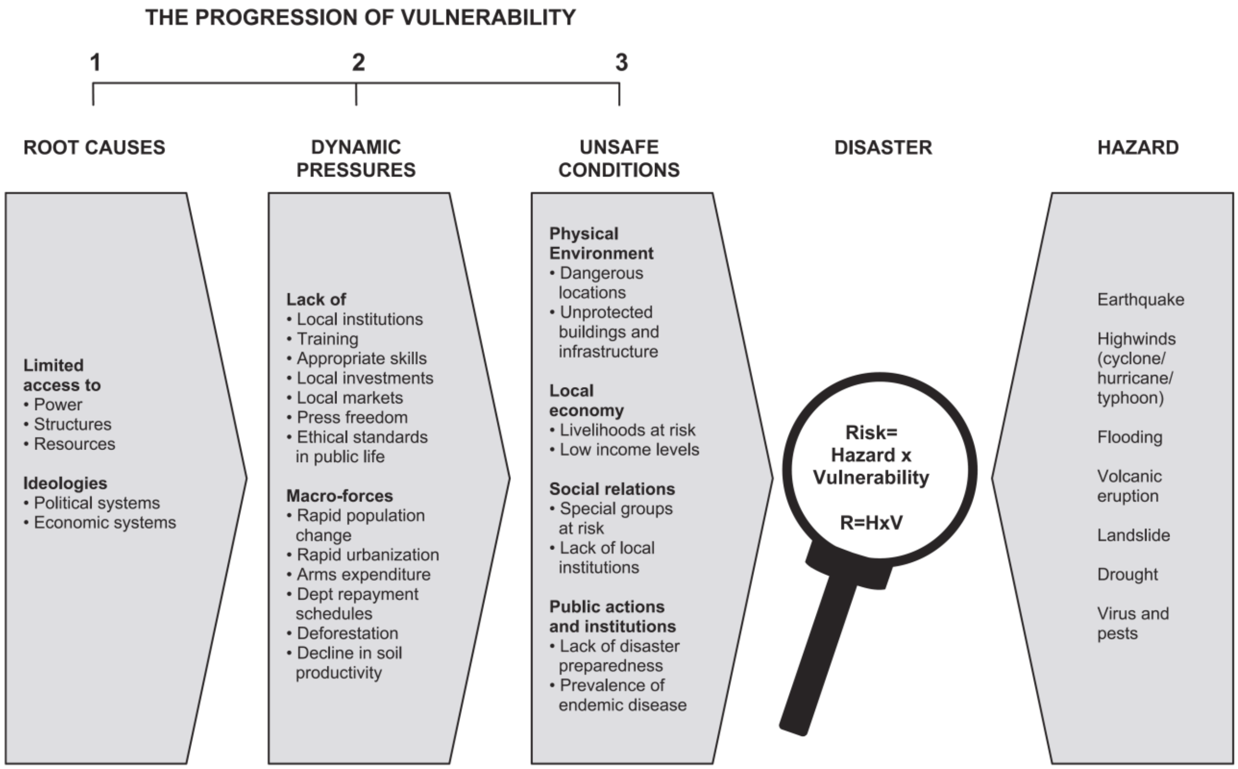


Figure 1.The Pressure and Release Model of Vulnerability (Wisner et al., 2004, p. 47)

The Access Model

The Access Model focuses on assessing sources of “everyday” vulnerability for a household and suggests an important role for governance structures and institutions in mediating household livelihoods (Wisner & Luce, 1993). Similar to the PAR model, this model assumes that a disaster occurs when a hazard impacts a vulnerable population. However, the access model exclusively focuses on the interaction between hazards and vulnerabilities (at the point of the magnifying glass in the PAR model) (Wisner et al., 2004). The Access model attempts to clarify the social and environmental interactions facilitating the occurrence of a hazard impact among specific social groups. In particular, the Access model focuses on the interaction of marginalizing factors (gender, age, and ethnicity) on a household’s access to resources and how this influences that household’s likelihood of experiencing the impact of a hazard. The impact of a disaster in this model is therefore translated by access to resources (which is in turn determined by social relations and structures of domination). Wisner et al. (2004) defines social relations as “the flow of goods, money and surplus between different actors” (p. 85). Structures of domination refer to the political relations between those agents. These relationships can occur between individuals or between groups. The model is ultimately focused on how these kinds of social relationships can influence the kind of access to resources that is necessary to mitigate the impact of a hazard. The model therefore assumes that access to resources is a key mediating factor in determining vulnerability.

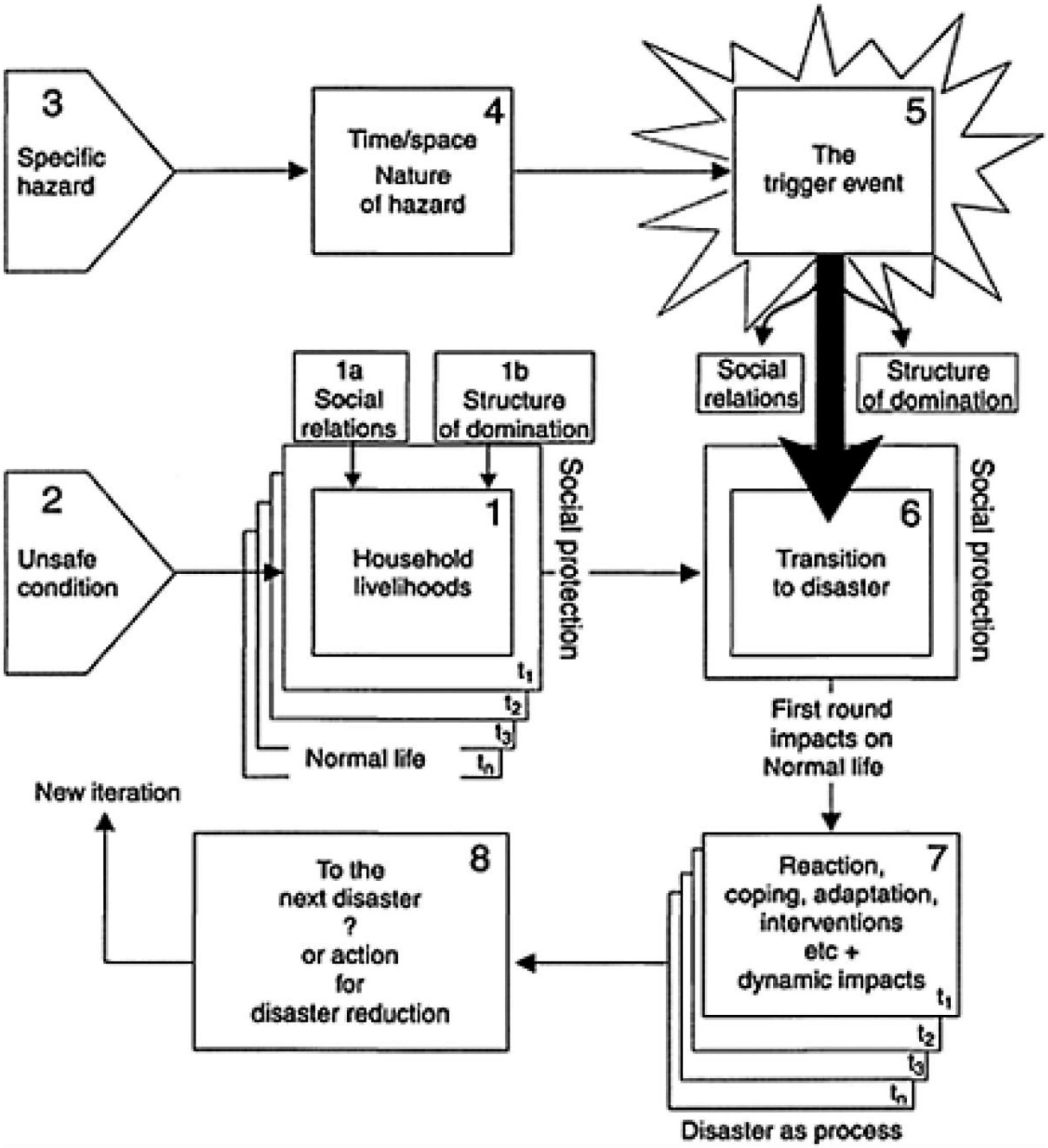


Figure 2. The Access Model (Wisner et al., 2004, p. 81)

The Process of Marginalization

The process of marginalization is used as a framework in the design of the Access Model and provides further explanation for how social relations can interact with both resource access and vulnerability. In this framework, groups in society are assumed to be in conflict with one another for access to resources. As such, certain groups will be better positioned to access certain resources than more marginalized groups (Wisner & Luce, 1993). This model also assumes that the marginalization of certain groups can increase the likelihood of a hazard impact. For example, the marginalization of the urban poor can position poor households in informal settlements with limited access to clean water, increasing the likelihood of cholera tainting that water supply (a hazard impact). As a case study of this model at work, Wisner et al. (2004) describe the state of southern Somali herdsman during the 1991-1993 Somali famine and how their social marginalization led to their displacement, reduced herd quality, and limited access to aid. In this case, the impact of pre-existing social prejudice (in the form of stigma or policy favoritism) on the distribution of food in urban areas following a disaster made these herdsmen more vulnerable to food insecurity. Sen (1981) demonstrated how pre-existing expansionist policies favoured the distribution of aid to Calcutta at the expense of rural areas during the Bengali famine. This policy led to the inpouring of rural migrants into Calcutta in search of food and created a food security crisis in the city. As an example of the relationship between vulnerabilities and social prejudices, individuals living with disabilities can suffer more extreme impacts from disasters when compared to the general population. In the 1963 Skopje earthquake, nearly 1/3 of those injured had a pre-existing disability (Alexander et al., 2012). Individuals with disabilities may also be susceptible to marginalization in the aftermath of disasters. After the 2004 Tsunami, local Non-Government Organizations (NGOs) reported several cases of Sri Lankan hospitals turning away injured patients due to their mental illness (Alexander et al., 2012). These pre-existing and contextually laden vulnerabilities can increase the severity of a hazard's impact on a household. As such, Wisner et al. (2012) suggest that vulnerabilities can be understood as a triangle of interacting structures (political, social, and economic). When access to resources or services in any of these three structures is disrupted, households can become marginalized and have limited ability to avoid harm.

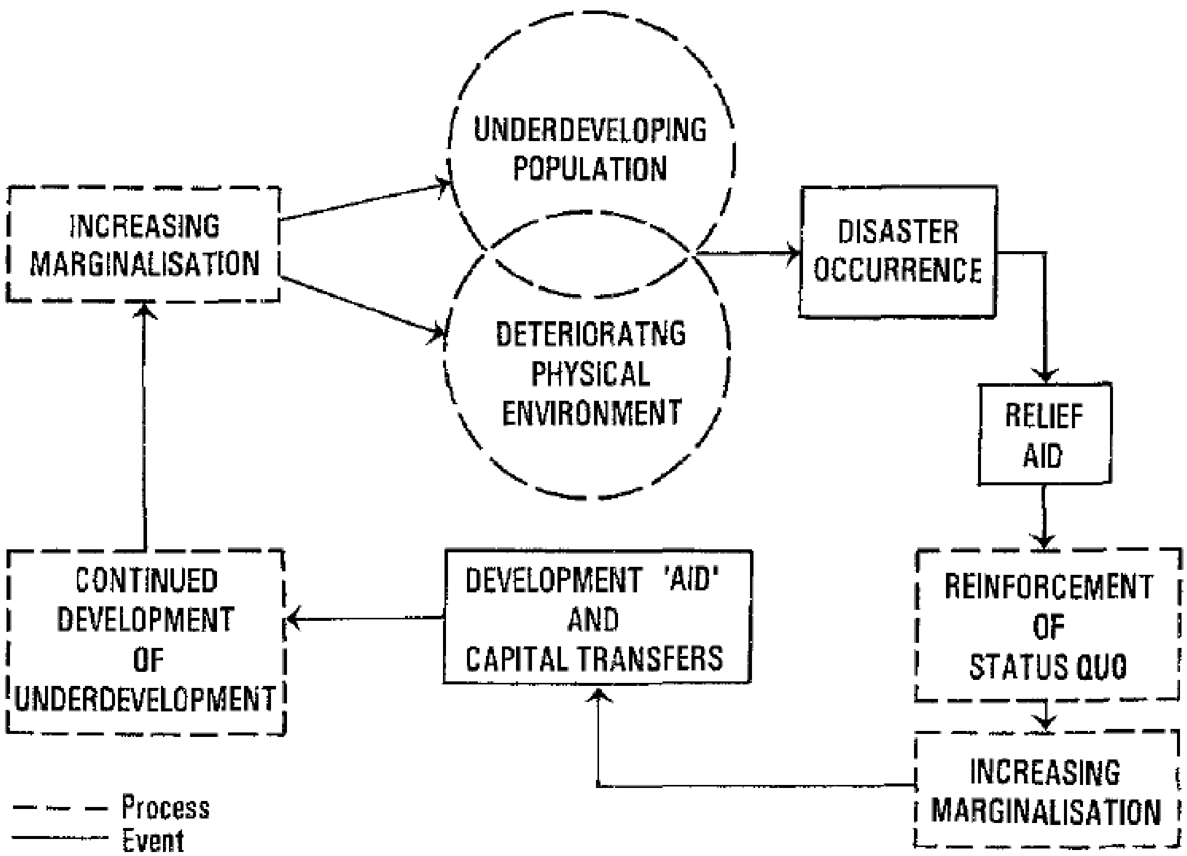


Figure 3. The Process of Marginalization (Wisner & Luce, 1993, p. 129)

The Holistic Model

The Holistic Model suggests that vulnerability is defined by physical exposure, the existence of a fragile system, and limited adaptive capacity to recover (Birkmann, 2006). These elements interact with hazards to produce hard risk (the potential for damage to physical systems) and soft risk (the potential for damage to social systems). The model suggests that the identification of these risks can be integrated into a broader disaster risk management system to provide corrective measures (through risk identification, reduction, and transfer as well as disaster management) which then give feedback into the model and changes the original risk assessment (Carreño, Cardona, & Barbat, 2006). While some aspects of this model have not been demonstrated empirically, the model remains an important application of a complex systems approach to disaster risk reduction (through the integration of adaptive feedback loops) (see Arthur, 1990 for a more detailed definition of feedback loops). This model also suggests that there are two key components of DRR practice: the use of indicators to measure disaster risk dynamically and the implementation of effective policy responses to those disaster risks. In other words, this model suggests that DRR requires the effective use of feedback loops in order to mitigate disaster hazards (Birkmann, 2006). In Comfort's (2006) assessment of Hurricane Katrina's impact in New Orleans, the interaction between economic decline (soft risk) and fragile infrastructure (hard risk) in the city had serious implications for the effective management of Katrina's impact on the city. A vivid example of the urban food security outcomes from this disaster are the 25,000 New Orleans residents forced to take refuge in the Superdome without access to safe water or food supplies. This case frames the interaction of poor infrastructure and economic stagnation (hard and soft risk) as a potential vulnerability when those features interact with hazards.

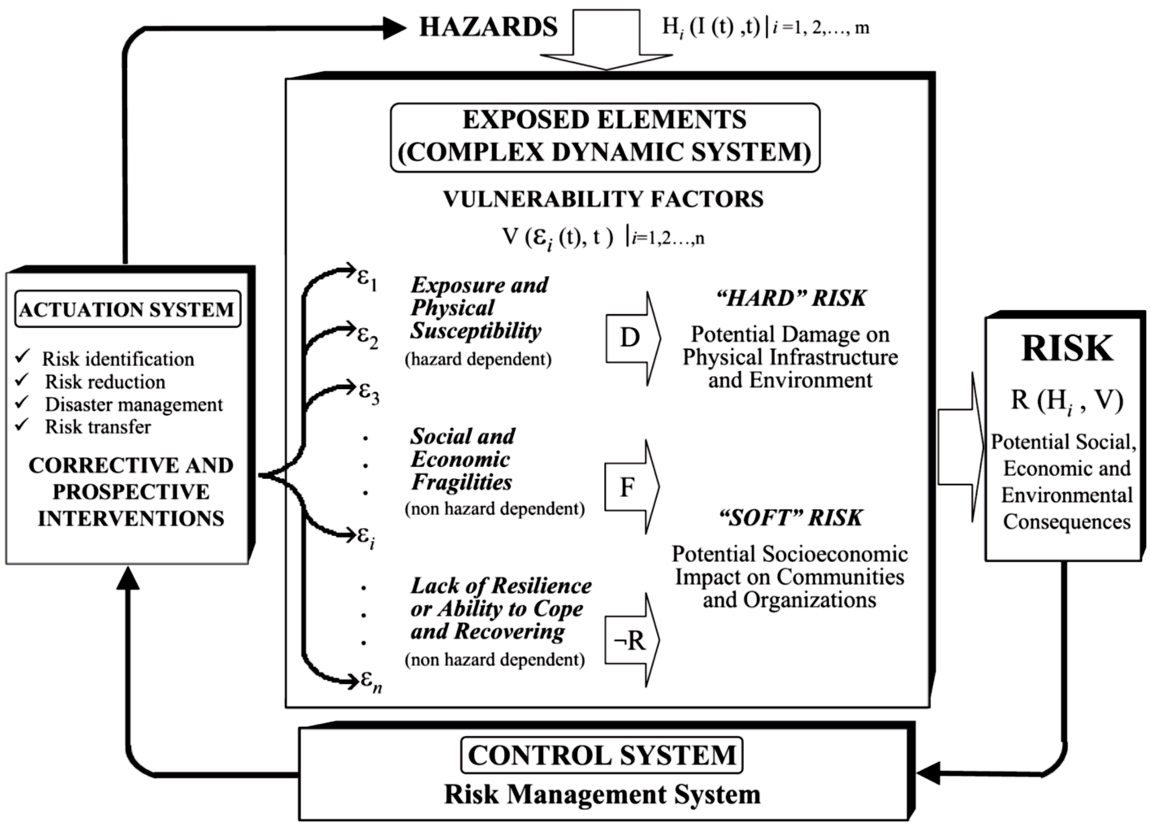


Figure 4. The Holistic Model (Birkmann, 2006, p. 32)

The Onion Framework

The Onion Framework integrates a “reality axis” representing the cascade of disaster impact (from a causal trigger event to system damage to disaster impact) and an opportunity axis representing the points at which the disaster can be mitigated (proceeding from the point of hazard to risk to vulnerability) (Birkmann, 2006; Wisner et al., 2012). The layers of the onion which are intersected by these axes represent the natural, economic, and then social impacts of a disaster. These layers have a cascade effect on one another as the disaster event occurs and progresses from an event to a disaster impact. This model demonstrates how actions taken at the right point of hazard development can mitigate the impact of disasters. While this model does incorporate the multiple layers of loss that occur due to a disaster impact, the progression of the layers of disaster impact (natural to economic to social) appears contextually bound and may not be generalizable to all hazards. One case of this model at work is demonstrated by the 2004 Boxing Day Tsunami and its impact in countries like Sri Lanka, Thailand, and Indonesia (Birkmann et al., 2008). The progression of impacts began with an earthquake at the seafloor of the Indian Ocean, followed by the tidal wave impact on coastal cities and communities (wiping out infrastructure in fisheries, agriculture and tourism sectors in the country), and finally resulted in social (disrupted communities and social trauma) and governance chaos in the management of food aid and infrastructure rebuilding. While these progressive impacts represent knock-on hazard impacts, the impacts also represent opportunities for intervention. These interventions included the development of Tsunami early warning systems (natural impacts), the resettlement of communities, the creation of buffer zones along coastal areas, and the development of new institutions to oversee the implementation of these interventions and organize the distribution of food aid (social impacts).

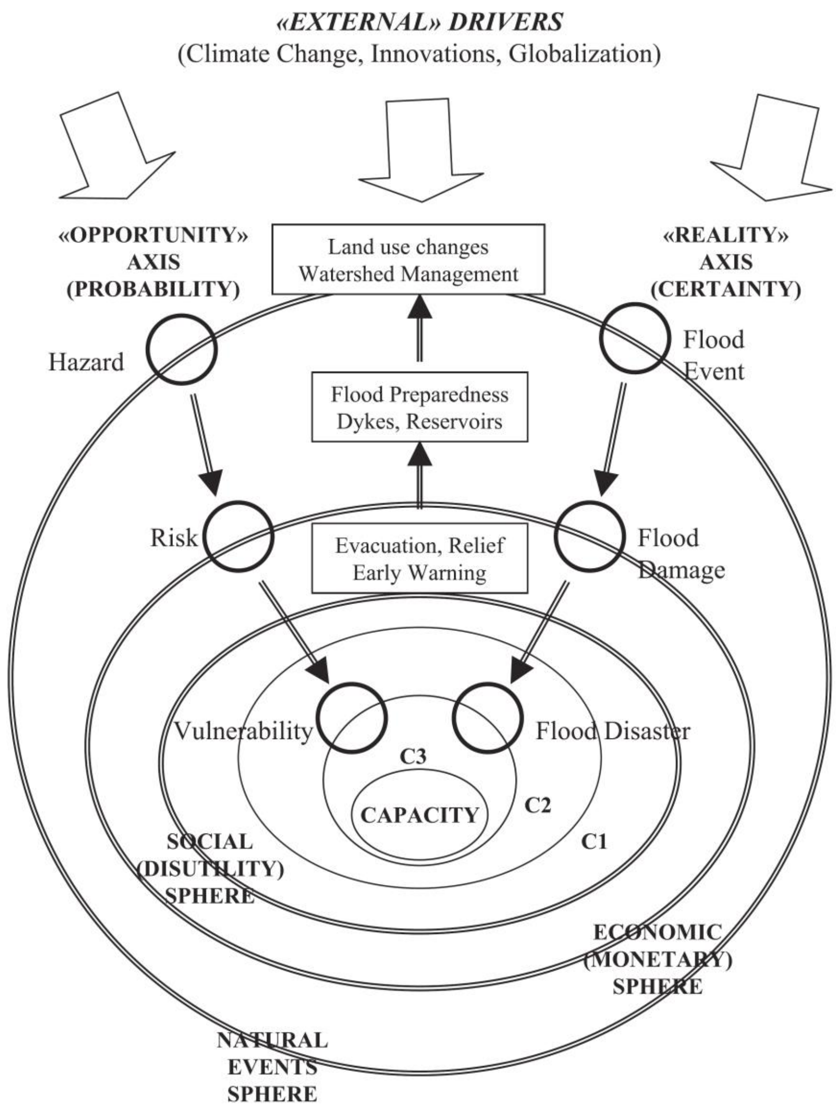


Figure 5. The Onion Framework (Birkmann, 2006, p. 28)

The BBC Model

The BBC Model (named after its developers: Bogardi, Birkmann, and Cardona) links disaster risk reduction with sustainable development and human security (Birkmann, 2006). The BBC model assumes that vulnerabilities are dynamic and exist within feedback loops (represented by adaptive responses to hazards). In addition, the model frames disasters as highly contextual events in that disaster impacts are defined by the unique features of the disaster and the context in which they occur. Vulnerability is conceptualized through social, economic, and environmental contexts. The BBC model also integrates an assessment of the exposed elements of a system as well as the coping capacities of a system which can mediate the impact of a disaster event on that system. The framework suggests that intervention can occur either before a disaster occurs or when a disaster is occurring in order to reduce its potential impact (Birkmann, 2006). An example of this model at work is provided by Wisner et al. (2004) in a review of the Burmese civil war. During this civil war, a drought occurred in the country and provided the initial conditions for a famine. The civil war, however, eroded public trust in the government's effectiveness and limited the government's ability to intervene and mitigate the impact of the famine. As such, the vulnerability of communities in Burma was determined by the feedback loops (represented by the coping strategies in place) and the social-ecological system in which those coping strategies are applied. In this case, a lack of trust in the government hindered the implementation of adaptive policy responses.

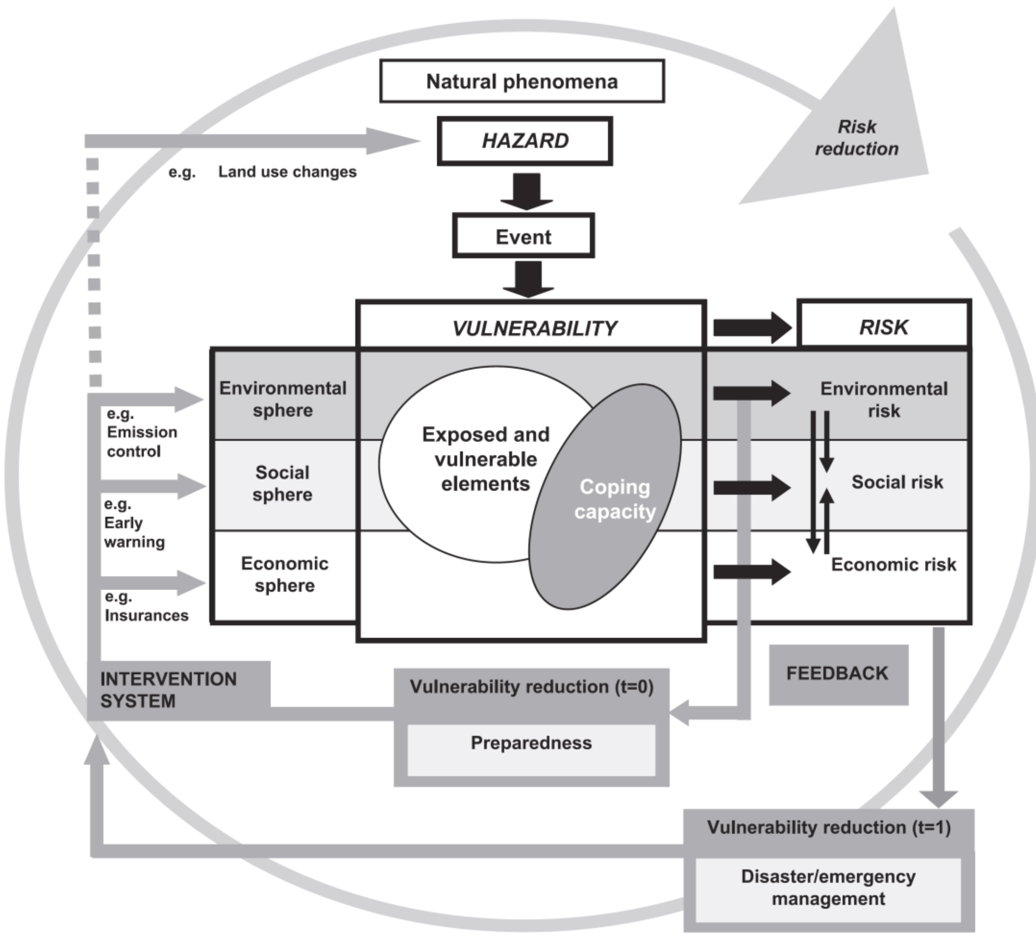


Figure 6. The BBC Framework (Birkmann, 2006, p. 35)

The Vulnerability Framework

In Turner et al.'s (2003) vulnerability framework, vulnerability is determined by feedback loops between human and environmental processes (however both of these feedback loops occur at a different scale and location). The focus of the framework is on the determination of place-based approaches (the combination of human and environmental factors at one geographic location). Place-based approaches are meant to be participatory, involving stake-holders in the definition of that place and the actions taken in that place. While the model integrates multiple scales of analysis, the model can be applied to any scale (thus demonstrating its suitability for this review of household vulnerability). Vulnerability in this model occurs at the coupling of environmental and human systems in such a way that the coupled system is sensitive to perturbation (based on the exposure of that coupled system and the capacity of that system to cope with perturbations) (Birkmann, 2006; Turner et al., 2003). An excellent case study of this model at work is provided by Turner et al. (2003) in their review of farming practices in the Southern Yucatan Peninsula. The Southern Yucatan Peninsula is exposed to hurricanes and water stress which can destroy farmer's crops. Farmers in the region have adjusted to this hazard by growing chili which is pest and disease sensitive. While this change has increased household income, it has had unintended consequences like swings in household income due to variability in chili prices resulting from crop failures. The wide-spread practice of farming chili also resulted in deforestation (mostly by slashing and burning in preparation for chili fields). This method has allowed bracken fern to invade agricultural areas and potentially deplete nutrients in the soil. As a result of these human influences (in the form of adaptation strategies), farming households in this area have become even more sensitive to the impact of hurricanes and water stress.

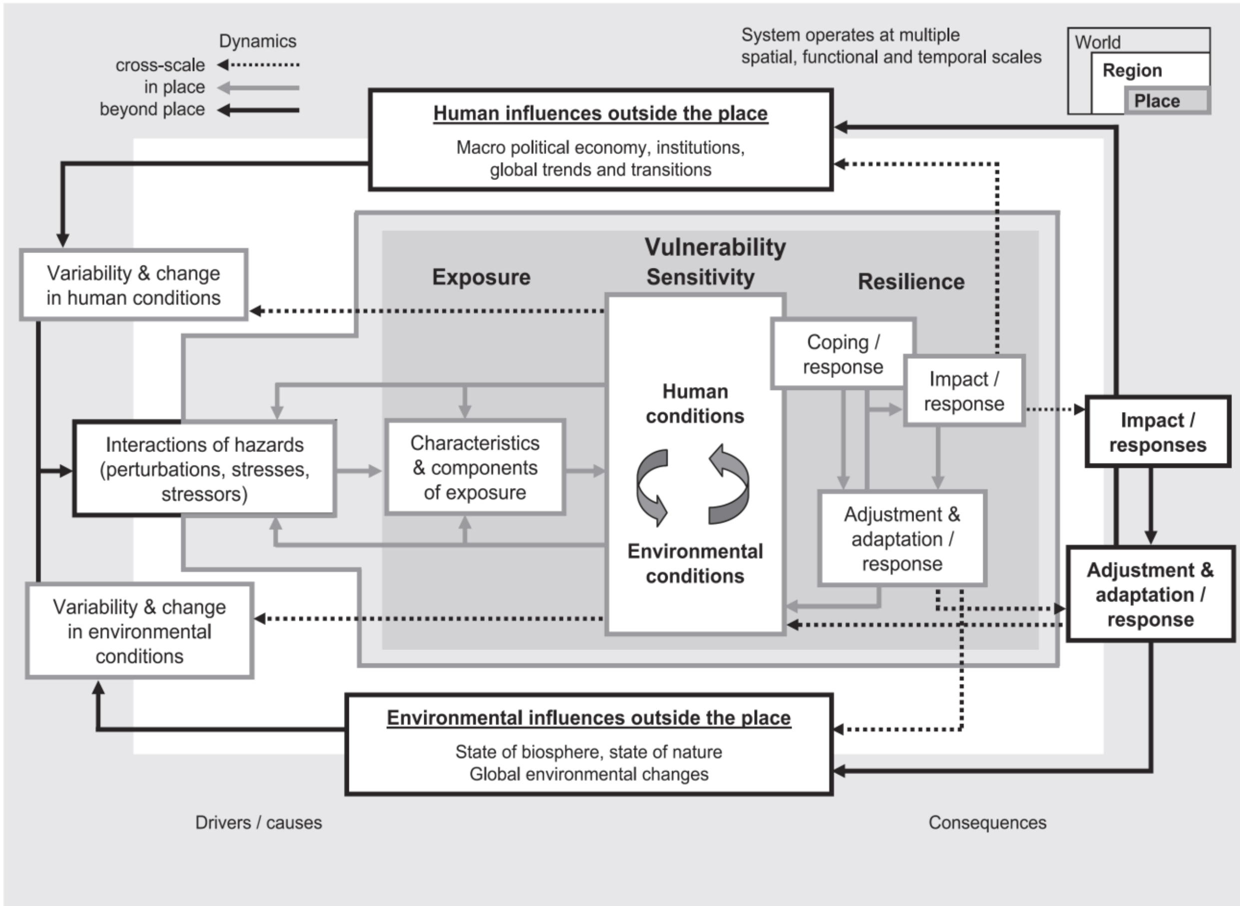


Figure 7. The Vulnerability Framework (Birkmann, 2006, p. 27; Turner et al., 2003)

The Sustainable Livelihood Framework

The Sustainable Livelihood Framework is another approach to defining vulnerability (Birkmann, 2006). This framework integrates five livelihoods asset categories (financial, social, human, natural, and physical) which are susceptible to contextual factors (shocks, trends and seasonality) (Wisner et al., 2012). The impact of those factors on a household's livelihood is mediated by transforming structures (levels of government or the private sector) and processes (laws, policies, culture, or institutions). These transforming structures and processes interact with the vulnerability context to determine household outcomes (more income, increased well-being, reduced vulnerability, improved food security, or more sustainable use of natural resources) (Birkmann, 2006). These outcomes are then fed back into the system as increased adaptive capacity to mediate the household's future livelihood strategies (Wisner et al., 2012). The 2008 food price crisis provides a key example of this model at work in urban food security systems (Cohen & Garrett, 2010). International food prices became volatile due to the shock of the global recession which was potentially influenced by the unregulated trade of agricultural futures and the purchase of cereals for biofuels (Clapp, 2011). These shocks increased the price of food in the cities of many developing countries, thereby reducing the value of assets used to access food from urban food systems. The vulnerability being demonstrated here in urban food security systems is the impact of shocks to the value of entitlements and the effectiveness of transforming structures in responding to those shocks.

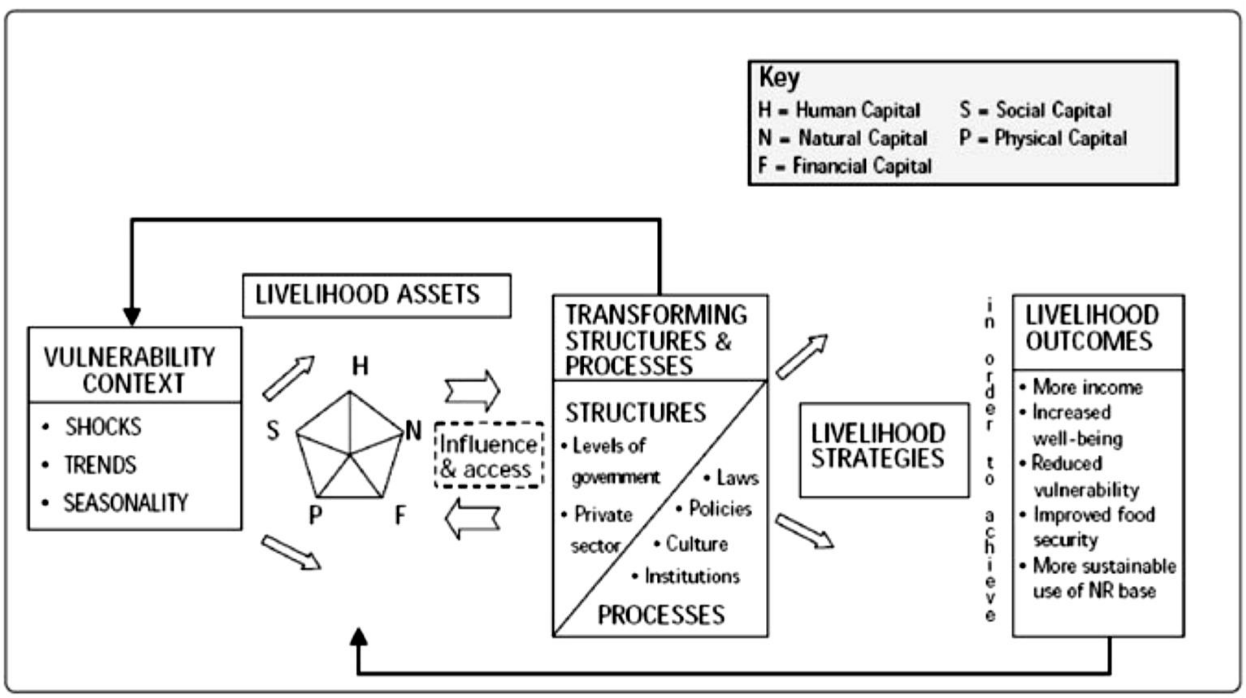


Figure 8. The Sustainable Livelihood Framework (Birkmann, 2006, p. 21)

Theoretical Framework

As a reminder of the key definitions from these models: a hazard is a potential event that can inflict damage or loss of human life, vulnerability is the extent to which a human population is sensitive the impact of a hazard and a disaster occurs when a vulnerable population experiences the impact of a hazard. It is important at this point in the discussion to differentiate social vulnerability from social infrastructure. Social vulnerability refers to the sensitivity of a household to the impact of a hazard (such as food insecurity). Social vulnerability is a characteristic of a human population or, given the scale of analysis in this investigation, a household. Social infrastructure on the other hand is a characteristic of the environment. Social infrastructure specifically refers to the social services available to a household from the system of institutions in a given city. Inconsistent household *access* to physical and social infrastructure may determine a household's vulnerability to food insecurity (as the access model and sustainable livelihoods model would predict) (Birkmann, 2006). That said, the relationship between inconsistent household access to infrastructure and household food insecurity may be better explained by other indicators of social vulnerability (like the marginalizing factors discussed in the process of marginalization model) (Wisner & Luce, 1993). Turner et al.'s (2003) vulnerability framework would also predict that households with limited access to infrastructure may be food insecure but, in Turner et al.'s framework, this relationship is better explained by household income poverty. In order to achieve the purpose of this study, the analyses presented in this investigation will need to determine whether the impact of infrastructure on household food security is better explained by previously empirically established indicators of social vulnerability (as Turner et al.'s framework would suggest) in order to rule out any confounds in the relationship.

The assumption that a lack of infrastructure access could facilitate household sensitivity to food insecurity is taken from both the PAR model and the Access model, as described by Wisner et al. (2004). As a part of the theoretical framework being designed here, food insecurity is conceptualized as the impact of a hazard. While this is an intentionally narrow approach to defining food insecurity, this framework will expand the definition of a hazard to include more than natural events. There are multiple hazards potentially giving rise to food insecurity, including climatic events (such as droughts or flooding), macroeconomic events (such as international food price volatility or food import dependency) (Timmer, 2000), socio-political events (such as war or rampant looting), and medical crises (epidemics or food-borne diseases) (Wisner et al., 2004). This expanded definition of a hazard to include natural and social processes is similar to the understanding of hazards presented in Turner et al.'s (2003) vulnerability framework as well as the BBC framework (Birkmann, 2006). In this investigation, a disaster occurs when a hazard impact is experienced by a vulnerable urban population. In other words, food insecurity is the impact of a hazard (such as a drought) on a vulnerable population (such as a poor urban household). Therefore, this investigation is exclusively focused on the left-hand side of the PAR model (the progression of vulnerability).

Given that vulnerability can represent interactions across multiple scales (e.g. knock-on hazard impacts from a global scale to a household scale, as demonstrated by the Onion model) and can include some complex interactions (e.g. feedback loops representing adaptive coping), the operationalization of this term is a challenge (Birkmann, 2006). For the purposes of this investigation, coping capacity will not be included in assessing social vulnerability. While coping capacity does play a role in determining the impact of a hazard on vulnerable populations, the concept may be better defined as a relational dynamic mediating the relationship between vulnerable populations and hazards rather than as a determinant of social vulnerability. In other words, adaptive coping will be treated as a feedback loop that, over the long-run, could influence a hazard impact. Given the cross-sectional nature of this investigation, adaptive coping will not be included in the analysis. As such, this investigation will provide a picture of static vulnerability rather than dynamically evolving vulnerability. Cutter, Boruff, and Shirley (2003) used a similar framework in their modelling of human vulnerabilities to environmental hazards. Given the constrained focus being developed in this theoretical framework, this model of vulnerability should not be treated as a comprehensive and unifying model of vulnerability in the DRR field.

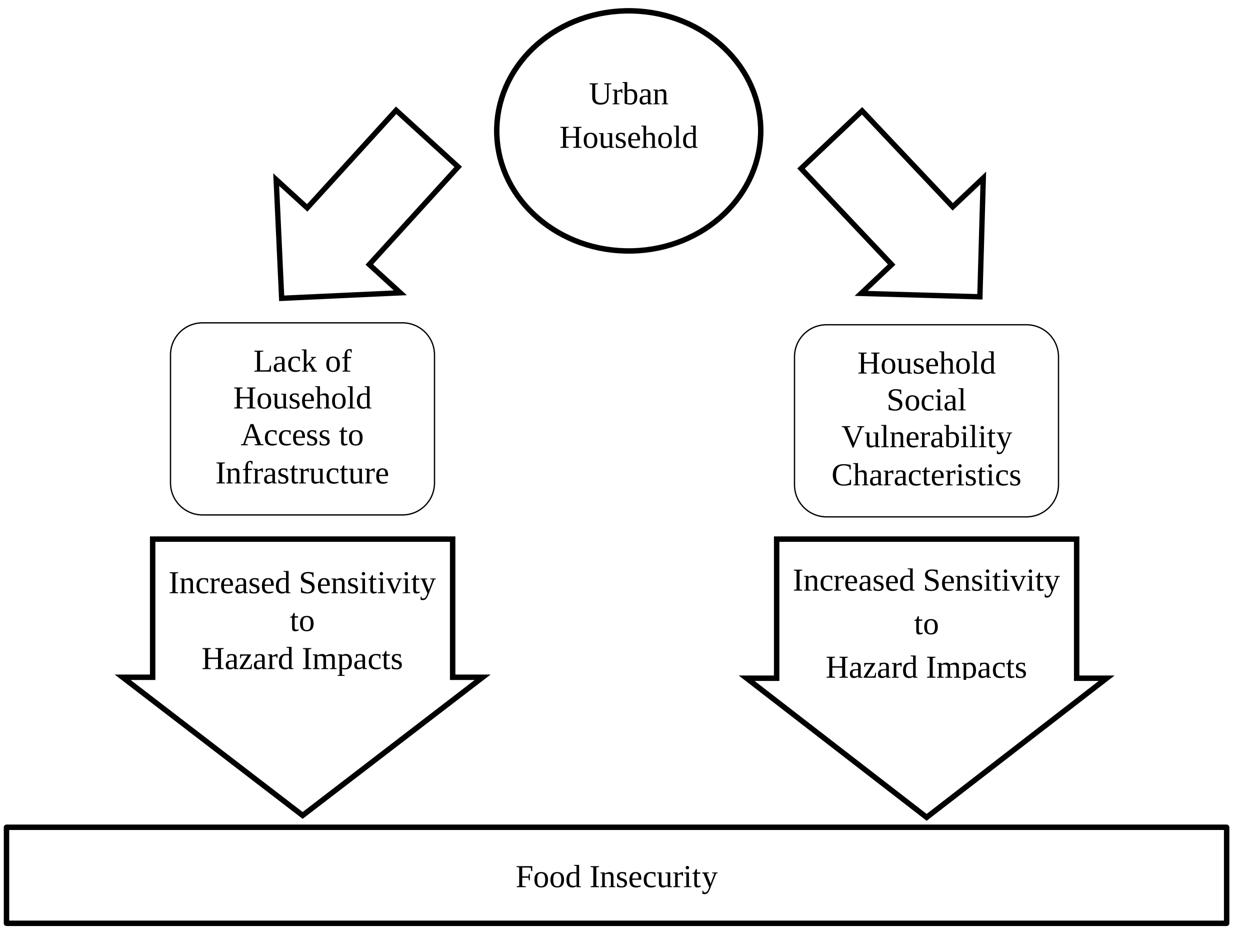


Figure 9. Theoretical Framework

In summary, and for the purposes of this investigation, sensitivity will be used as an indicator of vulnerability in this theoretical framework. This investigation's theoretical framework assumes that households can be sensitive to food insecurity via two broad categories of probabilistic relationships (relationships which are predicated on the probability that one event will occur conditionally based upon the occurrence of another event). Households are either sensitive to food insecurity due to inconsistent infrastructure access (inconsistent infrastructure access may increase the probability that a household is food insecure) or due to the social vulnerability characteristics of the household (households carrying an indicator of social vulnerability may have an increased probability of being food insecure). This framework also assumes that multi-dimensional indicators can represent the social vulnerability of a given household (social vulnerability can be determined by indicators from more than one dimension, e.g. social, economic, public health, etc.). Food insecurity is also represented as the impact of a hazard (stemming from multiple potential hazards). The model, however, does not investigate or make any assumptions about the nature of the hazards which give rise to food insecurity. As such, the theoretical framework is solely meant to clarify the vulnerability analysis performed within the scope of this investigation. The results of this investigation will provide some of the indicators of household vulnerability to food insecurity, rather than provide a holistic model to explain all factors (across domains and scales) and all relationships (dynamic and static) inherent in defining household vulnerability to food insecurity.

Operationalization of Vulnerability

In statistical analysis, causality is normally conceptualized as the degree to which the presence or absence of a variable is associated with a significantly different outcome in a controlled environment (for further discussion on this topic, see Holland, 1986). While the inference of causal chains plays a pivotal role in many of the models reviewed in this chapter, the approach taken by this investigation accounts for the challenges inherent in determining causality using social science research. In order to show how this is achieved in this research, the unique dimensions required to demonstrate causality are discussed below.

“the presence or absence of a variable”

The difficulty in determining the presence or absence of a variable in social research is that this kind of analysis requires the use of control groups. One group will be exposed to, or carry, the variable. The other group will not be exposed to, or carry, the variable. Survey data can be used to infer the presence or absence of a variable, but survey data can only measure the reported presence or absence of the variable, not the actual presence or absence of a given variable. To truly determine the presence or absence of a variable requires absolute control over that variable. This can be both ethically and pragmatically challenging. If one was to determine whether having an income impacted household food security, one would be required to have absolute control over which households have an income and which households do not have an income. This is not only unethical but nearly impossible to control (a topic which is significant in this discussion of causality).

“is associated with a significantly different outcome”

Measuring the strength of association between an independent variable and dependent variable is also a challenge in social research. Human participants in social research are not necessarily passive agents in these relationships. For example, a household that goes without a formal income source will likely engage in coping mechanisms (such as informal marketing or urban agriculture) to limit the impact of this lack of formal employment on household food security. Engaging in these coping mechanisms creates a feedback loop that can obscure the relationship between unemployment and food insecurity. In social research, this can mean weaker associations, lack of statistical significance, or narrow differences between the means of two groups of measures.

"in a controlled environment"

This is most likely the defining statement which explains why determining causality is such a challenge to social research. In order to properly evaluate a causal relationship (as has been suggested in the previous paragraphs) all other variables must be controlled. In other words, it is necessary to rule out the influence of all other variables. While it is possible to statistically control for the influence of some variables, it is impossible to control for, or even account for, all the potential variables that may be mediating the relationship being measured. As such, a truly controlled environment is impossible to engineer in social research. Even if a controlled environment could be engineered, the relationships observed in these settings may not represent the quality of those relationships in a real setting (a setting outside of that controlled environment).

In sum, the closest that social research can come to determining causality is through the inference of a causal relationship, all the while qualifying that statement with the limitations of a social research approach. In the context of this investigation, causality will not be determined. Instead, this investigation will focus on determining the sensitivity of the relationship between inconsistent social and physical infrastructure access and household food insecurity.

Sensitivity is defined in this investigation as the likelihood that a human population which is exposed to a hazard will experience the impact of that hazard (Cutter et al., 2003). This is a statement about the probability that a human population will experience the impact of a hazard. As such, an assessment of sensitivity would require the determination of probabilistic relationships (in other words, the probability that a household will be food insecure). The variables that make a household more sensitive to the impacts of a hazard (e.g. food insecurity) are identified as household vulnerabilities in this framework. Hazard exposure is a necessary pre-requisite for the measurement of sensitivity as only human populations that are exposed to the hazard have any chance of experiencing the impact of that hazard (Birkmann, 2006; Cutter et al., 2003). As such, the operationalization of vulnerability used in this investigation considers all households in the study area to be exposed to the hazard of food insecurity. Given the case that is being analyzed in the course of this research, food insecurity is likely a continuously present hazard.

Physical infrastructure (treated here as hard infrastructure) is defined in this theoretical framework as the network of physical utilities that provides household access to physical resources (such as water and electricity). Social infrastructure (treated here as soft infrastructure) is defined in this theoretical framework as the system of institutions that provides household access to social assets (such as financial services and health care). These definitions differentiate these two kinds of infrastructure as well as broaden the definition of infrastructure beyond the narrow definition of all infrastructures as physical infrastructure. Social vulnerability is defined in this theoretical framework as any characteristic of a human population that increases the odds that the population will experience the impact of a hazard (in this case, food insecurity). This definition of social vulnerability excludes inconsistent infrastructure access in order to test the explanatory value of inconsistent infrastructure access versus social vulnerability in defining food insecurity vulnerability.

Chapter Three: Demonstrating the Validity of the Theoretical Framework

Introduction

Theoretical frameworks are deductively premised on observation or the conclusions of previously established models. While modelling provides a cost-effective platform for hypothesis formation, modelling complex phenomena (like food security and vulnerability) also presents a number of challenges due to the necessary simplification of those complex phenomena during model formation (Rosenblueth & Wiener, 1945). This simplification presents epistemological challenges for three reasons.

First, the properties of complex systems (which may define the interaction of systems to define household vulnerability) are largely closed to mathematical modelling. Conant & Ashby (1970) suggest that modelling any system is a necessary requisite for the regulation of that system. This is because the regulation of a system requires an understanding of the mechanisms guiding that system (this is necessary for the anticipation of system changes). In order to achieve this goal, it is often helpful to mathematically model these mechanisms, which is a challenging endeavor. There are several lines of evidence to demonstrate the ineffectiveness of bounded mathematical modelling in the analysis of complex systems. The first line of evidence is the importance of scale in describing interactions within complex systems. In complex systems, decentralized agents may interact in ways that yield unique patterns when those interactions are combined together (Holland, 1992). The presence of power-law distributions, as opposed to normal distributions, in complex systems can also confound mathematical models that rely on probability distributions (Newman, 2000; Mitchell, 2009). For this reason, the theoretical framework designed in this investigation was purposefully constructed to facilitate empirically testing the framework by excluding dynamic and multi-scalar relationships.

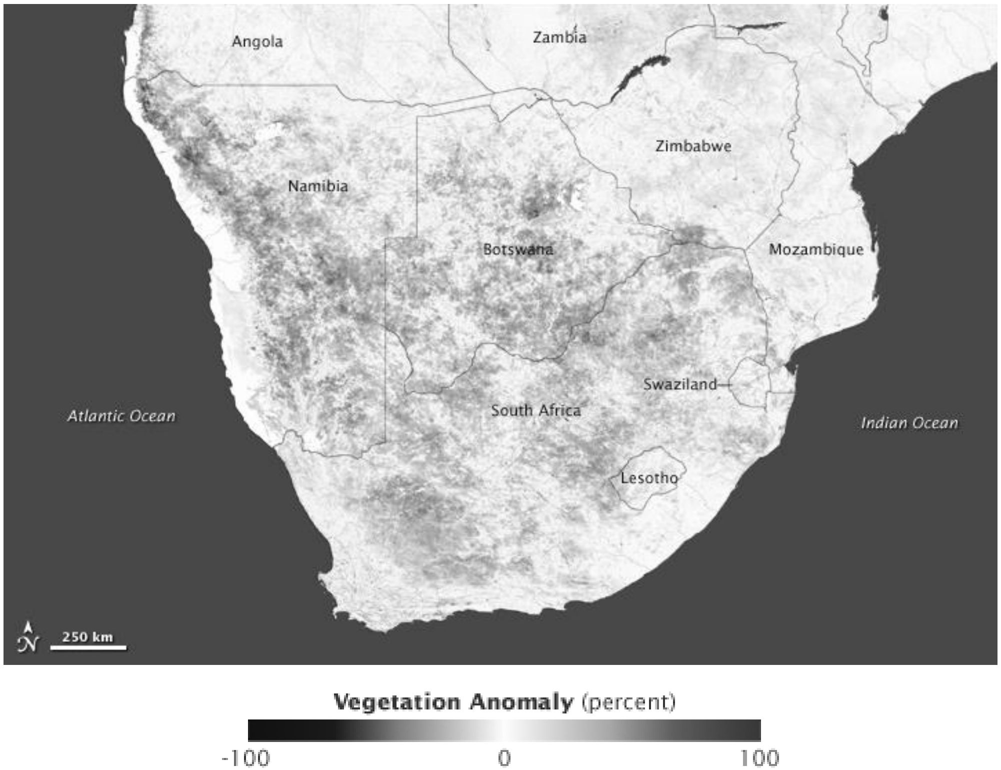
Second, complex phenomena (like vulnerability) are difficult to define. This difficulty in modelling complexity is tied to the definitions used in a given model. As an example, Picket et al. (2012) suggest that the way in which ecosystems are defined is based within a context of epistemological approaches to the environment. In other words, the definitions ascribed to different ecosystems can engender the investigation of those ecosystems. Picket et al. (2012) suggest that the term “ecosystem” is ultimately a composition of metaphors that are used to make sense of the raw unarticulated observations of that ecosystem. In his discussion of metaphors, Boyd (1979) suggested that there are three different views of metaphors. When describing these views of metaphors, I will refer to a target phenomenon (the event or object being described by a metaphor) and a source phenomenon (the event or object being compared to the target phenomenon by metaphor in order to describe the target phenomenon) for points of reference. Boyd (1979) identified the following views of metaphors: the *substitution view* (where metaphors are comprehensively equivalent to literal descriptions of a target phenomenon), the *comparison view* (where metaphors represent underlying similarities between the target phenomenon and the source phenomenon), and the *interaction view* (where metaphors ascribe qualities to the target phenomenon from the source phenomenon). In Boyd’s (1979) argument, the interaction view is really a demonstration of epistemic access, where the metaphor acts as a conduit for ascribing qualities from the source phenomenon to the target phenomenon. This is advantageous because the metaphor can concisely define the target phenomenon. Boyd (1979) describes this process as ostensive (where a term is defined using examples). Kuhn (1979) agreed with this statement and suggested that metaphors can make the choice of models to describe a phenomenon difficult given the context rich qualities of the different metaphors used in each model. These contributions suggest that modelling is subject to epistemological bias due to the diversity of definitions inherent in metaphors.

Third, many theoretical frameworks are deductively premised on “motley” assumptions (Winsberg, 2001). I will define the term “deductively motley” by first explaining what I mean by “deductive” and then “motley.” Theoretical frameworks are deductive in that the organization of a framework is informed by logically or empirically established premises. Many theoretical frameworks are “motley” in that those premises are informed by heterogeneous information sources of varying degrees of reliability and validity. These premises are sets of assumptions which may be biased (Boyd, 1979). This deductive “motleyness” often occurs because frameworks must explain phenomena where data is either limited or unattainable (Winsberg, 2001). The theoretical framework used in this investigation does not escape the epistemological challenges inherent in metaphorical thought. A good question here is whether a model should attempt to escape such a challenge. Knowledge itself is ultimately a representation of phenomena (Boyd, 1979; Kuhn, 1979). Metaphors allow for the quick transmission of knowledge and facilitate the integration of observed phenomena with other established concepts through epistemic access. Instead of avoiding such a challenge, theoretical frameworks should retain an explicit description of its premises in order to facilitate the falsification of such premises (as I have done in the formation of the theoretical framework for this dissertation).

Given the challenges inherent in developing a theoretical framework, this theoretical framework needs to be tested in order to demonstrate the framework’s validity as an explanation of urban household food security vulnerability. Before this framework is empirically tested in this investigation’s case study of Maputo, the explanatory validity of the framework needs to be reviewed. This section will demonstrate how this theoretical framework can explain various cases of household vulnerability to food insecurity. In other words, these case studies will demonstrate the extent to which this theoretical framework can explain some of the factors and mechanisms that determined household vulnerability to food insecurity. This section will therefore provide some evidence for the explanatory validity of the theoretical framework designed for this investigation, but this review will not demonstrate a comprehensive analysis of the framework. Instead, this review is only meant to demonstrate the mechanisms involved in this theoretical framework and show that there are previous cases of urban household vulnerability to food insecurity that may be explained by this framework.

Case Study 1: The 2007 Famine in Lesotho

In 2007, Lesotho experienced a severe famine. At the time, the Food and Agriculture Organization (FAO) announced that Lesotho was experiencing one of the worst droughts in 30 years (Buerkle & Smerdon, 2007). Variable rainfall resulted in the loss of crops, which undermined the already limited supply of domestically produced maize. The FAO estimated that by the end of 2007, around 20% of the population in Lesotho would require food assistance due to the food shortage (Buerkle & Smerdon, 2007). At the time of Lesotho's food security crisis, however, a NASA satellite image from March 2007 demonstrated that reduced vegetation cover (a proxy for agricultural productivity) was actually spread across all of Southern Africa (NASA, 2007). So, the question is, why did Lesotho report the direst food security crisis in the region and what factors explain the vulnerability of households in Maseru (the capital of Lesotho) to food insecurity?



Map 1. March 2007 Vegetation Anomaly in Southern Africa (NASA, 2007)

As with many of the case studies being investigated here, there are several potential answers to these questions. One answer may be that Lesotho was highly reliant upon food imports to maintain food supply. The terrain in Lesotho is mountainous with variable temperatures. Only the north eastern area of the country is suitable for maize production (Moeletsi & Walker, 2013). As a result, domestically produced maize is more expensive than even processed maize imported from South Africa (Mukeere & Dradri, 2006). Lesotho imports much of its maize from South Africa (which also experienced the drought conditions during 2007, but without the widespread famine that was experienced in Lesotho). Due to limited food trade partners and the limited capacity to domestically produce maize, Lesotho was particularly vulnerable to any disruptions in food trade (Leduka et al., 2015). In spite of the unsuitability of the Lesotho geography, agriculture remains one the primary sources of livelihood for households within Lesotho. It is likely that the drought also undermined the livelihoods of agricultural workers in Lesotho.

In the years leading up to this drought, unemployment and food price volatility was on the rise in Lesotho (Leduka et al., 2015). Two main sources of employment for Maseru households were lost: textile manufacturing and mining. Due to a series of changes in the Multi-Fibre Trade Agreement, Lesotho textile exports fell dramatically due to heightened international competition (Peerally & Cantwell, 2012). Chinese companies systematically began closing textile factories in Lesotho. At the same time, mining jobs in neighbouring South Africa (a major source of mining employment for Basotho migrants) began to go to South African workers, limiting this job prospect for Basotho migrants (Rosenberg, 2007). These twin factors resulted in a rising unemployment rate in Lesotho in the years leading up to the 2007 famine. Lesotho also experienced increasing food price volatility. While the food prices continued to drop after the liberalisation of Lesotho's food market, food price volatility grew in the years leading up to 2007 (Thamae & Letsoela, 2014). As a result of this rising unemployment, volatile food prices, and dependence upon food imports in Lesotho, the country was particularly vulnerable to the impact of the drought conditions as a threat to both food supply and livelihoods in the country (both of which provide pre-conditions for a famine).

Using this investigation's theoretical framework, it is evident that household vulnerability to food insecurity in Lesotho was determined by a number of contextual factors, beyond the regional drought, which increased the sensitivity (likelihood) of these households to food insecurity. These contextual factors were dynamically produced over time and included diminishing employment opportunities and increasing food price volatility since the liberalization of Lesotho markets. The presence of these factors increased the sensitivity of these households to food insecurity by making it more likely for households to experience food insecurity as a result of the drought-like conditions in the region. It can therefore be concluded that these unique characteristics made households in the city vulnerable and therefore sensitive to the impacts of the food security hazard.

It is clear that it was the unique combination of these factors which was involved in heightening household sensitivity in Maseru. All of Southern Africa was exposed to the hazard of food insecurity, as demonstrated by the widespread drought-like conditions in the region. However, the unique and unsafe conditions dynamically created specifically in Lesotho resulted in households in that country becoming more sensitive to food insecurity (becoming more likely to experience food insecurity). This point demonstrates another assumption of the theoretical framework: food insecurity exists as the impact of a hazard on a vulnerable population.

Case Study 2: Hurricane Katrina and Urban Food Insecurity

In 2006, Hurricane Katrina swept inland over New Orleans. That storm flooded the city and destroyed levees, costing over 250 billion dollars to rebuild from the damage (Comfort, 2006). An estimated 80% of the city was flooded as a result of this hurricane (Munasinghe, 2007). As a result of the infrastructural damage in the city, families were stranded without food, water, or shelter for days and many were eventually forced to evacuate the city. In total, the storm claimed the lives of over 1,800 people and 1.5 million were displaced by the storm (Comfort, 2006; Shrum, 2013).

While the storm's path could not have been altered, the impact of the storm on New Orleans may have been avoidable. In addition to the fact that New Orleans is situated an average of seven feet below sea-level, Comfort (2006) notes that the impact of the hurricane on the city was accentuated by an aging infrastructure and poverty, which were prevalent throughout the city (Shrum, 2013). The flood levees in the city contained structural flaws and the networks of roads into and out of the city were therefore flooded, cutting off transportation and food supply (Brodie, Weltzien, Altman, Blendon, & Benson, 2006). Residents were unable to leave the city, in part due to road flooding, but also due to poverty and lack of access to vehicular transportation (Comfort, 2006). The flooding and winds (estimated at 145 mph by Comfort, 2006) effectively knocked out electricity in the city, cutting off the capability of residents to safely store food as well. The economic downturn that New Orleans faced over the years leading up to Hurricane Katrina also played a role. Comfort (2006) estimates that, at the time of the flood, one quarter of the residents in the city were impoverished. This was the partial result of a weakened stake in the petroleum industry, an industry within which the city once thrived. Many of residents lacked effective personal transportation and, as Comfort (2006) reports, lacked the crucial education about the likelihood of a hurricane impact in the city. As a result, the people of New Orleans were socially vulnerable to the impact of the hurricane. Burby (2006) also notes that the inefficient management of federal disaster risk reduction funding to mitigate the impact of flood risks also increased the risk of a flooding hazard in the city. This inefficient management extended to the ecological management of the Mississippi delta plain. Day et al. (2007) suggested that the dredging of the plain, logging and oil exploration have exacerbated the erosion of this plain and increased the vulnerability of New Orleans to storm surges.

The interaction of these political, economic and physical environmental systems with the environmental effects of the storm resulted in an urban food security disaster in New Orleans. This case demonstrates the means by which multiple system interaction points can interact in one moment (the moment Hurricane Katrina made landfall in New Orleans) to produce widespread urban food insecurity. This case also demonstrates how the interaction of multiple variables (political, economic, and physical variables) at multiple scales (national, municipal, and household scales) can influence the sensitivity of urban household to food insecurity.

In the theoretical framework for this investigation, the hurricane represents the hazard whose impacts are represented by the extensive infrastructure damage and the food and water security crisis that resulted from this storm (not to mention the loss of life that resulted from the storm). The extent to which the residents experienced the impacts of this hurricane, however, was determined by factors that had been developing long before the hurricane hit. The aging physical infrastructure (in the form of both flood levees and effective drainage in road networks) coupled with the widespread household poverty produced the kind of unsafe conditions necessary for residents of New Orleans to experience the impacts of hurricane Katrina. In this case, water and food insecurity due to limited means of transportation or access available.

This case demonstrates how urban infrastructure can predispose the vulnerability of urban households to food insecurity impacts, albeit without the presence of a hazard until the arrival of Hurricane Katrina. This case also demonstrates how key social vulnerability indicators (income poverty, lack of access to transportation, and a lack of formal education) can increase the vulnerability of households to food insecurity.

Case Study 3: The Global 2008 Food Price Crisis

In 2008, there was a sudden and sharp global spike the in the nominal price of cereals (Headey, 2011). This sharp rise in the price of food was followed by widespread food insecurity in many developing nations (Anríquez et al., 2010). While estimates based on computational simulations estimate that 75-160 million people became food insecure as a result of this crisis, large-scale studies using self-reported food insecurity suggest the number to be much lower and the food insecurity impacts to be less universal (Verpoorten, Arora, Stoop, & Swinnen, 2013). For example, urban households appeared to be more affected than rural households. Urban households responded to the rising food prices by seeking credit, taking on casual employment, migrating in search of employment, engaging in urban agriculture, and reducing food consumption (Cohen & Garrett, 2010). In addition, one of the knock-on impacts of the rising food prices was rioting in urban areas (as was observed in Haiti) (Cohen & Garrett, 2010).

Following the 2008 food crisis, four theories have emerged (among many others) to explain the cause of the food crisis. First, it was theorized that the food crisis had resulted from a combined lack of cereal productivity and rising cereal demand within specific nations (either due to weather shocks or hoarding) (Headey & Fan, 2008). The rising demand of cereals in particular could have been exacerbated by the rising proportion of grains which were being purchased on the international market for biofuels (Headey, 2011). A second theory is that excessive agricultural speculation on the long-term prices of cereals led to increased short-term food price volatility (Clapp, 2009; Minot, 2010). Agricultural futures are financial agreements that set an agreed upon price for the future trade of agricultural products. These futures can be traded and that trade (and the speculation regarding future prices) can create price volatility for agricultural products being currently traded. A third theory regarding the cause of the food crisis suggests that rising oil prices could have caused knock-on price increases in the international trade of food by increasing transportation costs (Headey & Fan, 2008; Minot, 2010). Given the globalized nature of food supply chains, a hike in oil prices would necessitate a rise in food prices at the level of the consumer. A final theory suggests that the depreciation of the USD could have resulted in trade shocks (sudden increases in exports) in the international food market resulting in rising food price volatility (Headey & Fan, 2008). This is due in part to the size of U.S. maize exports as a proportion of international trade.

It is likely that many of these factors played a role in the 2008 Food Crisis, to a greater or lesser extent. As such, the 2008 food price crisis demonstrates how multiple regional and international economic factors from multiple economic sectors could have combined to manipulate international food price volatility and, ultimately, impact household food security.

While this is not a comprehensive account of the development of the food price crisis, these theories are only meant to explain the development of a hazard. In this case, the hazard is represented by international food price volatility. The impact of this hazard (in the form of food insecurity), however, did not uniformly affect all households. Ruel and Garrett (2010) suggest that urban households were more heavily impacted than rural households (due to the greater reliance of urban households on food sources linked to international food systems). Among urban households, poor, female-headed, and large households were the most likely candidates to experience food insecurity as a result of this food price volatility (Anríquez et al., 2010; Ruel & Garrett, 2010). Using the terminology established in the theoretical framework, the international food price volatility represented the hazard (which may have dynamically developed according to some of the theories reviewed here). Urban households represented the vulnerable population. These households were made vulnerable by the unique characteristics they carried (accessing globalized food sources, being large, female-headed, and suffering from income poverty). Finally, food insecurity represented the impact of the hazard on the vulnerable population. This case lends further credibility to the impact of social vulnerability factors in determining urban household food security vulnerability.

Case Study 4: The HIV-Food Security Nexus in Sub-Saharan Africa

The spread of the HIV virus has left an inequitably high mark on urban areas of the developing world. Urban areas are associated with higher HIV/AIDS prevalence rates than rural areas, particularly among the urban poor (Crush, Drimie, Frayne, & Caesar, 2011). Crush et al. (2011) estimate that households affected by the HIV virus (containing household members living with HIV) experience a 60% reduction in household income in comparison to other households. In addition to the economic challenges of individuals living HIV/AIDS, these individuals face social stigmatization and discrimination. Among Southern African nations, where the prevalence rate surpassed 15% in 2007, households living in informal settlements are particularly affected (Crush et al., 2011). These households are particularly vulnerable to the impacts of HIV/AIDS due to limited access to medical care, utilities, and vulnerable livelihoods (Joseph, 2009).

The impact of HIV/AIDS on urban food security is pronounced. Brown and Funk (2008) estimate that diseases (like HIV/AIDS and malaria) account for the cause of about half of all cases of malnutrition globally, demonstrating the importance of illness as a determinant in household vulnerability to food insecurity. There are two mechanisms explaining how the HIV virus can impact urban household food security. The first mechanism focuses on the individual carrier of the virus and how the HIV virus influences the individual's capability to utilize calories and nutrients (Rosegrant & Cline, 2003). The mechanism suggests that there is a negative feedback loop between the worsening condition of the individual living with HIV/AIDS and that individual's food access. As the disease progresses, the individual requires a greater caloric intake, however, the disease progression reduces the individual's ability to earn an income and thereby reduced the individual's access to food, further exacerbating the progress of the disease (Crush, Drimie, Frayne, & Caesar, 2011).

The second mechanism is based on a hypothesis called the New Variant Famine (NVF) hypothesis (de Waal & Whiteside, 2003). This hypothesis suggests that an incremental increase in the prevalence of HIV amongst rural farmers can lead to an incremental increase in the potential for famines. Mason, Jayne, Chapoto, and Myers (2010) found some evidence for this hypothesis in a case study from Zambia, suggesting a relationship between HIV/AIDS prevalence among rural farmers and reduced agricultural productivity.

The evidence reviewed here suggests a circuitous but impactful relationship between HIV/AIDS and urban household food security. The relationship between the virus and urban household food security demonstrates the importance of multi-scalar determinants, affecting both household food access and utilization. This relationship describes how the hazard of HIV/AIDS can produce a food insecurity impact. That said, the vulnerability of households with members living with HIV/AIDS demonstrates the means by which a chronic illness can increase the sensitivity of a household to food insecurity. This case demonstrates a mechanism by which social vulnerability indicators (the chronic illness of a household member) can influence the sensitivity of a household to the impact of food insecurity.

Case Study 5: Caste Marginalization and School Meals in India

Marginalization can be represented in many forms. As demonstrated in the process of marginalization framework (Wisner & Luce, 1993), households can be marginalized economically, politically, and socially (see Figure 3). The impact of marginalization as it relates to urban food security can be interpreted in this investigation’s theoretical framework as an increased sensitivity to hazards. In the caste system in India, a social system of discrimination may be institutionalized within a society that increases the sensitivity of households categorized in low castes to food insecurity. The lower castes (the backward or scheduled castes) experience ongoing marginalization due to their status in Indian society (Deshingkar & Start, 2003). Membership in these lower castes is often associated with illiteracy, poverty, and exclusion from employment opportunities. Caste-based discrimination can also have a negative impact on household food security (by limiting options for food access).

The food insecurity impacts of caste discrimination appear to be accentuated among children. Mortality risk, an associated measure of food insecurity, is higher among children under the age of 16 who are members of a lower caste than for members of other castes (Subramanian et al., 2006). This finding was confirmed and added to by Thorat and Sadana (2009) who found that children from lower castes tended to also have worse nutrition, worse health, and worse access to public health services. In particular, children from these castes tended to have higher rates of anemia, stunting, and diarrhea.

Thorat and Sadana (2009) found in a review of school meal programs for children in India that meals were sometimes administered according to caste (where lower castes were served last), limiting the accessibility of those meals for children who were members of lower castes. In addition, caste membership can affect household access to public health due to the social prerogative that certain caste members could not be physically touched, limiting the willingness of health care workers to treat members of lower castes (Thorat & Sadana, 2009). This social prerogative hampers the effective administration of medical assessments and procedures. There is also evidence that certain caste members are denied engagement in certain entrepreneurial activities (such as the sale of milk) (Thorat & Saldana, 2009). In one case of a milk cooperative operated by members of lower castes in India, consumers were unwilling to purchase the milk because it had been handled by members of a lower caste. As a result of this lack of local employment opportunities, lower caste members often migrate to find work (Deshingkar & Start, 2003).

This evidence demonstrates potential mechanisms for how social vulnerability (in the form of social marginalization) can influence household sensitivity to food insecurity. By limiting access to income, access to food aid, and medical care, a system of social exclusion can increase the vulnerability of a marginalized household to food insecurity. Using the terminology in the theoretical framework for this investigation, the degree of sensitivity that is experienced by a household to food insecurity (hazard impacts) is mediated by social vulnerability characteristics (like membership in an excluded social group). It is possible that a similar mechanism may exist to explain how female headed households may become sensitive to food insecurity (as suggested by Wisner & Luce, 1993).

Case Study 6: Hyperinflation and Food Insecurity in Harare

Since the year 2000, Zimbabwe has experienced consistently low domestic production of cereals, requiring the country to increasingly rely upon food imports (leaving the country increasingly susceptible to shocks in global food prices) (Muhoyi, Mukura, Ndedzu, Makova, & Munamati, 2014). In addition to these challenges, the municipal government in Harare has demonstrated a limited capacity to maintain infrastructure in the city. According to Chirisa's (2014) analysis, Harare has suffered from ineffective building codes, a lengthy bureaucratic approval process for new construction projects, and outdated urban planning schemes that rely on colonial era notions of urban development. These challenges have limited employment opportunities in Zimbabwe’s construction sector and have hampered the development and upkeep of urban infrastructure within Harare.

These characteristics predisposed Harare to the impacts of the hyperinflation that Zimbabwe experienced in 2008. During this time, monetary inflation in the country was 200 million percent while the country's unemployment rate was over 80% (Tawodzera, 2014). This hyperinflation occurred at a time of weak governmental monetary policies (which allowed the unchallenged over-printing of currency) and also coincided with the global food price crisis (which further undermined household access to food in Harare). In addition to the already poor maintenance of urban infrastructure within the city, the monetary crisis led to widespread outages in power and water throughout the city (Tawodzera, 2014). In a 2008 survey of Harare, Tawodzera, Zanamwe and Crush (2012) found that, among poor urban households, only 1% of households had consistent access to electricity and only 8% had consistent access to clean water in the last year.

The impact of the hyperinflation on household food insecurity in Harare was mediated by the social links between households. In particular, international remittances and household access to multiple sources of income provided greater household resilience to food insecurity (Tawodzera, 2012, 2013). Households in Harare were also able to mitigate their sensitivity to food insecurity by engaging in alternative food production schemes, like urban agriculture (Tawodzera, 2012). As a note, it is difficult to distinguish the impact of these pressures from the international food price volatility that was observed during the same time as this hyperinflation. That said, this case is meant to describe the predisposition of urban households to food insecurity. In this case, the food price volatility observed during this time represented a hazard while the hyperinflation in Zimbabwe represented the development of a household vulnerability to that hazard.

In the context of the theoretical framework used in this investigation, monetary hyperinflation was the consistently present hazard for all households in Harare, while only vulnerable households (those with limited access to sources of monetary income) were likely to experience the impact of that hazard in the form of food insecurity. This case study demonstrates how the failure of a social infrastructure (financial institutions) can increase the sensitivity of urban households to food insecurity.

Conclusion

The cases reviewed here provide further confirmation that the theoretical framework constructed earlier in this chapter has deductive value in explaining household vulnerability, specifically household sensitivity, to food insecurity. Each case reviewed here referred to very different contexts and none of the cases reviewed here related to Maputo. For this reason, the framework will need to be tested in the context of Maputo. At the same time, this review was helpful because it established that the framework could explain other instances of food insecurity (although only as a possible explanation for the observations made in these case studies).

While some of these cases demonstrated the progression of the hazards that gave rise to food insecurity, this is not a part of the focus of this investigation. Instead, this investigation is focused on how urban households are made vulnerable to food insecurity. Thus, as a reminder, the theoretical framework is intentionally narrowed to household vulnerability in order to ensure that the conclusions of this investigation are empirically defensible and testable within the confines of the collected data.

Now that the framework has been deductively validated as an explanatory model of household vulnerability to food insecurity (at least in the context of this review), the framework needs to be empirically tested in a case study of an urban environment. In the case of this investigation, the framework will be assessed in an empirical investigation of households in Maputo, Mozambique.

As a means of testing the applicability of this framework to household vulnerability in Maputo, the following thesis will be explored for the remainder of this investigation:

Inconsistent social and physical infrastructure access plays an important role in determining urban household vulnerability to food insecurity in Maputo

This thesis will be investigated by answering the following primary research question:

To what extent does inconsistent access to social and physical infrastructure determine urban household vulnerability to food insecurity in Maputo in 2014?

In order to answer the primary research question, the analysis undertaken in this thesis will focus on answering two subordinate questions:

1. Does inconsistent access to physical and social infrastructure play an important role in determining urban household vulnerability to food insecurity in Maputo?
2. Are these inconsistent infrastructure access impacts on vulnerability to food insecurity as important as other indicators of social vulnerability among urban households in Maputo?

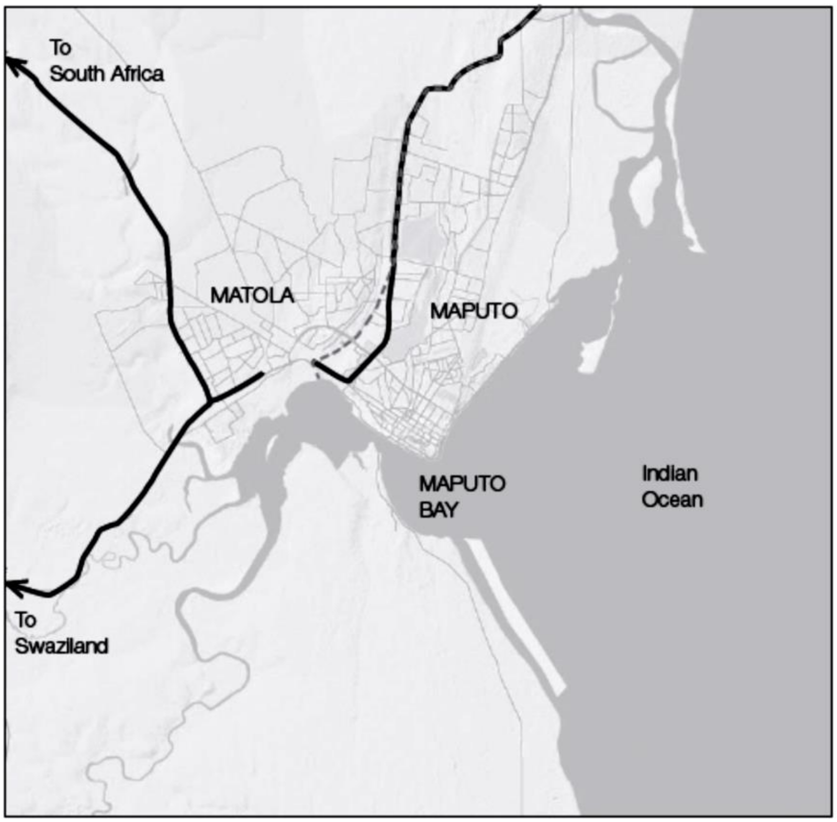
These two research questions guide the outlined methodology in the next chapter, which is designed to determine whether inconsistent infrastructure access is an important determinant of urban household vulnerability to food insecurity. As such, the following methodology described in this dissertation is meant to reasonably answer these questions in a way which is empirically and epistemologically defensible.

Chapter Four: Methodology

Given the theoretical framework designed for this investigation (along with the operationalization of that framework), it is now necessary to devise valid and reliable methods to empirically test such a framework in the context of Maputo. This chapter introduces a method to test such a framework. More specifically, this chapter introduces and defends the indicators selected to test this framework as well as the analyses used to test the relationship between those indicators. Before engaging in this discussion, this chapter introduces Maputo as a case study into the relationship between inconsistent infrastructure access and urban household vulnerability to food insecurity.

Introduction to Maputo

Maputo provides a fertile ground for assessing this investigation's thesis and theoretical framework. Maputo is the capital of Mozambique in South Eastern Africa. Mozambique is a former Portuguese colonial coastal nation, which emerged in 1992 from decades of civil war (Barros, Chivangue, & Samagaio, 2014). As is the case for other Southern African nations, Mozambique has undergone rapid urbanization. The city of Maputo has grown from 181,223 in 1960 to 1,856,217 in 2013 (World Bank, 2014). While Maputo has grown significantly over the past 50 years, the urban population in Mozambique has decentralized from Maputo as other urban centers have developed in the country (World Bank, 2014). Infrastructural development in Maputo has tended to occur in piece-meal projects (Nielsen, 2011). Many infrastructure development projects in Maputo tend to be privately organized by households. For example, a group of households may join together to share the cost of extending the electrical grid into their community. As a result, Maputo represents a rapidly growing city in a developing nation experiencing challenges in providing effective and efficient infrastructure access to its residents.



Map 2. Maputo (Raimundo, Crush, & Pendleton, 2014, p. 2)

In this review of the Maputo case study, I introduce the history, geology, urban infrastructure development, healthcare challenges and recent household economic trends of Maputo. This review provides a context for the investigation into the relationship between infrastructure and food security vulnerability in Maputo. In addition, this review demonstrates the unique challenges and vulnerabilities faced by Maputo.

History of Maputo

Prior to the Portuguese arrival in Maputo, the bay was home to several clans that shared one language and resided in the area since at least 100 AD (Jenkins, 2000a). Although the Portuguese explored the area, the Dutch were the first colonial occupiers to build a fort in Maputo (Barros et al., 2014). After the Dutch abandoned the fort, Maputo was established as a Portuguese military fort in 1799 (although it had been used as a Portuguese prison since 1781) and was first named

Lourenço Marques (after the Portuguese explorer who first noted the significance of Maputo bay for trade) (Barros et al., 2014; Jenkins, 2000a). In 1825, the Lourenço Marques and Inhambane trading company was established in Maputo and began engaging in the slave trade. The trading company was ultimately forced to shut down, however, in 1835 after warring with the Nguni people (Barros et al., 2014).

In 1868, a city was built on an island facing Maputo bay (in what is now the KaNyaka district) in order to provide a defensive position for the city (Barros et al., 2014). As the neighbouring South African economy grew (first with the establishment of farmlands, then through the discovery of diamonds and gold), a rail line was built connecting South Africa to Maputo bay to facilitate trade via the port (Newitt, 1995). This rail line facilitated a sudden rise in migration to Maputo bay to support the labour demands of the growing South African economy (Jenkins, 2000a).

As Maputo continued to grow, the port and rail line attracted migrants in search of employment within Maputo, in the industrial sector established in the 1940's in neighbouring Matola, and in neighbouring South Africa (which was now accessible via rail) (Newitt, 1995). These migrants often ended up living in the unplanned periphery of the city (known as suburbios). The residents of these suburbios were not granted land tenure by the local government and the suburbios were treated as temporary residential areas by the government (Jenkins, 2000a). However, the continued and rapid in-migration into Maputo meant that these suburbios would continue to grow and spread around the periphery of the downtown core.

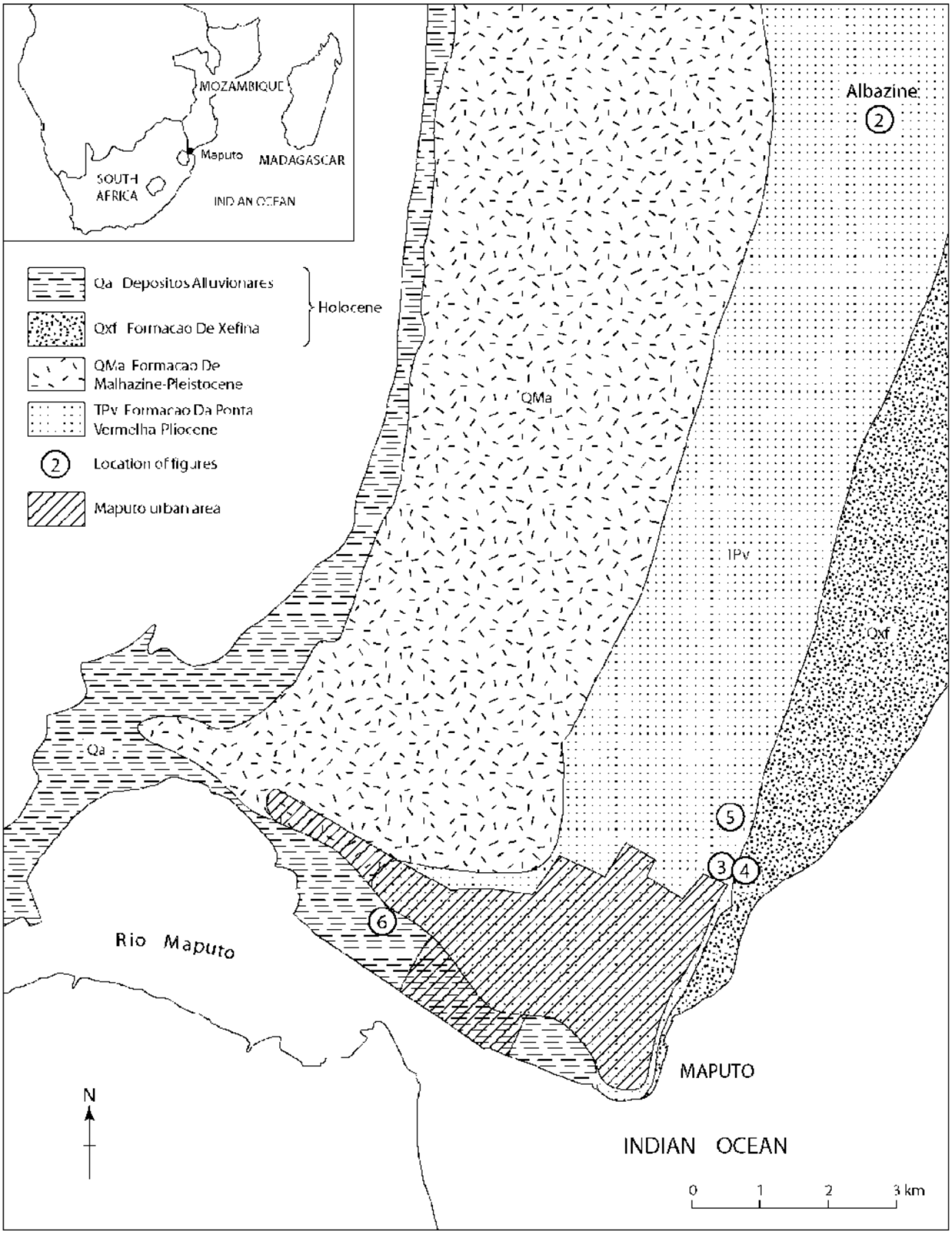
Maputo's rapid growth took the form of dense high rises in the downtown core of the city and a growing spread of informal housing in the urban periphery. A master plan was drawn up in 1972 in order to rezone open areas of Maputo and to provide low income housing in Matola. This plan was short-lived, however, as investment in residential development halted in 1973 over uncertainty due to the on-going civil war in the country (Jenkins, 2000a). In 1975, the colonial period came to an end in Mozambique and Lourenço Marques was officially renamed Maputo (Newitt, 1995). With the end of the colonial period, however, Mozambique became embroiled in a second chronic civil war that lasted from 1975 to 1992 (Barros et al., 2014). The on-going war effort continued to hamper residential development projects in Maputo.

As an example, a program called the “Basic Urbanization Programme” in the 1980s provided the groundwork for the creation of formal residential areas in the city in an attempt to stay ahead of the growth of informal settlements (Jenkins, 2000a). However, political corruption, the ongoing war effort, and highly centralized fiscal governance stalled further formal urban development in the city (Jenkins, 2001; Jenkins, 2000b). As insecurity grew during the continuing civil war, many of the peri-urban residential areas were abandoned and households fled to the city center to escape attacks (Barros et al., 2014; Jenkins, 2000a). As a result, the programme was ultimately abandoned amid growing insecurity, corruption and shifting migration patterns into the city.

In 1987, structural adjustment was introduced in Mozambique and the private sector in Maputo began to flourish again (including the informal sector) amid the years of conflict. A growing list of international donors attempted to fund residential development in Maputo. The funding for many of these efforts, however, was hampered by political corruption in the now weakened centralized government (which was still focused on the on-going war effort). While private industry continued to grow under the Frelimo liberal market policies, housing and infrastructure continued to receive limited financial support from the municipal government (Jenkins, 2000a).

As a product of this historical context, Maputo has developed into a dualistic city with a formal urban core and a poverty belt across the informal outskirts of the city. The peri-urban areas of Maputo are populated (to a greater or lesser degree) by households with limited property rights and hampered access to sanitation and utilities (Barros et al., 2014). While this uneven development is represented by the broad categories of formality versus informality, the differences between these areas of Maputo can be obscured in ways not easily defined by dualistic notions of formality and informality (Jenkins, 2004), as will be explained during the discussion of the current state of urban infrastructure in Maputo.

Geology of Maputo



Map 3. Geological Formations in Maputo (Forster, 2004, p. 19)

Maputo is a low lying coastal city with the Indian Ocean lying to East and South Africa lying to the West. The low elevation of Maputo, particularly along the Infulene river and the western coast of the city, mean that the city is particularly susceptible to storm surges (Forster, 2006). Incredibly, mangrove forests are an indigenous and common tree species among residential areas along the western coast of Maputo (Chemane, Motta, & Achimo, 1998). This is because these areas of the city flood with the rising tide on a daily basis, allowing mangrove vegetation to thrive (Vicente, Jermy, & Schreiner, 2006).

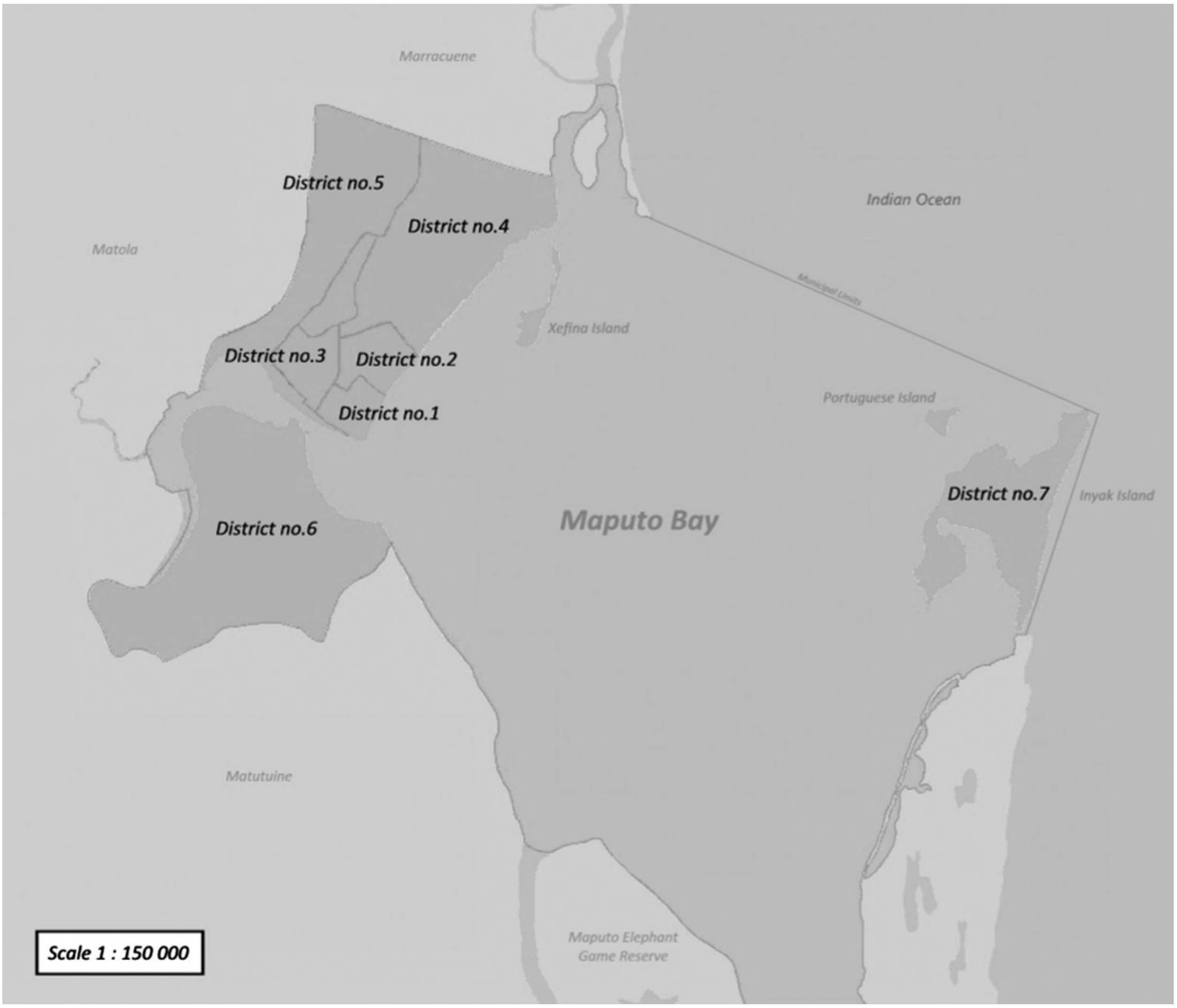
The unique geology of Maputo renders the city vulnerable to a number of natural hazards. The soil composition in the city, especially in the coastal areas, is composed of alluvial deposits along the coast line and the majority of Maputo is built upon granular sands (Vicente et al., 2006). The characteristics of these sands change with depth. Most of Maputo is built upon red sandstone that transitions into silt and then yellow sand with increasing depth (Forster, 2006). Vicente, Jermy, and Schreiner (2006) summarize the unique geology of Maputo into four zones:

"*(a) littoral accumulation zone, corresponding to beach and tidal deposits; (b) coastal zone, inclined to the sea, with a maximum elevation of 8 m, comprising dunes and alluvium; (c) platform of 40 to 50 meters elevation, gently sloping to the West with degraded interior fixed dunes and sand sheets; (d) Maputo hill, 50 to 60 m maximum elevation, which comprises a residual relief resistant to erosion, probably associated with neotectonism phenomena*" (p. 2).

In addition to these unique geological features, there are two faults in Maputo: the Polana fault in the East of the city and the Infulene fault, which runs with the Infulene river in the West of the city. There is also a steep slope, which ranges from 10 to 50 meters, across the southern portion of Maputo city (Vicente et al., 2006).

The combination of these geological characteristics means that Maputo is susceptible to erosion, especially during heavy rains when the ground becomes saturated with water and creates the sufficient conditions for slope failure. The soil composition within Maputo also leaves the city vulnerable to flooding when the soil becomes saturated. The sections of the city that form a natural depression (lower elevation than the surrounding areas) then become flood basins during heavy rainfalls. As an example, in the year 2000, heavy rainfalls led to extensive gullying in the city. In one informal area of the city, Polana Canico, the heavy rainfall led to the formation of a 7m deep gully (Forster, 2004). Several households were also swept away in the process. This geological profile has also resulted in the tilting of some older buildings in the downtown are due to underground erosion as a result of water flow (Forster, 2006).

Urban Infrastructure in Maputo



Map 4. Map of Maputo Districts (Barros et al., 2014, p. 78)

Table 1. Household Infrastructure Characteristics of Maputo Districts (Calculated from Barros et al., 2014, p. 78)

Percentage of Houses:	District 1	District 2	District 3	District 4	District 5	District 6	District 7
with electricity	97.86%	55.32%	67.77%	61.27%	54.00%	42.54%	18.58%
with toilets	93.21%	29.12%	18.97%	22.40%	23.05%	11.28%	4.54%
with water	91.98%	77.25%	53.60%	36.27%	52.75%	15.92%	1.44%
made from brick/cement	97.77%	72.39%	87.93%	89.79%	83.60%	5.26%	16.72%
made from wood/other	2.23%	2.76%	12.07%	1.02%	16.40%	47.38%	83.28%

As is demonstrated throughout the history of Maputo, the city is a mix of formal and informal areas (Barros et al., 2014). The downtown core of Maputo (the oldest section of the city) is predominantly formal and also represents the central business district for the city, while many of the surrounding areas to the north of the downtown core are informal. The differences between the formal and informal areas can be defined by the presence and absence of physical utilities and by the kind of land tenure held by households (Jenkins, 2004). Effective drainage and sanitation represents some of the key infrastructure services lacking in informal areas of Maputo.

The ineffective drainage infrastructure in the informal settlements is a hazard in part due to the low-lying geography of many of the informal areas surrounding the downtown core (Vicente et al., 2006). As mentioned, the low-lying geography, in addition to the soil composition in the area, provides the necessary pre-conditions for flooding. Given the informal nature of these areas, however, implementing drainage infrastructure can be a challenge (Jenkins, 2002). The drainage in many of these areas tends to be open sewer systems running beside roadways. Ineffective drainage can have both physical and social impacts. Physically, flooding in Maputo degrades buildings in the affected area in addition to increasing the chances of erosion. Erosion can also cause secondary impacts in the form of shifting foundations for buildings (Forster, 2006). The social impacts of flooding can include a disruption to traffic and the spread of contagious diseases that rely upon water-borne vectors (Wisner et al., 2004).

The lack of electricity availability and access by households also characterizes the difference between formal and informal areas of Maputo. Outside of the downtown core of Maputo, significantly fewer households have access to electricity (Barros et al., 2014). Access to electricity in informal areas is also predominantly post-hoc, where, households work together to pool resources in order to make electricity first available within the ward and then to provide household access to that electricity (Baptista, 2013). The availability of electricity in Maputo is managed by the Electricidade de Mocambique (EDM), the state-owned electrical company. In order to fit any given house with a connection to the electrical grid, homeowners are required to submit the appropriate application materials (covering the technical, administrative and legal requirements for electricity access). Some of the required paperwork can be challenging to collect and appears arbitrary. For example, the application requires households to submit a copy of their next-door neighbour's most recent electrical bill (Baptista, 2013). The home is then inspected by a technician from EDM to ensure the feasibility of installing electricity in the home. This process is can be costly and time consuming for a homeowner.

Household access to water utilities is common in the downtown core (Carvalho, Carden, & Armitage, 2009) and the availability of water utilities in the downtown core is predominantly municipally governed (Barros et al., 2014). Outside of this downtown core, however, water is primarily accessible via private providers (known as SSIP's) or private boreholes (Carvalho et al., 2009). Ironically, households in the per-urban areas of Maputo can often pay more for water than households in the downtown core. One potential explanation for this discrepancy is the prolific use of private water suppliers in the peri-urban areas of the city. The fee-structure established by some of these suppliers can be oppressive. Some of the private water suppliers have formed cartels and have the opportunity to impose a high cost for poor services (low water pressure and quality) (Ahlers et al., 2013). Another potential explanation for this discrepancy is the sunk cost associated with building the infrastructure necessary for households to access private water grids. The cost of building this infrastructure access is, in most cases, off-loaded onto the consumer thereby increasing the overall cost of water access (Ahlers et al., 2013). That said, there is diversity among these private suppliers, where, in some areas of Maputo, the private provision of water is cheaper and associated with better service than the municipal provision of water (see Map 5, which only encompasses districts 1-5).

Map 5. Prevalence of Private Water Suppliers (SSIPs) in Maputo (Ahlers et al., 2013, p. 475)

As mentioned, one of the common sources of water access in Maputo (particularly outside of the downtown core) is through the use of private boreholes (Ahlers et al., 2013; Carvalho et al., 2009). The main source of water for these boreholes is local groundwater. Groundwater contamination (due to leaching metals flowing through underground water systems), however, can be a major problem in some areas of Maputo due in part to a 25 ha waste-dumping site in the Hulene ward in northern Maputo (Vicente et al., 2006).The ecological impacts of this site are predominantly unmanaged and metal leaching can be a common occurrence. The households in the areas surrounding this dumping site are also vulnerable to this contamination due to their inconsistent access to the municipal water grid and their reliance upon boreholes for water access. In addition, previous studies have indicated that the groundwater in Maputo may be outside of the threshold for safe potable water (as indicated by the World Health Organization) (Vicente et al., 2006).

In addition to infrastructure access, the difference between formal and informal land in Maputo can also be characterized by land tenure (Jenkins, 2004). Households in the informal (and often peri-urban) areas of Maputo have limited legal tenure of the land they occupy. Nielsen (2011) found that land tenure in these areas is instead established via informal arrangements (at times involving civil servants) instead of engaging in the lengthy and at times costly process of attaining formal legal tenure of the land. Paul Jenkins (2004) explains that while the establishment of formal land tenure in Maputo has historically been determined by a centralized government, a parallel informal system also existed predominantly in the rural areas based customary traditions. During the colonial era, land in the urban periphery of Maputo was allocated by chiefs; however, this form of land tenure had limited legal recognition. In fact, until the 1950’s, the African population had a limited capability to gain legal tenure of any land in and around Maputo (Jenkins, 2001). While this informal system of land allocation has evolved to incorporate members of local government, the informal system continues to exist in tandem with the continually changing mechanisms for gaining formal land tenure in Maputo. The formal mechanisms for gaining land tenure have evolved from being socialist oriented (from 1974 to 1990), where the purchase and sale of land was actively hampered by government policy, to a more open market mechanism under the Frelimo government (Jenkins, 2004). The agreements made in the informal system of land allocation can, however, become superseded by formal building projects in Maputo (Nielsen, 2011). Over the decades since independence, informal mechanisms for attaining land tenure have become more commonly used, while formal mechanisms are increasingly less commonly used (Jenkins, 2001). In addition to these formal and informal mechanisms for attaining land tenure, households can also purchase land for their own development (although this is a separate process from gaining land tenure). While payments are commonly made when formally or informally attaining land tenure, these payments are not meant to purchase the land so much as to purchase the right of tenure. The sale and purchase of land in Maputo is rare, however, as most land is transferred via inheritance or swapped among families while maintaining that family's formal or informal tenure of the land (Jenkins, 2001).

Map 6. Informal Settlements in Districts 1-5 of Maputo (Cities Alliance, 2011)

Healthcare and Economic Trends in Maputo

Households in Maputo are exposed to multiple epidemiological hazards. The Mozambique National Institute of Statistics et al. (2012) published the results of a national mortality survey conducted from 2007-2008. The results of the survey indicated that infection and parasitic diseases represent common causes of death. For example, the estimated HIV/AIDS mortality rate for Maputo City was 336.2 per 100,000. There also appears to be unique mortality trends in Maputo in comparison to other areas. First, the malaria mortality rate was lowest in Maputo City (132.5 per 100,000) while Maputo City also demonstrated one of the highest circulatory diseases mortality rates in the country (106.6 per 100,000).

Some of the epidemiological hazards faced by the residents of Maputo may be related in part to the challenge of providing physical infrastructural resources. A 1996 survey found that women living in Maputo who cooked with wood (a cheaper cooking fuel than charcoal, petroleum or electricity) demonstrated significantly greater respiratory distress symptoms than women who cooked with other fuels. This is due to the fact that wood-burning releases over twice the particulates that charcoal-burning releases and around four times the particulates released by petroleum (Ellegård, 1996). Traffic accidents account for 43.7% of deaths due to injury in Maputo, demonstrating the impact of the congested transportation infrastructure on public health in Maputo (Nizamo, Meyrowitsch, Zacarias, & Konradsen, 2006). The impact of these medical emergencies may be inequitably higher among poor households, due in part to the healthcare system in Maputo.

There are two categories of medical services available to households in Maputo: a public medical care system and private medical care clinics. The public medical care system comprises a network of state-run hospitals while the private medical care clinics are not governed by the state. Both of these medical services offer the same kind of care and, in some cases, share the same medical care practitioners. The difference between these categories of medical care is demonstrated by the fact that patients at the private care clinics are able to reserve appointments, choose their doctors, and are required to pay higher fees for medical services. These special clinics may also contribute to the general operating costs of a public hospital (as is the case of the Maputo Central Hospital and the private clinic attached to that hospital). The public hospitals are also associated with longer wait-times for medical care (McPake, Hongoro, & Russo, 2011). Given the way these medical services are organized, this system seems to favour the accessibility of medical care by wealthier households and might create barriers to healthcare access by poorer households who are often forced to wait longer for medical treatment compared to patients of private medical clinics regardless of medical emergencies.

The inaccessibility of healthcare can be exacerbated by the economic status of households in Maputo. In a 2008 survey of 397 households in Maputo, only 43% were engaged in full-time employment with 17% engaged in part-time or casual employment. Informal employment also represented an income source for 27.9% of employed individuals, demonstrating the importance of the informal economy in Maputo (Raimundo et al., 2014). These statistics actually demonstrate a growing participation of Maputo households in the formal economy, however, the informal economy still remains an important source of employment in Maputo. In addition, unskilled work represented 38.2% of the employment sources for the surveyed individuals, while skilled work represented 34.3% of the surveyed individuals. Wage employment was an income source for 66.2% of surveyed households with informal business representing an income source for 25.4% of households, and casual work represented the income source for 14.1% of households (Raimundo et al., 2014). These statistics demonstrate the importance of the informal economy for employment among households in Maputo while also demonstrating the extent to which unemployment is a hazard for Maputo households.

Maputo Case Summary

Maputo is a well-suited case study for this investigation. As a coastal city, Maputo is exposed to numerous climatic and social hazards (such as storm surges) that have the potential to impact household food security. Infrastructural development in Maputo has also been piece-meal at times, resulting in informal areas with limited access to social or physical infrastructure. All the while, Maputo has continued to grow at a quickening pace. As a result, Maputo provides a case study of a rapidly growing city that is exposed to natural hazards and has faced challenges in the development of its infrastructure.

Epistemology

This investigation of household vulnerability in Maputo is based on a post-positivist paradigm. A post-positivist paradigm assumes that the researcher is biased by values and previous knowledge and those biases can influence the observations made by the researcher. In addition, this paradigm assumes that all knowledge develops through a process of falsification (disproving the premises of knowledge) and all knowledge is open to falsification (all knowledge premises are based on probabilistic conjectures and are open to challenge). When the premises of knowledge are falsified by new evidence, the falsified knowledge is amended to better represent both the new and old evidence (Popper, 1935).

Scientific models are therefore constructed to explain observations and/or predict future events. These models can be falsified by the extent to which they explain observations and/or predict future events. Scientific models can also be falsified by the lack of validity or reliability of the observations informing the premises of those models.

Case Study Research Strategy

In order to understand the relationship between infrastructure and household food security in Maputo, this investigation uses a case study approach. Case studies represent a pragmatic approach to testing a model (Eisenhardt, 2014). Using Popper's notion of falsification, a model may be falsified on the basis of one case as that one case may demonstrate a lack of support for the assumptions underpinning that theory (although this one case should be validated in order to ensure that the results of the case are not better explained by error) (Flyvbjerg, 2006). The key here is that I am determining whether this relationship is supported by observations made in a case study of Maputo. This approach is pragmatic in that only a limited sample needs to be collected to disprove this relationship, rather than collecting enough evidence to conclusively prove this model as a universally applicable truism. This is because disproving a presumably universal truism only requires one case where the truism is not true (demonstrating that the truism is not universal). Attempting to prove a universal truism would require an exhaustive test of the truism across an entire universal population comprehensively (which is impossible within the boundaries of this investigation).

Case studies are also well suited for investigations in which little is known (Eisenhardt, 2014). Some investigations, such as this one, have little to no prior empirical evidence to draw upon. This is in part due to the novelty of urban food security as a research focus but also potentially due to the evolution of food security paradigms over the past 50 years. As was previously mentioned, food security has been historically defined by national food supply since around World War 2 (Barrett, 2010). The importance of food access at finer scales of analysis is a relatively recent conjecture (since Sen's (1980) seminal work on the topic). New food security paradigms are currently being debated with some inferring a complex interaction between environmental and human systems through exposure to hazards (see Barrett, 2002), but the evolution has been slow. As such, there is little work in the way of food security paradigms that would predict or explain the relationships being assessed here. This situation requires the collection and analysis of new empirical evidence to test novel theoretical frameworks.

Case studies allow for a grounded investigation of scientific models where the focus of the investigation is the collection of empirical data rather than a discourse in theoretical concepts. Case studies are also particularly well suited for descriptive analysis of causal mechanisms as opposed to an analysis of causal effects (Meyer, 2001). In other words, case studies are meant to describe how a causal mechanism operates between variables (by describing the variables in a causal chain) rather than comprehensively predicting the causal effects of certain variables of interest. The descriptive nature of case studies recognizes the limited capacity for generalizations (beyond falsification) within one case study. That said, the findings of one case study can be assessed in larger case studies to confirm the potential for generalization. In sum, case study research is designed to explore the unknown rather than confirm the known. Within this exploration, theories can be built by falsifying hypotheses in a hypothetical deductive fashion using the gathered empirical evidence to test the assumptions and predictions of a given hypothesis. This particular case study explores the relationship between infrastructure and urban household food security in Maputo.

Principal Research Question

To what extent does inconsistent access to social and physical infrastructure determine urban household vulnerability to food insecurity in Maputo in 2014?

Subordinate Research Questions

- Does inconsistent access to physical and social infrastructure play an important role in determining urban household vulnerability to food insecurity in Maputo?
- Are these inconsistent infrastructure access impacts on vulnerability to food insecurity as important as other indicators of social vulnerability among urban households in Maputo?

Research Design

As a cross-sectional design, this investigation determines the relationship between the indicators included in this investigation at one point in time (2014) in Maputo. As such, the investigation demonstrates the strength and quality of relationships between indicators independent of temporal effects. This investigation also takes place at the household scale. While operating at this scale of measurement may mask individual differences in food insecurity among household members, a household level investigation in the context of Maputo captures the shared resilient or vulnerable characteristics of the entire household. Operating at this scale also assumes that food is shared among household members (a factor that is important in the context of Maputo where household level food sharing is common). In addition, this scale is important given the definition of a household in this survey (a household is any group of members residing in the same dwelling and eating from the same pot). All the data in this investigation is derived from household level surveys.

Data Collection

Survey

In October 2014, I undertook the fieldwork in Maputo. Using the African Food Security Urban Network (AFSUN) household survey questionnaire, data was collected on a range of topics, including household food access, long term household food access, household dietary diversity, household income, housing informality, sex of the household head, employment status, and chronic illness. The survey was also designed to determine sources of household food.

25 student enumerators (supervised by 3 enumerator field supervisors) from Eduardo Mondlane University administered this survey to 2071 households in Maputo. 19 wards were randomly selected for the survey in Maputo. The sample sizes for these wards were stratified using proportionate allocation according the total population of each ward in Maputo. Within each ward, enumerators were given sections of the ward to survey systematically, covering the entire ward as much as current maps allowed. The enumerators surveyed every third dwelling in a serpentine walking pattern from a starting point defined by the field supervisors. Within each selected dwelling, the first available household was surveyed. The analysis in this survey is exclusively focused on survey data collected within Districts 1-5 of Maputo (indicated by the area within the dotted line in the map below). Assuming a Maputo population size of 1,856,127 (World Bank, 2013) and an average household size of 5 members in Maputo, this sample size provides an estimated 99% confidence level and a confidence interval of $\pm .03$.

Map 7. Maputo Sampling Area (Indicated by the Dotted Line)

The AFSUN 2014 survey was completed using android tablets. The tablets were loaded with the digital version of the household survey using ODK collect. ODK collect is an android application that is used to administer surveys and then collect and organize the survey data into coded data sets. This application allows for immediate data validation in the field. The data collected via ODK collect is uploaded to an encrypted online database where the data is stored. The data is then downloaded from the online database and exported into an excel file for statistical analysis. In order to maintain confidentiality, all AFSUN 2014 data was encrypted on the tablet, on the online database and during storage. All data transmissions from the tablets to the online database were also encrypted using a VPN.

Indicator Measures

Dependent Variables: Urban Food Insecurity

This investigation includes three measures of household food security as dependent variables: The Household Food Insecurity Access Prevalence (HFIAP) scale, the Months of Adequate Household Food Provisioning (MAHFP) scale, and the Household Dietary Diversity Score (HDDS). These measures cover food access, long term food provisioning, and dietary nutrition.

Household Food Insecurity Access Prevalence (HFIAP)

The HFIAP is an index of 9 forced answer ordinal level scales related to the household experience of food access. The scales are ordered by the frequency of inconsistent food access (never, rarely, sometimes, or often) in the past four weeks across the 9 questions related to the experience and severity of different kinds of food access challenges. The HFIAP categorizes the results of these subscales into four different categories of food access (1=food secure, 2=mildly food insecure, 3=moderately food insecure, and 4=severely food insecure). These subscales are determined using a scoring algorithm that takes into account the frequency and severity of food access challenges faced by an entire household.

Months of Adequate Household Food Provisioning (MAHFP)

The MAHFP is a measure of the number of months in the past year during which a household has had adequate food provisioning. The index is scored out of 12. The MAHFP is administered by first confirming whether the household has gone without adequate food in the last 12 months. If the household member responds that the household has gone without adequate food, the household is asked to indicate the months during which the household went without food in the last 12 months (starting with the previous month). The final MAHFP score represents the number of months during which the household had adequate food provisioning in the last year. This score is determined by adding the number of months during which a household has identified as having inadequate food provisioning.

Household Dietary Diversity Score (HDDS)

The HDDS is a measure of the number of dietary groups that a household has consumed in the previous 24 hours. The HDDS is administered as a series forced answer nominal level questions (yes/no). The scale covers 12 food groups and confirms whether the household has consumed any of the 12 food groups. The final HDDS score represents the number of food groups that a household has consumed over the previous 24 hours. The following is the list of the 12 food groups assessed by the HDDS:

1. Any bread, rice, noodles, biscuits, or any other foods made from millet, sorghum, maize, rice, wheat, or any other locally available grain?
2. Any potatoes, yams, manioc, cassava, or any other foods made from roots or tubers?
3. Any other vegetables?
4. Any fruits?
5. Any beef, pork, lamb, goat, rabbit, wild game, chicken, duck, other birds, liver, kidney, heart or other organ meats?

6. Any eggs?
7. Any fresh or dried fish or shellfish?
8. Any foods made from beans, peas, lentils, or nuts?
9. Any cheese, yoghurt, milk, or other milk products?
10. Any foods made with oil, fat, or butter?
11. Any sugar or honey?
12. Any other foods such as condiments, coffee, tea?

In the analysis of these food insecurity dependent variables, all of these variables have been transformed into binary variables. These variables are transformed in the following manner. The HDDS is categorized according to whether a household has consumed less than or equal to 3 food groups or more than 3 food groups in the previous 24 hours. The HFIAP has been categorized according to whether a household scored 1 in the HFIAP (which is categorized as food secure) or scored 2-4 in the HFIAP (which is categorized as food insecure). The MAHFP has been categorized according whether a household has had 12 months of adequate food provisions or less than 12 months of adequate food provisions. As a reminder, given the purpose of this investigation, these food security variables serve as the dependent variables in the analyses in this investigation.

Table 2. Food Insecurity Categorical Variable Descriptions

Variables	*Level*	*Categories*	
HDDS	Binary	> 3 Food Groups	<= 3 Food Groups
HFIAP	Binary	Food Secure	Food Insecure
MAHFP	Binary	12 Months	< 12 Months

Dependent Variable Categories

The independent variables in this investigation have been categorized as either indicators of inconsistent access to infrastructure or as social vulnerability variables. These two groups are defined differently. The inconsistent infrastructure access variables are defined by the consistency of household access to either resources or services which are products of either social or physical infrastructure within Maputo. The social vulnerability variables are defined as variables which have been previously established as determinants of social vulnerability. These two groups can be distinguished according to differences in scales of analysis, recall periods, qualities being measured, and levels of empirical and theoretical support as determinants of household vulnerability to food insecurity.

These two categories are at different scales of analysis in that all of the consistent infrastructure access variables are exclusively at the household level of analysis while the social vulnerability variables are at both the household scale and the household member scale of measurement. These two categories of independent variables also have different recall periods. All of the consistent access to infrastructure variables have the same recall period of 1 year while the social vulnerability variables either have a recall period of up to one month or simply a measure of the variable at the time of the survey. As such, these social vulnerability variables do not measure the consistency of access to an infrastructure service or product. These two independent variable categories can also be differentiated according to the qualities being measured. All of the inconsistent access to infrastructure variables measure the consistency of household access to infrastructure resources and services. None of the social vulnerability variables exclusively measure access. Instead, these variables represent either the assets or the characteristics of a household which previous literature has suggested to be significant determinants of social vulnerability. That said, some of the variables could be used to infer access. For example, the amount of income earned by a household over the last month could be used to infer household access to financial infrastructure within the last month. In addition, the highest level of education attained by the household head could be used to infer whether or not that one household member has ever accessed education. The difference here is that none of these variables measure the consistency of household access to these services and none of these measures are direct measures of access. Instead these variables are treated by this investigation as either assets or as characteristics of a household.

Finally, these two categories of independent variables can be distinguished by levels of empirical and theoretical support as determinants of household vulnerability to food insecurity. The consistent access to infrastructure services have limited direct empirical support as measures of vulnerability to food insecurity while each of the social vulnerability variables has been empirically and theoretically established as determinants of household vulnerability to food insecurity. This difference addresses the primary need for including these variables in this analysis. Because consistent household access to infrastructure resources and services has not been established in the literature as determinants of food insecurity vulnerability, this relationship needs to be compared with established social vulnerability indicators to determine the significance of these infrastructure access variables as predictors of household vulnerability to food insecurity.

Inconsistent Infrastructure Access

Inconsistent household infrastructure access (to both social and physical infrastructure) is determined by the subscales in the Lived Poverty Index (LPI). The LPI measures the frequency with which a household has gone without access to electricity, water, medical care, and a cash income over the previous 12 months. Each infrastructure resource (electricity, water, medical care, or a cash income) is a subscale in the LPI. The frequency with which households go without these resources is categorized into the following options: never, just once or twice, several times, many times, and always. Each of these subscales is an ordinal level Likert scale. The final LPI score can be categorized on an ordinal scale of 1-4 (where 1 demonstrates continuous access to infrastructure resource and 4 represents a complete lack of access to infrastructure resources). The LPI score can also be represented as a scaled score out of 4. In this investigation, only household access to water, electricity, medical care and a cash income are included as indicators of inconsistent infrastructure access. This is done in order to preserve the independence of observations of urban food security (the dependent variables) and access to food or cooking fuel (the independent variables).

Household Access to Water

Household access to water is intuitively conceived as a necessary precondition for household food security (Rosegrant & Cline, 2003). Water provides both immediate consumption for humans as well as a necessary input for agricultural productivity. In many cases, water is also required in the preparation of food and in securing food safety (i.e. in the case of boiling raw foods). Water therefore impacts both food utilization as well as food supply. Water is a necessary condition for human life as well as being a potential vector for disease (Wisner et al., 2004). Access to clean water, therefore, represents an important determinant of both food security and health. As such, this indicator has the potential to be a statistically significant predictor of human poverty in urban areas.

Household Access to Electricity

Household access to electricity in urban environments may be a proxy for informality. Access to the electrical grid, at least in Maputo, is either formally planned or it is arranged post-hoc by organizing neighbours to pool their money and resources into supplying electricity to their neighbourhood (Baptista, 2013). This post-hoc supply of electricity can be expensive. In addition to this, electrical outages can be a common occurrence in Maputo. Household access to electricity can also be a proxy for the insecurity of urban households, due to the impact of electricity access as a household expense (Tawodzera, 2014). This indicator of household electrical access can serve as an indicator of household informality/poverty (in that the indicator may demonstrate weather or not a household is linked to electrical grid), electrical grid reliability (in that the indicator demonstrates electrical outages in the city), and wealth (in that households with consistent electricity may have multiple sources such as the city electrical grid, solar panels, and perhaps a generator).

Household Access to Medical Care or Medicine

Household access to medical care or medicine also has the potential to disrupt household food insecurity, though perhaps in a circuitous manner. First, a lack of access to medical care or medicine is determined when medical care or medicine is needed but not accessible (as, I would argue, access is determined to all resources in research on human livelihoods). The lack of access to medical care is a shock to households because this lack of access occurs stochastically (unpredictably when a disease occurs) (Bhojani et al., 2012). When medical care is required, a household may be forced to trade off resources meant for food access in order to support access to medical care. This indicator therefore represents a potentially statistically significant predictor of household poverty.

Household Access to a Cash Income

Household access to a cash income represents a vital indicator of human livelihoods in urban settings. In order to effectively access resources in cities, engagement in commerce to negotiate that access is necessary (Ruel & Garrett, 2010). Income and expenditures also represent a common indicator of poverty and a proxy for a household's vulnerability to food insecurity (Barrett, 2002; Carter & Barrett, 2006). In this survey, the definition for a cash income included wages, net revenue from self-employment, interest earned on investments, cash gifts, remittances, and loans. The "inconsistent access to cash income" variable therefore refers to whether the household has had consistent or inconsistent access to cash from any of these sources over the past year (in either physical cash form or as digital currency). As such, this variable is similar to a measure of financial exclusion, so long as that definition of financial exclusion is in reference to inconsistent access to cash as an output of a financial infrastructure (as was suggested by Collard, 2007). For example, Marshall (2004) suggested that financial exclusion could be measured by a lack of access to financial infrastructure products (credit, transfers, payment settlements). This understanding is validated by case studies of digital currency in developing countries. In these case studies, access to money has been treated as a measure of financial infrastructure functionality and digital money as a means of bridging gaps in a country's financial infrastructure (Andrianaivo & Kpodar, 2012; Angadi, 2003). Leyshon and Thrift (1994) also proposed that financing was a product of financial infrastructure services.

This indicator should be differentiated from household income. This indicator does not represent the amount of income earned by a household but the stability of access to any cash income (earned from all income sources). This indicator therefore has a high probability of being a statistically significant predictor of household food security in urban settings. That said, it should be noted that this indicator is not a comprehensive assessment of access to financial infrastructure, but represents access to a part of the services provided by financial infrastructure.

As was the case for the food security variables included in this investigation, these variables have been transformed into binary variables. For each infrastructure service (water, electricity, medical care and a cash income), the variable is demonstrated by two categories: consistent access and inconsistent/no access. In addition to these variables, this investigation includes a total LPI category variable (all services). This variable demonstrates whether a household has consistent access to all of these infrastructure services or inconsistent/no access to any of these infrastructure services. As such, this variable represents the cumulative impact of all four infrastructure services on household food security vulnerability.

Table 3. Infrastructure Categorical Variable Descriptions

Variables	*Level*	*Categories*	
All services	Binary	Consistent Access	Inconsistent/No Access
Clean water	Binary	Consistent Access	Inconsistent/No Access
Medical care	Binary	Consistent Access	Inconsistent/No Access
Electricity	Binary	Consistent Access	Inconsistent/No Access
A cash income	Binary	Consistent Access	Inconsistent/No Access

Social Vulnerability

In this investigation, social vulnerability is defined using a suite of variables that have been established as indicators of vulnerability (according to background literature) and are measured in the AFSUN 2014 survey. The binary indicators used to measure social vulnerability in this investigation include: the sex of the household head, the household head employment status, whether the household head has a formal education, the existence of chronically ill household members (suffering from diabetes, arthritis, asthma, hypertension, malnutrition, obesity, heart problems, tuberculosis, chronic diarrhoea, or cancer), the informality of the household dwelling (categorized as a traditional dwelling, backyard shack, shack in an informal area, or mobile home), whether the household income is in the lowest tercile, and whether the household size is more than 5 household members. Household income terciles are calculated by dividing the entire sample household income into three categories with equal proportions. These terciles are then ranked according to low, middle, and high income.

Household Head Sex

Wisner and Luce (1993) suggest that, in many contexts and based on previous research, women may have fewer opportunities to be involved in decision-making than men and also tend to experience less resource access. The marginalization of women is highly dependent upon context but may be applicable in the context of Maputo. The sex of the household head has therefore been added to this investigation as a potential social vulnerability variable that may explain household food insecurity in Maputo. This indicator was collected as the reported gender of the household head, as indicated by the interviewee who was answering survey questions on behalf of the household.

Household Head Formal Education

The education status of the household head has the potential to interact with household food security in a number of dimensions (Vatsa, 2004). First, household head education demonstrates the kind of human resources available to the household for gaining meaningful employment. In addition, the household head level of education may inform the diversity of foods consumed by the household. In a review of the challenges associated with food insecurity, Rosegrant and Cline (2003) suggest that the education level of parents is associated with the greater nutritional status of children. Given the multidimensional impact that formal education appears to have on household vulnerability to food insecurity, this variable has been included as a social vulnerability indicator in this investigation. The formal education status of the household head was collected as the reported highest level of education, as indicated by the survey respondent. While numerous categories of formal and informal education were collected in answering this survey question, this indicator was collapsed into a binary indicator indicating whether the household head had completed any form of formal education.

Household Head Employment Status

Household head employment may be a significant predictor of food insecurity (Wisner & Luce, 1993). Amendah, Buigut, and Mohamed (2014) found in a survey of poor households in Nairobi that households whose members had formal employment were less likely to engage in food coping strategies like eating fewer meals. Engagement in the labour force also indicates an income source for the household that can be used to secure food access (Aliber, 2003; Cohen & Garrett, 2010b). Given the extent of the research literature which suggests that employment is a resiliency factor in limiting household vulnerability to food insecurity, this variable has been included as an indicator of household social vulnerability. As with the previous indicators in this section, this variable was defined by the report of the survey respondent on behalf of each household included in this survey. This variable does not take into account the age of the household head (retired individuals were categorized as unemployed) or the intent to find employment (job seekers who were unemployed were categorized as unemployed).

Table 4. Household Head Social Vulnerability Categorical Variable Descriptions

Variables	*Level*	*Categories*	
Sex of household head	Binary	Male	Female
Education level of household head	Binary	Formally Educated	No Formal Education
Employment of household head	Binary	Employed	Unemployed

Informality of Dwelling

Informality is usually used as an indicator of the area in which a household resides and serves as a description of the legal status of households in these areas and the extent of infrastructure access and availability (Jenkins, 2004). In the context of this investigation, however, this variable specifically describes the dwelling in which a household resides. In the case of this indicator, dwellings that are categorized as traditional dwelling, shacks in an informal settlement, or backyard shacks are considered informal. The classification of dwellings was established by the observation of the survey enumerators, who were trained to recognize these categories of dwellings (which are common to Maputo). The materials used to construct a dwelling can influence the vulnerability of the household, specifically in relation to the impacts of natural hazards (Bosher & Dainty, 2011).Vicente et al. (2006) found that households in informal settlements in Maputo were commonly constructed with semi-permanent materials like corrugated metal, discarded packaging and collected materials. As such, the materials used to construct a dwelling can serve as a proxy for informality. That said, this indicator specifically relates to the informality of a dwelling (in terms of its construction) as opposed to legal tenure or infrastructure access. Nielsen (2011) also demonstrated how dwelling construction was primarily a private endeavor in Maputo with very little government oversight of the construction process and weak governance of building codes. As such, this means that dwelling construction does not represent the output of an infrastructure service (given the definition of infrastructure provided in this dissertation as well as the definition provided by Torrisi, 2009), in that this is not the administrated provision of a good to address a human need. Rather this is the private creation of a good to address a human need. Both Torrisi (2009) and Buhr (2003) also discuss how the mass provision of a resource is also a key feature of infrastructure resources and services. This is in reference to the fact that infrastructure is the administration of systems of humans and assets. In addition, this variable is not a measure of consistent access to an infrastructure resource or service, only the extent to which the dwelling was constructed using formal or informal building materials at the time of the survey.

Low Household Income Tercile

The amount of income that a household earns on a monthly basis can be an indicator of that household's ability to access and command resources such as food (Wisner & Luce, 1993). In addition, several studies have indicated that the food price crisis particularly affected low income urban households (Cohen & Garrett, 2010b). This is due in part to the proportionally greater share that food takes up of household income when that income is limited. In a case study of households in Harare, Tawodzera (2012) noted that the survival of households under the pressures of hyperinflation depended on the number of income earning activities that a household engaged in. This evidence demonstrates the important role that income plays in determining the vulnerability of households to food insecurity. Given the importance of this variable, this indicator has been included in this analysis. In the context of the survey, household income was calculated by first confirming all household income sources in the last month. The household was then asked to give the income that the household had received from each income source in the last month (this total income amount did not include loans or credit in order to avoid the potential artificial doubling of the total income calculation). The amounts earned from each income source were then summed to represent total household income. Using this total household income variable, the households were divided into three terciles (proportionately equal thirds) to categorize households into high, middle, and low income. In this variable calculation, the ‘low income’ category represents a household income less than 3,500 MZN in the last month, the ‘middle income’ category represents a household income between 3,501 and 8,500 MZN in the last month, and the ‘high income’ category represents a household income greater than 8,501 MZN in the last month. In this particular investigation, these categories were further collapsed into a binary variable representing low income households (the lowest third in household income or less than 3,500 MZN in the last month) and middle/high income households (greater than 3,501 MZN in the last month).

Household Size Larger Than Five Members

In many developing nations, larger households tend to be associated with food insecurity. In a case study of the Murehwa district in Zimbabwe, Muhoyi et al. (2014) found that household size was an important predictor of household food insecurity. This finding was validated by the World Food Programme (2008) in a survey of urban households in Lesotho, which indicated that larger urban households tended to be categorized as food insecure. In the context of the AFSUN survey, households were defined as any dwelling where one or more individuals share meals and sleep on an ongoing basis (there may be multiple households in one dwelling). Household members were defined as individuals who resided at a given household for at least six months of the year. The number of household members at a given household was reported by the survey respondent. This number was then transformed into a binary variable representing households with less than five members and households with greater than five members. The five-member cut-off for this variable was chosen since the average household size in Maputo varies approximately around five, giving approximately equal proportions of households in each of the categories of this variable.

Chronically Sick Household Member(s)

There is a growing literature on the impact of chronic illness on household food insecurity. Chambers (2006) noted that chronic illness can obstruct an individual's ability to earn a livelihood and may limit that individual's ability to seek aid when needed. As such, chronic illness can bias the affected individual to poverty. Chronic illness also has the potential to increase household expenses while limiting the ability of the affected member to gain meaningful employment (due to the potentially debilitating nature of the chronic illness) (Bhojani et al., 2012). Vatsa (2004) also noted that illness can increase a household's vulnerability to the impacts of a disaster. The presence of a chronically ill household member has therefore been added as an indicator in this investigation. This variable was constructed using the AFSUN survey data. Household respondents were asked about the health status of each member of the household. For each member of the household, the respondents were asked whether that member suffered from diabetes, arthritis, asthma, hypertension, malnutrition, obesity, heart problems, tuberculosis, chronic diarrhoea, or cancer. During the construction of the survey instrument, these diseases were identified as having a significant impact on food insecurity by medical experts. Due to ethical requirements, the AFSUN survey did not include HIV/AIDS status in this list of chronic illnesses. The final indicator was then transformed into a binary indicator that represented whether the household had a member suffering from any of these diseases or not.

Table 5. Logistic Regression of Household Social Vulnerability Categorical Variable Descriptions

Variables	*Level*	*Categories*	
Informality of dwelling	Binary	Formal	Informal
Low household income tercile	Binary	Middle or High Income	Low Income
Household size	Binary	<=5 Household members	>5 Household members
Chronically ill household members	Binary	No Chronically ill members	Chronically ill members

Before continuing further, it is important to make a note here on the interpretation of some variables that may appear to overlap. The interpretation of the consistent access to a cash income variable should be clearly distinguished from the interpretation of the low household income variable. The low income variable refers to the quantitative amount earned from all income sources (including gifts), while the access to a cash income variable refers to the extent to which the household has experienced consistent or inconsistent/no access to a specifically cash-based income over the previous year. The difference between these variables is defined by a qualitative access to a cash-based income as opposed to the quantity earned from all income sources. In addition to these lines of evidence, there are distinctions in how these variables were measured and in the different impacts of these variables on household vulnerability. The inconsistent access to cash income variable includes loans while the total household income variable did not. The total household income variable is a measure of the quantity of cash earned over the last month while the inconsistent access to cash income variable measure the extent to which a household has had consistent or inconsistent access to cash income over the last year.

In addition to these differences, the two measures may have different impacts on household vulnerability. Duncan (1996) suggested that stable access to income had a different impact on health when compared with the amount of income earned. This suggestion is validated by Kohen et al. (1975) in their review of the impact of stable versus transitory income on young men and middle-aged men. Hill et al. (2013) also suggested that unstable access to income is more detrimental to childhood wellbeing than the amount of income earned by a household. Similarly, Mishra and Sandretto (2002) suggested that maintaining a stable income reduced the exposure of farmers to income shocks (sudden reductions in the amount of income generated). This discussion was nuanced by Hannagan and Morduch (2015) who suggested that greater income generation was only associated with income stability among poor households. This suggestion is potentially explained by Andersen (2015) who suggested that income volatility has the greatest impact on household poverty for low income households. Together these studies demonstrate that the stability of household access to income has been treated by previous researchers as a qualitatively different indicator than the amount of income earned by a household. In addition, these studies also suggest that these two variables may have different impacts on household wellbeing and vulnerability to poverty.

Similarly, the employment status of the household head variable should be interpreted differently from either of these variables. This variable refers to the employment status of only the household head at the time of the survey. This variable differs from the access to cash income on two counts. First, the employment status variable does not necessarily specify whether the employment was paid in cash (the payments for employment in Maputo could be made in-kind).

Second, the variable is only in reference to the household head while the access to a cash income variable refers to any member of the household. Thus, this variable occurs at a different scale of analysis and refers to a different measure of economic activity. Furthermore, these variables were tested using multicollinearity tests (described in Chapters 5 and 6), which demonstrated a Pearson's R correlation value of less than 0.08 between each of these variables (indicating a very weak relationship).

Analysis

Defining Preliminary Concepts

The relationship between the indicators included in this analysis is assessed using probabilistic modelling techniques. Before continuing further in this discussion, it is necessary to articulate the different definitions for Probability, Relative Risk, and Odds Ratios. Probability is the likelihood of an event occurring. This likelihood is usually determined by the frequency with which the event occurs. In other words, if a survey were to be repeated several times, the probability is the estimation between 0 and 1 that indicates the percentage of those surveys which would yield a given result (Grimes & Schulz, 2008). The probability of independent events is calculated by dividing the frequency of that event by the total number of events. So if we wanted to calculate the probability of a household being food insecure, we would divide the number of food insecure households by the total number of households surveyed.

Relative risk is the ratio of the probability of an event occurring given exposure to another event (e.g. the probability of a household being food insecure given that household's exposure to inconsistent infrastructure access). Relative risk is calculated as the ratio of the probability that a household is food insecure given exposure to inconsistent infrastructure access divided by the probability that a household is food insecure given no exposure to inconsistent infrastructure access. Relative risk statistics are ultimately used to compare the probabilities of events occurring between two groups (usually an experimental group and a control group, but for the purposes of this investigation, these two groups are formed based on their classification in social vulnerability indices). If the relative risk statistic is greater than 1, there is a greater probability of an event occurring in the target group than in the control group (e.g. among households with inconsistent infrastructure access compared to households with consistent access to infrastructure). If the relative risk statistic is less than 1, there is a smaller probability of an event occurring in the target group than in the control group (Simon, 2001).

Odds ratios are defined slightly differently because, while relative risk is calculated as a change in probabilities, odds ratios are calculated as a change in odds. Odds are ratios of the frequency of events occurring divided by the frequency of events not occurring. For example, if we wanted to calculate the odds of a household being food insecure, we would divide the number of food insecure households by the number of food secure households (not the total number of households as you would when calculating probability). Odds ratios are the ratio of the odds of an event occurring given exposure divided by the odds of an event occurring given no exposure (Grimes & Schulz, 2008). In our example, the statistic would be calculated as the ratio of the odds that a household is food insecure given inconsistent infrastructure access divided by the odds that a household is food insecure given infrastructure access. When odds ratio statistics are greater than 1, there is a greater odds of an event occurring given exposure to another event. When odds ratio statistics are less than 1, there are lower odds of an event occurring given exposure to another event (Prasad et al., 2008).

These concepts are important in that they shape the interpretation of the results of the analyses performed in the course of this investigation. In particular, it is important to be careful to delineate the difference between probabilities and odds in the interpretation of relative risk and odds ratios. The following sections outline the various analyses I am performing in this investigation to test the theoretical framework.

Frequency Analysis

As a descriptive statistic, I used a frequency analysis to describe the relationship between the indicators in this investigation. I created cross-tabulations to demonstrate the proportion of households or wards within each indicator category by food insecurity score (as measured by the MAHFP, HDDS, and HFIAP). The cross-tabulations demonstrate the frequency of co-occurrence between these food security measures and the ward and household level indicators included in this investigation.

In order to perform the inferential statistics needed to infer the relationship between the indicators in this investigation, the equations underlying probability, risk and odds calculations need to be applied in the analysis of the relationships between indicators. For the following discussions of probability, relative risk, and odds ratios, I am using the following cross-tabulation in order to explain the different equations used to calculate these statistics. The variable states in this cross-tabulation (A, B, C, and D) represent frequencies of occurrence for presence and absence of both Event A and Event B.

Table 6. Events Cross-Tabulation for Probability, Relative Risk, and Odds Ratio Examples

		Event A	
		Event A Present	**Event A Absent**
Event B	**Event B Present**	**A**	**B**
	Event B Absent	**C**	**D**

Probability

As mentioned, probability is defined, in the frequentist approach, as the likelihood that an event will occur over a set of repeated observations. In other words, if it is estimated that there is a .95 probability that a household from a given city will be food insecure and we then surveyed 200 households from that city, we would expect that 190 of those 200 households would be food insecure. Probability is calculated as the rate of a given event over the total number of events. So, using the cross-tabs provided above, if we wanted to determine the probability of event A occurring (independent of event B), we would use the following calculation:

Equation 1. Probability of Event A Occurring

$$P(Event\ A\ Present) = \frac{A + C}{A + B + C + D}$$

If we were only interested in calculating the probability of event A occurring only among households where event B was also occurring, we would use the following equation:

Equation 2. Probability of Event A Occurring Only When Event B Occurs

$$P(Event\ A\ Present\ Only\ When\ Event\ B\ is\ Present) = \frac{A}{A + B}$$

In the case of this investigation, the probability estimation only plays a part in the calculation of relative risk and the significance of statistical tests. As a test of statistical significance, probability determines the likelihood that, if the statistical tests were repeated several times, the percentage of times that the results of the statistical test will fall within a range of scores (confidence interval). Aside from this role, probability calculations also play a role in calculating relative risk, is demonstrated in the following equations.

Relative Risk

As mentioned earlier, relative risk is the ratio of the probability that event A will occur (given the presence of event B) divided by the probability that event A will occur (given the absence of event B). As such, relative risks determine the change in probability that a given household will take on a state in one variable, given the state which that household occupies in another variable. So, given the cross-tabulation provided above, relative risk is calculated using the following equation:

Equation 3. Relative Risk

$$RR = \frac{A/(A+B)}{C/(C+D)}$$

In the case of this investigation, relative risk complements the odds ratio calculations provided for each independent variable (inconsistent infrastructure access and social vulnerability indicators) and dependent variable (food insecurity scores) pairing. While both odds ratios and relative risk probabilities provide a similar calculation, the interpretation can be different. Given the use of probabilities, relative risk scores tend to be more intuitive in their interpretation (Grimes & Schulz, 2008). In addition, some researchers argue that relative risk estimates provide a more accurate demonstration of the probabilistic relationship between variables than odds ratios when the sample sizes in each category of the binary variable are large enough. In other words, odds ratios are more accurate for rare events while relative risk is more accurate for commonly occurring events (Altman, Deeks, & Sackett, 2015; Simon, 2001). That said, odds ratios are more amenable to more complex regression analyses. Thus, for comparison, odds ratios are used independently and within a regression analysis to determine the relationships between all independent variables and all dependent variables.

Odds Ratio

As mentioned earlier, odds ratio statistics demonstrate the ratio of the odds of event A occurring among households were event B is present divided by the odds of event A occurring among households where event B is absent. So an odds ratio, similar to relative risk, determines the odds of a household being categorized as food insecure given the way in which that household was categorised in the independent variables in this investigation (the social vulnerability and inconsistent infrastructure access indicators). The equation for calculating odds ratios is provided below:

Equation 4. Odds Ratio

$$OR = \frac{A/B}{C/D}$$

In this investigation, odds ratios are used in cross tabulations in order to demonstrate the impact of each independent variable (inconsistent infrastructure access and social vulnerability indicators) on the dependent variables (food insecurity scores). These calculations indicate the impact of each variable independent of the other variables included in this investigation. These calculations alone, however, are not sufficient to answer the research question of this investigation. In order to determine the impact of the inconsistent infrastructure access variables on household sensitivity to food insecurity, and then compare the quality and strength of those impacts with the impacts of other social vulnerability indicators, these odds ratios need to account for the influence of multiple variables. Thus, independent odd ratios are not sufficient. Instead, odds ratios are used in the binary logistic regression models that determine the influence of each variable on household food insecurity while holding all other independent variables constant.

In order to provide a test statistic for these odds ratio cross-tabulations, a Fisher's Exact Test is used. This test assesses the independence of the rows and columns between two binomial variables in a cross-tabulation. The test can be used to determine the probability that the two variables are independent of one another. The p-value demonstrated by this statistic can then be compared with a given alpha (e.g. a p-value cut-off of .05 or .01) to determine whether the two variables in a cross-tabulation are significantly associated.

Equation 5. Fisher's Exact Test Hypergeometric Distribution

$$p = \frac{(A+B)!\,(C+D)!\,(B+D)!}{A!\,B!\,C!\,D!\,N!}$$

In the case of these calculations of relative risk and odds ratios, this test demonstrates whether the associations observed are statistically significant. In other words, given the minimum alpha of .05, this test demonstrates whether there is less than a .05 probability that, if this survey were repeated several times, there would be a survey where no association was observed in these cross-tabulations.

The goodness of fit measure demonstrates the differences between the actual values (the values observed in household measures) and the predicted values (the values expected for these household measures). The Pearson's Chi-Square Test of Independence tests whether two categorical variables are statistically independent. The Pearson's Chi-Square equation is provided below:

Equation 6. Pearson's Chi-Square

$$x^2 = \sum_{i=1}^{R} \sum_{j=1}^{C} \frac{(O_{ij} - E_{ij})^2}{E_{ij}}$$

Where, O represents the observed variable values and E represents the expected or predicted dependent variable values based on a chi-square distribution. In the results of a Pearson's goodness-of-fit measure, the p value demonstrates the probability that the two variables are independent.

Regression Analysis

In order to determine the extent to which inconsistent infrastructure access predicts urban food insecurity, I use Binary Logistic Regression analysis. This form of regression analysis accepts binary, ordinal and continuous data as independent variables and binary data as dependent variables. In general, regression analyses determine how well independent variables predict a dependent variable. This is accomplished by determining the extent to which changes in the dependent variable are explained by changes in the independent variable. In logistic regression analysis, the regression equation determines the conditional odds of a value occurring in the dependent variable given the occurrence of a given value in the independent variables. As such, the term binary logistic regression analysis is a bit of a misnomer. A better interpretation of this form of analysis may be classification (given that the analysis determines the odds of a value occurring in the dependent variable given the values in the independent variables). The binary logistic regression equation is provided below:

Equation 7. Logistic Regression

$$\ln\left(\frac{P(event)}{\left(1 - P(event)\right)}\right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_k X_k$$

Where, the natural logarithm of the odds that an event occurs in the *dependent variable* (known as the logit) is equal to the linear combination of the log odds (β) and values of each *independent variable* X in the equation. In binary logistic regression models, these β values indicate the log odds that a change from 0 to 1 in the independent variables of the model (e.g. from having a male headed household to having a female headed household) will result in a household being categorised as a 1 instead of a 0 in the dependent variable of the model (categorised as food insecure on a food insecurity scale). These log odds are calculated while holding all other independent variables in the model constant. The odds ratios for each independent variable are then calculating as the exponentiation of this variable (e^{β}). In summary, the binary logistic regression analysis demonstrates the odds of a household being categorized in a given food security category given the variables included in the model and while holding all other variables in the model constant (holding all other independent variables at 0).

Among the test statistics I am using to assess the binary logistic regression analysis, I am checking Wald's test statistic. Wald's test is used to calculate the statistical significance of each of the independent variables (the predictors) in the binary logistic regression model. Wald's test is calculated by dividing the squared β value and by the squared standard error for that β value:

Equation 8. Wald's Test

$$W = \frac{\beta^2}{SE_{\beta}^2}$$

The result of this test demonstrates the extent to which the association between the independent variable and dependent variable is statistically significant (given a desired alpha value such as .05). As such, the Wald test provides an indication of the statistical significance of each independent variable as a predictor of household food security scores (holding other variables in the model constant).

I am checking for multicollinearity among the predictor variables in the regression analysis. Multicollinearity occurs when there is a significant and strong linear relationship among the predictor variables included in the analysis. The result of these correlations is that the regression outcomes can change wildly when small changes are made in the inclusion or exclusion of certain predictor variables. As an outcome, the regression model is less reliable and has less predictive power when there is multicollinearity among the predictor variables. There are two ways in which multicollinearity is assessed among the regression variables. The first method is via a Pearson's correlation, which is applied to relate all variables included as dependent variables in the regression analysis (Midi et al., 2010). The second method for determining multicollinearity is via calculating the VIF and Tolerance values. Tolerance demonstrates the extent to which the addition of a given variable affects the R^2 statistic of the overall regression model (as a reminder, the R^2 value demonstrates the proportion of the dependent variable variance that is explained by the model). In this case, the tolerance value is determined for each individual predictor variable.

Equation 9. Tolerance Test

$$T = 1 - R_V^2$$

The R^2 value being calculated here is normally used to test linear regression analysis results (Pearson's R^2). The VIF statistic is then determined by the inverse of the Tolerance value.

Equation 10. VIF Statistic

$$VIF = \frac{1}{T}$$

In both of these assessments, I am submitting the binary indicators included in this investigation to OLS linear regression in SPSS in order to determine the Tolerance and VIF values associated with these independent variables. The application of Pearson's r coefficient (and the resulting R^2 calculations) to binary data for the purposes of testing for multicollinearity is justifiable in this context (Dunn-Rankin et al., 2012; Midi et al., 2010).

The predictive validity of a Logistic Regression model is assessed by comparing the predicted values of the model with the values actually observed in the data set (Hosmer & Lemeshow, 2004). In order to test the extent to which the regression equation sufficiently explains the dependent variables (food security measures), I have determined the R^2 value and the goodness of fit for the regression equations. In linear regression, the R^2 value demonstrates the proportion of the variance in the dependent variable that is explained by the independent variables included in the regression equation. The R^2 value is calculated differently for a Logistic Regression Analysis. In this analysis, a suite of pseudo R^2 values are calculated to demonstrate the predictive validity of the logistic regression equation. The following R^2 equations are being used to estimate the R^2 in the logistic regression equations in this investigation:

Equation 11. Cox and Snell R^2

$$R_{CS}^2 = 1 - \left(\frac{L(\tilde{\pi})}{L(\hat{\pi})}\right)^{\frac{2}{n}}$$

Equation 12. Nagelkerke R^2

$$R_N^2 = \frac{R_{CS}^2}{1 - L(\tilde{\pi})^{\frac{2}{n}}}$$

In these equations, $L(\hat{\pi})$ is the log-likelihood for the regression model that is being estimated in this investigation and $L(\tilde{\pi})$ is the log-likelihood for a regression model that does not have any independent variables (only the regression constant). As such, the regression model is compared to a regression model that only uses the regression constant to predict the dependent variables. In the results of these equations, the regression model with the highest R^2 value is considered the superior estimation of the predicted values (better fit to the data being analyzed).

As mentioned, the chi-square test demonstrates the differences between the actual values (the values observed in household measures) and the predicted values (the dependent values that the regression equation has predicted for these household measures). The Hosmer and Lemeshow Test uses a chi-square distribution and is designed to test the extent to which the logistic regression model fits the data being analyzed. The equation for the Hosmer and Lemeshow Test is provided below:

Equation 13. Hosmer and Lemeshow Test

$$x_{HL}^2 = \sum_{k=1}^{g} \frac{(O_{1k} - E_{1k})^2}{E_{1k}(1 - \xi_k)}$$

Where, O represents the observed values, E represents the expected or predicted values, and ξ_k represents average predicted probability of the kth group of observations. In the Hosmer and Lemeshow test, cross-tabulations of the observed versus expected rates are designed for approximately 5 to 10 subgroups of observations from the model population against the 2 values in the dependent variable (0 or 1). The 5 to 10 subgroups are created according to percentiles of probability (the likelihood of each observation co-occurring with either a 0 or 1 in the dependent variable). The distribution is then tested for independence using an asymptotic chi-square distribution (comparing the observed rate against the expected rate in each of the 10 groups across the 2 values in the dependent variable). The results demonstrate the extent to which the observed and expected rates differ. If the rates differ widely, this result suggests that the model is not accurately predicting probabilities and, therefore, does not fit the collected data well. In the results of a Hosmer and Lemeshow test, an insignificant value demonstrates that the regression model fits the data well.

Plan of Analysis

In order to determine the differential strength of the inconsistent infrastructure access variables and the social vulnerability variables as predictors of the three food insecurity measures using the methods described here, the following plan was used to guide the analysis:

1. Determine the relationship between the inconsistent social and physical infrastructure access variables and the three food security measures using relative risk, odds ratios, and binary logistic regression models

2. Determine the relationship between the social vulnerability variables and the three food security measures using relative risk, odds ratios, and binary logistic regression models

3. Determine which of the previously established regression models better predict food insecurity by comparing the regression model test statistics for the models relating inconsistent social and physical infrastructure access to the food insecurity measures and the test statistics for the models relating the social vulnerability variables to the food insecurity measures.

4. Determine which variables better predict food insecurity by designing regression models that incorporate all inconsistent social and physical infrastructure access and social vulnerability variables in the prediction of the three food security measures and comparing the Wald statistics and β values for each independent variable in each of the three regression models.

Reliability of Methods and Results

The reliability of the survey was ensured through training and technological assistance. All enumerators engaged in administering the survey received the same training regime by the same instructor. In order to minimize inter-survey errors, all data entry occurred at the point of survey administration using digital data collection on tablets. The enumerators used the same hardware and software to administer the surveys. The analysis was performed using SPSS software in order to bolster the reliability of the analysis. All data entry was checked for outliers, cross-variable validity and other quality assessment indicators. Any potential errors were then confirmed with the enumerator team.

Validity of Methods and Results

The AFSUN 2014 survey was pilot tested with South African urban households prior to the survey administration. Established and standardized scales were incorporated into the survey. These scales included the Lived Poverty Index (LPI), HFIAP, MAHFP, and the HDDS. These scales have demonstrated external and cross-validity in previous studies. The food security scales were validated by external measures of food security. The LPI has demonstrated external validity with income and political freedom (as measured by survey indices). All quantitative analyses were performed using SPSS software. This software relies on algorithms that are designed using established mathematical proofs to perform statistical analysis.

Ethics

AFSUN 2014 has a memorandum of understanding with Eduardo Mondlane University that includes ethics clearance by Queen’s University. Additionally, the University of Waterloo ethical clearance for this investigation has been granted. This investigation was carried out in participation with Dr. Ines Raimundo from Eduardo Mondlane University. Informed consent from the household head (or a representative adult for the household) was sought before the administration of the AFSUN 2014 household survey. All variables in this investigation have been analyzed and presented at the aggregate city level. This means that it is impossible for someone just reading the final report to be able to identify survey participants or link any demographic data to any survey participants.

Chapter Five: Inconsistent Social and Physical Infrastructure Access and Household Food Insecurity in Maputo

Introduction

In this chapter, the relationship between the four inconsistent infrastructure access variables and the three household food security measures is analyzed. This chapter begins with an analysis of descriptive statistics, including the calculation of relative risk, for the inconsistent infrastructure access and food insecurity variables. The relationship between inconsistent infrastructure access and the food insecurity measure is then assessed using odds ratios and statistical tests of significance. Finally, the relationship is assessed using binary logistic regression analysis and the associated model test statistics for this analysis. The progression of this analysis is intentional. The assessment of relative risk and odds ratios (along with the statistical tests of significance) determines the extent to which each independent variable (inconsistent infrastructure access) increases the odds or chances of food insecurity, independent of other variables. The logistic regression analysis then performs this same analysis while holding all the other independent variables constant. In doing so, the logistic regression analysis determines whether these independent variables (inconsistent infrastructure access) are still statistically significant predictors of food insecurity when the other measures of inconsistent infrastructure access are taken into account. As such, this chapter provides a good test of the predictive relationship between inconsistent infrastructure access (as determined by inconsistent household access to water, electricity, medical care, and a cash income) and household food insecurity.

Descriptive Statistics

The distribution of the HDDS scores in the sample population reveals that none of the surveyed households consumed more than 11 different food groups in the previous 24 hours. No single food group was excluded (all food groups listed in this scale were consumed by at least one households in the survey). Over half the sample population of households consumed four or less food groups in the past 24 hours. These scores indicate that the sampled households consumed a limited diversity of food groups.

Table 7. Distribution of HDDS Scores

Household Dietary Diversity Score	n(%)
0	10(0.5)
1	70(3.4)
2	468(22.6)
3	326(15.7)
4	366(17.7)
5	339(16.4)
6	229(11.1)
7	139(6.7)
8	66(3.2)
9	29(1.4)
10	22(1.1)
11	7(0.3)
12	0(0.0)
Total	2071(100.0)

The distribution of HFIAP scores in the sample population reveals some interesting patterns. First, almost one third of households surveyed were categorized as food secure in this scale, demonstrating a high degree of food accessibility among the surveyed households. That said, almost 40% (787) of the surveyed households were categorized as severely food insecure (receiving a four on the HFIAP, indicating high frequency of going without food access in the last month). The distribution of these scores appears to indicate a high degree of inequity in the distribution of food access among households in Maputo. This inequitable distribution may be an indication of inequity in the distribution of the resources necessary to maintain household food access (e.g. household income). Determining the reasons for this distribution, however, is not within the boundaries of this investigation. Rather, this distribution demonstrates that food access appears to be inequitably distributed among the sampled household population.

Table 8. Distribution of HFIAP Scores

Household Food Insecurity Access Prevalence	n(%)
Food secure	589(28.6)
Mildly food insecure access	227(11.0)
Moderately food insecure access	453(22.0)
Severely food insecure access	787(38.3)
Total	2056(100.0)

The majority of households sampled claimed to have had sufficient food provisioning in the previous 12 months (61.6% of the surveyed households). This is a slightly surprising finding, given that the HFIAP indicated that about 70% (1,467) of the surveyed households had struggled with some form of inconsistent access to food in the previous 4 weeks. This discrepancy is likely due to the different formats with which these measures were administered and may also be explained by the degree to which households are aware of, or rate the severity of, their own food access. It is also interesting to note that 3.2% (65) of the sampled households also mentioned never having had a month in which they had sufficient food provisioning over the previous year. This statistic does not imply that the household has gone 12 months without any food, rather, this statistic suggests that the household has not had sufficient enough food access to meet their dietary needs during any given month in the past 12 months. The distribution of scores in this measure demonstrates that a long-term lack of food access is not commonly identified by respondents; however, there is a broad range of inconsistent food access severity among the households that claim to have had long-term inconsistent food access.

Table 9. Distribution of MAHFP Scores

Months of Adequate Household Food Provisioning	n(%)
0	65(3.2)
1	26(1.3)
2	11(0.5)
3	22(1.1)
4	12(0.6)

5	26(1.3)
6	34(1.6)
7	42(2.0)
8	93(4.5)
9	122(5.9)
10	188(9.1)
11	152(7.4)
12	1270(61.6)
Total	2063(100.0)

The majority of the surveyed households did not have consistent access to water, electricity, medicine, or a cash income (63.1% or 1306, of surveyed households). This finding demonstrates that disruptions in household access to any of these resources are common among the surveyed population. The majority of the households surveyed went without, or experienced inconsistent access to, electricity (52.1%, or 1064, of the surveyed households). The lack of consistent access to electricity may represent the extent to which the supply of electricity in Maputo is disrupted, rather than just demonstrating a lack of means to access that electricity. Similarly, over 33% of the surveyed households went without clean water on a consistent basis (demonstrating that disruptions in access water utilities, or the complete inaccessibility of water utilities, are a challenge in the city). It should also be noted that this question is in reference to clean water and that the prevalence of boreholes throughout the informal areas of the city may be a common coping mechanism for dealing with these disruptions in water access.

Table 10. Sample Distribution across Lived Poverty Index Sub-Scale Ordinal Variables

Lived Poverty Index Sub-Scale	Consistent Access n(%)	Inconsistent/No Access n(%)	Total n(%)
Clean water for home use	1353(66.1)	694(33.9)	2047(100)
Electricity in home	977(47.9)	1064(52.1)	2041(100)
Medicine or medical treatment	1552(75.6)	501(24.4)	2053(100)
A cash income	1371(66.9)	679(33.1)	2050(100)
Access to all infrastructure	718(34.7)	1306(63.1)	2024(100)

The distribution across the cross-tabulations of HDDS scores and inconsistent infrastructure access variables demonstrates the distribution of probabilities of households being categorized in either categorical value in the HDDS variable. In other words, these charts demonstrate the probability of a household being categorized as having a limited or diverse diet based on their response to the inconsistent infrastructure access variables. In the HDDS cross-tabulation, there is a large difference in the probabilities of households consuming less than or equal to 3 food groups based on their response to all of these inconsistent infrastructure access variables, except for the access to water variable. The relative risk of households that had inconsistent/no access to water consuming less than or equal to 3 food groups was only 1.012. This statistic suggests that there is a limited probability that a household will have a limited dietary diversity based on the consistency of that household's access to water. This calculation, however, does not take into account any other variables that may influence this relationship and does not present a probabilistic test of independence (such as a Chi-Square or Fisher's Exact Test) to determine whether the relationship between these variables is statistically significant. Inconsistent household access to a cash income and medical care both demonstrated large relative risk values (1.598 and 1.304 respectively), demonstrating that a lack of access to these infrastructure resources dramatically increases a household's relative risk of having limited dietary diversity (the same limitations apply to this analysis as the previous calculations of relative risk). That said, when all inconsistent infrastructure access variables are collapsed into the total score (representing the consistency of household access to all infrastructure services), the relative risk ratio is calculated at 1.271, suggesting that households with inconsistent or no access to any of these infrastructure services are almost 30% more likely to have consumed less than 4 food groups in the previous 24 hours (independent of other variables and without any statistical significance tests to corroborate the finding).

Table 11. Distribution of Household Infrastructure Access by HDDS Scores

Variables	Categories	HDDS>3 N(%)	HDDS<=3 N(%)	Total N(%)
All services	Consistent access to all	460(64.1)	258(35.9)	718(100.0)
	Inconsistent/no access to any	711(54.4)	595(45.6)	1306(100.0)
Clean Water	Consistent access	785(58.0)	568(42.0)	1353(100.0)
	Inconsistent/no access	399(57.5)	295(42.5)	694(100.0)
Electricity	Consistent access	595(60.9)	382(39.1)	977(100.0)
	Inconsistent/no access	589(55.4)	475(44.6)	1064(100.0)
Medical care	Consistent access	943(60.8)	609(39.2)	1552(100.0)
	Inconsistent/no access	245(48.9)	256(51.1)	501(100.0)
A cash income	Consistent access	887(64.7)	484(35.3)	1371(100.0)
	Inconsistent/no access	296(43.6)	383(56.4)	679(100.0)

The cross-tabulation of inconsistent infrastructure access and HFIAP scores demonstrate even larger relative risk ratios than the cross-tabulation of the same variables with HDDS scores. Independent of other variables or test of significance, households with inconsistent or no access to any of these infrastructure services were 1.779 times (80%) more likely to be categorized as food insecure on the HFIAP. This is the largest risk ratio observed in this cross-tabulation. Beside this comparison, access to a cash income and medical care both demonstrated a large relative risk ratio (1.521 and 1.461 respectively). This cross-tabulation suggests that there is a sizeable difference in household food access according to the consistency of household access to these infrastructure services. As with the previous cross-tabulation, however, these statistics are independent of the influence of other variables in the cross-tabulation and statistical tests of significance.

Table 12. Distribution of Household Infrastructure Access by HFIAP Scores

Variables	Categories	HFIAP=1 N(%)	HFIAP>1 N(%)	Total N(%)
All services	Consistent access to all	388(54.6)	322(45.4)	710(100.0)
	Inconsistent/no access to any	191(14.7)	1109(85.3)	1300(100.0)
Clean Water	Consistent access	507(37.8)	836(62.2)	1343(100.0)
	Inconsistent/no access	74(10.7)	615(89.3)	689(100.0)
Electricity	Consistent access	440(45.4)	529(54.6)	969(100.0)

	Inconsistent/no access	140(13.2)	918(86.8)	1058(100.0)
Medical care	Consistent access	552(35.8)	988(64.2)	1540(100.0)
	Inconsistent/no access	31(6.2)	468(93.8)	499(100.0)
A cash income	Consistent access	532(39.2)	826(60.8)	1358(100.0)
	Inconsistent/no access	51(7.5)	626(92.5)	677(100.0)

The cross-tabulation of household access to infrastructure and MAHFP scores also demonstrated large risk ratios. Long-term inconsistent household food access, however does not seem to share the same magnitude of relationship with inconsistent infrastructure access as was observed in the cross-tabulation with the HFIAP. Independent of other variables and tests of significance, access to medical care appears to make the most sizeable difference in long-term household food provisioning. Inconsistent or no access to medical care was associated with a 100% increase in the risk of a household having less than 12 months of adequate food provisions (independent of statistical tests of significance or other variables). While this finding needs to be corroborated with further tests, this is a preliminary indication of the important role that consistent medical care access may have in determining the long-term food access of a household.

Table 13. Distribution of Household Infrastructure Access by MAHFP Scores

Variables	Categories	MAHFP=12 N(%)	MAHFP<12 N(%)	Total N(%)
All services	Consistent access to all	543(76.1)	171(23.9)	714(100.0)
	Inconsistent/no access to any	694(53.3)	608(46.7)	1302(100.0)
Clean Water	Consistent access	893(66.3)	453(33.7)	1346(100.0)
	Inconsistent/no access	358(51.7)	335(48.3)	693(100.0)
Electricity	Consistent access	688(70.7)	285(29.3)	973(100.0)
	Inconsistent/no access	559(52.7)	501(47.3)	1060(100.0)
Medical care	Consistent access	1068(69.1)	477(30.9)	1545(100.0)
	Inconsistent/no access	190(38.0)	310(62.0)	500(100.0)
A cash income	Consistent access	988(72.4)	376(27.6)	1364(100.0)
	Inconsistent/no access	265(39.1)	413(60.9)	678(100.0)

The odds ratios for the cross-tabulations presented above provide further insight into these observed relationships. As a reminder, odds ratios are not calculated using probabilities (as is the case in the calculation of relative risk). Instead, odds ratios should be interpreted as the change in the odds of an event occurring given another event. In addition, the odds ratios provided below have been tested for statistically significant independence using a Fisher's Exact Test and a Pearson's Chi-Square Test, demonstrating the statistical significance of the observed distribution in the above cross-tabulations. In the case of the cross-tabulations with the HDDS, all inconsistent infrastructure access variables, with the exception of access to water, proved to be statistically significant predictors of HDDS scores. The odds ratios and p-values in these tests, however, were independent of the effects other variables (no weighting was implemented in these tests). Inconsistent or no access to a cash income demonstrated a very significant and impactful relationship with HDDS scores. The odds of households with inconsistent or no access to a cash income having limited dietary diversity were approximately 2.4 times greater than households that had consistent access to a cash income (independent of other variables). This relationship was even stronger than the relationship observed between the HDDS and the access to all services variable (which represents consistent household access to all infrastructure resources). This cross-tabulation also confirms that the distribution of scores between inconsistent or no household access to clean water and household dietary diversity is not statistically significant (as was inferred in the cross-tabulation of inconsistent infrastructure access scores and HDDS scores).

Table 14. Odds Ratios for Household Infrastructure Access and HDDS Scores

Variables	Odds Ratio	95% Confidence Interval Lower	Upper	Fisher's Test P-value	Chi Square P-value
Access to all services	1.492	1.237	1.799	<.001	<.001
Access to clean water	1.022	.849	1.230	.850	.819
Access to electricity	1.256	1.053	1.498	.012	.011
Access to medical care	1.618	1.321	1.981	<.001	<.001
Access to a cash income	2.371	1.965	2.861	<.001	<.001

(P-values are estimated using a 2-Sided Fisher's Exact Test and an Asymptotic 2-Sided Pearson's Chi-Square Test)

In the cross-tabulation of household inconsistent infrastructure access variables and HFIAP scores, all variables included in the cross-tabulation were statistically significant and demonstrated large odds ratios in their relationship with the HFIAP variable. Independent of all other variables, household access to medical care demonstrated the largest effect. Households with inconsistent or no access to medical care had roughly 8.5 times greater odds of being categorized as food insecure on the HFIAP, independent of other variables. That said, this relationship demonstrated a high degree of variability with a 95% confidence interval of 5.779 to 12.311 for the odds ratio provided. Household access to a cash income also demonstrated a large and significant relationship. Independent of other variables, households with inconsistent access to a cash income had roughly 8 times greater odds of being categorized as food insecure on the HFIAP. Similar to the access to medical care variable, however, the access to a cash income variable also demonstrated a large degree of variability.

Table 15. Odds Ratios for Household Infrastructure Access and HFIAP Scores

Variables	Odds Ratio	95% Confidence Interval		Fisher's Test	Chi-Square
		Lower	Upper	P-value	P-value
Access to all services	6.996	5.654	8.658	<.001	<.001
Access to clean water	5.040	3.866	6.571	<.001	<.001
Access to electricity	5.454	4.385	6.784	<.001	<.001
Access to medical care	8.435	5.779	12.311	<.001	<.001
Access to a cash income	7.906	5.824	10.730	<.001	<.001

(P-values are estimated using a 2-Sided Fisher's Exact Test and an Asymptotic 2-Sided Pearson's Chi-Square Test)

While the cross-tabulation of household inconsistent infrastructure access and MAHFP scores also demonstrated consistently statistically significant values in the Fisher's Exact Test and Pearson's Chi-Square Test, the magnitude of the odds ratios observed were not as large as those observed in the HFIAP cross-tabulations. The largest odds ratio observed in this cross-tabulation was between household access to a cash income and MAHFP scores. Independent of other variables, households with inconsistent access to a cash income had 4 times greater odds of going without consistent monthly food provisioning in the previous year when compared to households with consistent access to a cash income. Similar to the HFIAP cross-tabulation, household access to medical care demonstrated the second largest odds-ratio in this cross-tabulation. Independent of other variables, households with inconsistent access to medical care had 3.653 times greater odds of going without adequate monthly food provisioning in the previous year when compared with households that had consistent access to medical care.

Table 16. Odds Ratios for Household Infrastructure Access and MAHFP Scores

Variables	Odds Ratio	95% Confidence Interval Lower	Upper	Fisher's Test P-value	Chi-Square P-value
Access to all services	2.782	2.270	3.410	<.001	<.001
Access to clean water	1.845	1.530	2.224	<.001	<.001
Access to electricity	2.164	1.801	2.599	<.001	<.001
Access to medical care	3.653	2.960	4.508	<.001	<.001
Access to a cash income	4.095	3.371	4.975	<.001	<.001

(P-values are estimated using a 2-Sided Fisher's Exact Test and an Asymptotic 2-Sided Pearson's Chi-Square Test)

Regression Statistics

Up until this point, all analyses of the relationships between these inconsistent infrastructure access variables and food security measures have been done using cross-tabulations and associated statistical tests (relative risk, odds ratios, fisher's exact test, and chi-square tests). While these tests are helpful in determining the predictive relationships between categorical variables, the tests do not account for the influence of other variables. In other words, there may be other variables that better explain the observed relationship. In order to account for the influence of other variables in these relationships, multivariate regression analysis (in this case binary logistic regression analysis) can provide a means. Regression analyses achieve this by determining the regression equation for the entire model and then holding the values of each independent variable constant (at 0 in the case of logistic regression analysis) while the odds ratio for any one independent variable is being calculated. By holding the values for all other variables in the model constant, the odds ratios for each variable in the overall regression equation can represent the impact of each independent variable while accounting for the influence of all the other variables included in the model. As such, a multivariate regression analysis can give a more accurate representation of each independent variable's influence on the dependent variable.

The binary logistic regression analysis of the relationship between inconsistent infrastructure access and HDDS scores demonstrates a slightly different relationship than was observed in the individual odds ratio tests in the previous cross-tabulations. Inconsistent access to water went from having an insignificant relationship to a significant relationship with the HDDS and access to electricity and medical care both became insignificant predictors of HDDS (holding all other infrastructure variables constant in this analysis). The model demonstrated a Hosmer and Lemeshow Test statistic that was not statistically significant ($x^2(6) = 5.603, p = 0.469$), indicating that the model fits the data. That said, the pseudo R^2 tests indicated that the combined influence of the independent variables in the model did not predict the dependent variable (HDDS scores) significantly better than the null model (a model only containing the intercept). The model demonstrated a Cox and Snell R^2 value of .043 and the Nagelkerke R^2 demonstrated a value of .058. The model did demonstrate a high Pearson's r correlation between household access to water and electricity (-.405), which suggest multicollinearity may be a bias in this model (although VIF and Tolerance values for these equations suggest otherwise). All variables included in this investigation demonstrated Tolerance values between .699 and .943 and VIF values between 1.058 and 1.433. All of that said, the model did present better accuracy than the null model. While the null model only accurately categorized 57.9% of cases according to the

HDDS dependent variable, this regression model accurately categorized 61.9% of cases (at the 0.5 cut-off for both of these estimates).

Interestingly, the model suggests that inconsistent or no household access to clean water is associated with lower odds of having low dietary diversity. In other words, this model would suggest that inconsistent or no household access to water may be associated with greater dietary diversity (holding other variables in the model constant). This finding needs to be interpreted with care for two reasons. First, the confidence interval for this odds ratio demonstrates that an odds ratio of .944 is still within the 95% confidence interval range. This suggests that inconsistent water access may have little impact on household dietary diversity. Second, there may be other variables that better explain this relationship (as I am presenting in the upcoming chapter). The only other significant predictor of household dietary diversity in this model was the consistency of household access to a cash income. Households with inconsistent access to a cash income had twice the odds of having low dietary diversity when compared with households that had consistent access to a cash income (holding other variables in the model constant). The Wald test also demonstrates that the access to cash income variable was the strongest independent variable predictor in the regression model.

Table 17. Household Infrastructure Access and HDDS Binary Logistic Regression Results

Household Infrastructure Access	B	S.E.	Wald	df	P value	Exp(B)	95% C.I.for EXP(B)	
Household frequency of going without:							Lower	Upper
Clean water*	-.282	.115	6.054	1	.014	.754	.602	.944
Electricity	.037	.110	.110	1	.740	1.037	.836	1.287
Medical care	.182	.122	2.230	1	.135	1.199	.945	1.522
A cash income**	.857	.111	59.552	1	.000	2.356	1.895	2.929
Constant**	-.578	.070	69.053	1	.000	.561		

* p<.05
** p<.01

The binary logistic regression model of HFIAP scores by the household inconsistent infrastructure access variables indicates a similar finding to the earlier odds ratio cross-tabulations between these variables. In both of these analyses, the inconsistent infrastructure access variables significantly increased the odds of a household experiencing limited food access. The HFIAP regression model did not demonstrate a poor fit, as indicated by the insignificant p-value in the Hosmer and Lemeshow Test ($x^2(5) = 4.543, p = 0.474$). The independent variables included in the HFIAP model also appear to better predict the distribution of scores in the HFIAP variable than the HDDS variable. The HFIAP model demonstrated a Cox and Snell R^2 value of .207 and a Nagelkerke R^2 value of .296. This finding is also corroborated by the fact that the model accurately categorized 74.5% of the cases in this investigation according to HFIAP category, whereas the null model only accurately categorized 71.2% of those cases (at the 0.5 cut-off for both of these estimates). The highest correlation coefficient observed in the relationships among the independent variables in this model was -.399 between the access to water and access to electricity variables. This finding potentially indicates the influence of multicollinearity among these parameters (although VIF and Tolerance values do not indicate the existence of multicollinearity in this model). All variables included in this investigation demonstrated Tolerance values between .699 and .943 and VIF values between 1.058 and 1.433.

The odds ratios in this model demonstrate the significant impact that these inconsistent infrastructure access variables have on household food access. Holding all other independent variables constant in this model, a lack of consistent access to a cash income increased the odds of a household having limited food access in the previous 4 weeks by almost four times. Similarly, a lack of household access to medical care increased the odds that a household would have limited food access in the last 4 weeks by about 3.2 times (again holding all other variables in this model constant). That said, the Wald statistic reveals a slightly different story in this model. In spite of the relative magnitude of the odds-ratios observed for both the medical care access and cash income variables with the HFIAP variable, the Wald statistic suggests that the strongest predictors in this model are the access to cash income and access to electricity variables. In other words, while inconsistent or no access to a cash income or medical care can lead to a greater difference in the odds that a household will have limited food access, inconsistent access to electricity and a cash income seem to be the better predictors of insecure food access.

Table 18. Household Infrastructure Access and HFIAP Binary Logistic Regression Results

Household Infrastructure Access	B	S.E.	Wald	df	P value	Exp(B)	95% C.I.for EXP(B)	
Household frequency of going without:							Lower	Upper
Clean water**	.739	.159	21.758	1	<.001	2.095	1.535	2.858
Electricity**	.950	.130	53.341	1	<.001	2.586	2.004	3.337
Medical care**	1.169	.208	31.619	1	<.001	3.219	2.142	4.839
A cash income**	1.346	.167	64.885	1	<.001	3.843	2.770	5.333
Constant*	-.161	.071	5.135	1	.023	.852		

* p<.05
** p<.01

The binary regression model relating inconsistent household infrastructure access to MAHFP scores revealed a similar pattern of relationships to those observed in the HFIAP model. The household access to water variable went from being a significant predictor of the MAHFP, the variable became an insignificant predictor when all other inconsistent infrastructure access variables were held constant. Similar to the HFIAP, the remaining independent variables were significant predictors of the MAHFP when all other variables in the model are controlled for. This model did not demonstrate a poor fit to the data being modelled, as demonstrated by the insignificant p-value attained in the Hosmer and Lemeshow Test ($x^2(5) = 7.427, p = 0.191$). While not as significant as the pseudo R^2 values observed in the HFIAP model, this model demonstrated a Cox and Snell R^2 value of .121 and a Nagelkerke R^2 value of .165. These tests indicate that the inconsistent infrastructure access variables had a marginally greater likelihood of predicting MAHFP scores than HDDS scores, although not quite as well as the HFIAP scores. Similar to previous models, the highest independent variable correlation (as determined by a Pearson's r correlation coefficient) was -.410 and it was observed between the access to water and electricity variables in this model. All variables included in this investigation demonstrated Tolerance values between .699 and .943 and VIF values between 1.058 and 1.433. This model accurately categorized 69.1% of the cases included in this investigation according to MAHFP scores while the null model only accurately categorized 61.4% of those cases (at the 0.5 cut-off for both of these estimates). These values indicate that the model is a decent predictive model of MAHFP scores.

While the cross-tabulation of water access with the MAHFP demonstrated a statistically significant test of independence (as demonstrated by the Fisher's Exact Test), this relationship becomes insignificant when the other inconsistent infrastructure access variables are held constant (as is demonstrated in the following regression model). This finding suggests that the impact of inconsistent/no access to clean water on long-term household food access may be better explained by the other variables included in this model. Holding other variables in this model constant, inconsistent or no access to medical care or a cash income significantly increased the odds of a household going without consistent monthly food provisions by 2-3 times, approximately. In addition, this model indicates that a lack of consistent access to a cash income and medical care both significantly increase the odds of low MAHFP scores, according to the Wald statistic, indicating fewer months of adequate household food provisioning. In contrast to the findings in the HFIAP model, inconsistent/no access to electricity only increased a household's odds of going without consistent monthly food provisioning by 20% (holding other variables in the model constant). The access to electricity variable is also a less significant predictor of MAHFP scores than either the access to medical care or the access to a cash income variable.

Table 19. Household Infrastructure Access and MAHFP Binary Logistic Regression Results

Household Infrastructure Access	B	S.E.	Wald	df	P value	Exp(B)	95% C.I.for EXP(B)	
Household frequency of going without:							Lower	Upper
Clean water	.046	.118	.148	1	.700	1.047	.830	1.320
Electricity*	.237	.116	4.196	1	.041	1.267	1.010	1.590
Medical care**	.744	.123	36.366	1	<.001	2.105	1.653	2.682
A cash income**	1.053	.112	88.115	1	<.001	2.866	2.300	3.570
Constant**	-1.172	.077	230.828	1	<.001	.310		

* p<.05
** p<.01

Results Summary

The analyses presented in this chapter demonstrate that, holding all inconsistent infrastructure access variables constant, each inconsistent infrastructure access variable was a significant predictor of HFIAP and MAHFP scores (with the exception of the consistent access to water variable which was an insignificant predictor in the logistic regression model of the MAHFP). The same cannot be said of the HDDS, however. Holding other inconsistent infrastructure access variables constant, only the access to a cash income variable appeared to significantly increase the odds of a low HDDS value and there is a potentially paradoxical relationship between the inconsistent access to water variable and the HDDS dependent variable. The overall model test statistics also demonstrate that the HDDS model was a less reliable predictive model than either the HFIAP or MAHFP model. In summary, while inconsistent infrastructure access appears to explain the distribution of MAHFP and HFIAP scores, it seems that there may be other variables that better explain household dietary diversity.

Chapter Six: Inconsistent Infrastructure Access versus Social Vulnerability in the Determination of Household Food Insecurity in Maputo

Introduction

In this chapter, the predictive relationships between the social vulnerability variables used in this investigation and the household food security measures are evaluated. These relationships are established in the same fashion as the previous chapter relating inconsistent infrastructure access to household food insecurity. First, the relationship between these social vulnerability variables and the household food insecurity measures is assessed using relative risk and odds ratios (along with statistical tests of significance). This analysis determines whether each social vulnerability variable is a statistically significant predictor of household food insecurity independent of other variables. Second, this relationship is assessed using logistic regression analysis in order to determine whether each social vulnerability variable is still a statistically significant predictor of food insecurity when the other social vulnerability variables are taken into account.

Once the social vulnerability variables are evaluated as statistically significant predictors of household food insecurity, the social vulnerability variables are compared to the inconsistent infrastructure access variables according to the extent to which they predict household food insecurity. First, these comparisons occur using the logistic regression models for both sets of independent variables (comparing the model test statistics for each of the three inconsistent infrastructure access models predicting household food insecurity with the model test statistics for each of the three social vulnerability models predicting household food insecurity). Second, these comparisons occur amongst all the independent variables in this investigation (including inconsistent infrastructure access and social vulnerability variables in logistic regression models) according to their ability to significantly predict the three food insecurity measures (as determined by a comparison of the Wald statistics and log-odds for each independent variable).

These comparisons allow each variable to be compared in their relation to the HDDS, HFIAP, and the MAHFP. While interpreting the results of these analyses, it is important to keep in mind that the household social vulnerability variables reviewed here can also be compounded. In other words, each additional social vulnerability characteristic carried by a household has the potential to incrementally increase the household's vulnerability to food insecurity (thus demonstrating the need for regression analyses).

Descriptive Statistics

The cross-tabulations of the social vulnerability variables and household food security scores presented below demonstrate some interesting findings. First, 32% (622) of households surveyed identified themselves as a female-headed household. Only 80 (4%) households were identified as informally constructed in the sample population. As a reminder, this variable does not refer to the informality of the area in which a household resides, only the informality of the dwelling construction. In addition, 46% (948) of households identified themselves as having at least one household member with some form of chronic illness included in this investigation. The majority of households in the sample population were smaller than 6 people in size. Only 32% (1405) of households had more than 5 people in the household. These cross-tabulations also demonstrate that 22% (420) of household heads were unemployed among the sample population. Finally, the majority of household heads had attained some form of formal education. Only 15% (265) of household heads in the sample population had not attained any form of formal education.

The following cross-tabulations reveal the distribution of HDDS scores according to the social vulnerability variables that have been included in this investigation. Female-headed households demonstrated slightly higher relative risk ratios than male-headed households (1.083), suggesting that female headed households are 8% more likely to have less dietary diversity than male-headed households (independent of other variables and statistical tests of significance). Household heads with no formal education were also 36% more likely to have lower dietary diversity than household heads with formal education (independent of other variables or significance tests). Low-income households were also 49% more likely to have lower dietary diversity than other households (independent of other variables or significance tests).

Interestingly, larger households were associated with lower relative risk ratios in relation to the HDDS scores. Households that had more than 5 individuals in the household were 15% less likely to have low dietary diversity (independent of other variables or tests of significance). In addition, households that included chronically ill household members were 10% less likely to have low dietary diversity (again independent of other variables or test of significance). While these statistics need to be corroborated with statistical tests of significance and against the impact of other variables, these findings are paradoxical given that these independent variables were previously cited as social vulnerability indicators.

Table 20. Distribution of Household Vulnerability Characteristics by HDDS Scores

Variables	Categories	HDDS>3 N(%)	HDDS<=3 N(%)	Total N(%)
Household head sex	Male	778(58.9)	544(41.1)	1322(100.0)
	Female	345(55.5)	277(44.5)	622(100.0)
Household head education	Any formal education	899(59.1)	622(40.9)	1521(100.0)
	No formal education	118(44.5)	147(55.5)	265(100.0)
Household head employment	Employed	897(59.8)	603(40.2)	1500(100.0)
	Unemployed	213(50.7)	207(49.3)	420(100.0)
Informality of dwelling	Formally constructed	1140(58.8)	799(41.2)	1939(100.0)
	Informally constructed	33(41.3)	47(58.8)	80(100.0)
Low household income tercile	Middle and high income	392(60.8)	253(39.2)	645(100.0)
	Low income	131(41.7)	183(58.3)	314(100.0)
Household size	Less than or equal to 5	782(55.7)	623(44.3)	1405(100.0)
	Greater than 5	415(62.4)	250(37.6)	665(100.0)
Chronically ill members	No chronically ill members	627(55.8)	496(44.2)	1123(100.0)
	Chronically ill members	570(60.1)	378(39.9)	948(100.0)

The cross tabulations for the HFIAP scores by social vulnerability indicators demonstrates large differences in the conditional probability that a household will be categorized as food insecure on the HFIAP given the independent variables included in this cross-tabulation. Female-headed households were 10% more likely to be categorized as food insecure on this measure than male-headed households (according to a relative risk calculation and independent of other variables or tests of statistical significance). In addition, households with more than 5 members were 13% more likely to be categorized as food insecure on the HFIAP than households with less than 6 members (independent of other variables and statistical tests of significance). Low household income appears to be another variable that has a large impact on household food access. Low income households were 40% more likely to be food insecure according to the HFIAP than middle and high income households (independent of other variables and tests of significance). These cross-tabulations suggest that these social vulnerability variables have a predictive relationship with the HFIAP. That said, these findings need to be corroborated with further statistical tests that take into account the impact of other variables and include statistical tests of significance.

Table 21. Distribution of Household Vulnerability Characteristics by HFIAP Scores

Variables	Categories	HFIAP=1 N(%)	HFIAP>1 N(%)	Total N(%)
Household head sex	Male	404(30.8)	909(69.2)	1313(100.0)
	Female	147(23.8)	470(76.2)	617(100.0)
Household head education	Any formal education	467(30.9)	1046(69.1)	1513(100.0)
	No formal education	36(13.7)	226(86.3)	262(100.0)
Household head employment	Employed	468(31.5)	1020(68.5)	1488(100.0)
	Unemployed	78(18.7)	340(81.3)	418(100.0)
Informality of dwelling	Formally constructed	564(29.3)	1361(70.7)	1925(100.0)
	Informally constructed	9(11.3)	71(88.8)	80(100.0)
Low household income tercile	Middle and high income	238(37.2)	402(62.8)	640(100.0)
	Low income	38(12.2)	274(87.8)	312(100.0)
Household size	<=5	439(31.6)	952(68.4)	1391(100.0)
	>5	150(22.6)	514(77.4)	664(100.0)

Chronically ill members	No chronically ill members	387(34.8)	724(65.2)	1111(100.0)
	Chronically ill members	202(21.4)	743(78.6)	945(100.0)

The cross tabulations between these social vulnerability variables and the MAHFP indicates some significant relationships. Household head unemployment appears to be related to MAHFP scores. Households whose head was unemployed at the time of the survey were 43% more likely to go without consistent monthly food provisions in the last 12 months (independent of other variables and tests of significance). In addition, households residing in informally constructed dwellings were 67% more likely to go without consistent monthly food provisions in the last 12 months (independent of other variables and tests of significance). Low household income also appears to be associated with MAHFP scores. Households in the lowest household income tercile were 100% more likely to go without consistent monthly food provisions in the last 12 months (independent of other variables and statistical tests of significance). These calculations were made solely using relative risk ratios and require further statistical analysis.

Table 22. Distribution of Household Vulnerability Characteristics by MAHFP Scores

Variables	Categories	MAHFP=12 N(%)	MAHFP<12 N(%)	Total N(%)
Household head sex	Male	841(63.8)	477(36.2)	1318(100.0)
	Female	357(57.8)	261(42.2)	618(100.0)
Household head education	Any formal education	950(62.7)	566(37.3)	1516(100.0)
	No formal education	128(48.7)	135(51.3)	263(100.0)
Household head employment	Employed	972(65.0)	523(35.0)	1495(100.0)
	Unemployed	209(50.1)	208(49.9)	417(100.0)
Informality of dwelling	Formally constructed	1206(62.5)	725(37.5)	1931(100.0)
	Informally constructed	30(37.5)	50(62.5)	80(100.0)
Low household income tercile	Middle and high income	444(69.3)	197(30.7)	641(100.0)
	Low income	120(38.2)	194(61.8)	314(100.0)
Household size	<=5	880(62.8)	521(37.2)	1401(100.0)
	>5	390(59.0)	271(41.0)	661(100.0)
Chronically ill members	No chronically ill members	744(66.4)	376(33.6)	1120(100.0)
	Chronically ill members	526(55.8)	417(44.2)	943(100.0)

In the odds ratio calculations of the relationship between the social vulnerability variables and the HDDS variable (using the previous cross-tabulations), every variable except the sex of the household head was demonstrated as statistically significant (using a Fisher's Exact Test and Pearson's Chi-Square). These tests were established independent of other variables and need to be interpreted with care. The informality of the dwelling construction and the income of the household demonstrated the largest odds-ratios. The odds of low income households having a limited dietary diversity were approximately 2.2 times greater than middle and high income households. In addition, the odds of households residing in informally constructed dwellings were approximately 2 times greater than other households. Both of these odds ratios were calculated independent of other variables.

Similar to the relative risk calculations, households with more than 6 members or chronically ill members were also found to have greater dietary diversity than other households. This finding, however, needs to be interpreted with care. First, the range of the 95% confidence interval for these odds ratio estimates includes values close to 1 as an upper limit (0.913 and 0.999 for household size and chronically ill members respectively). This range suggests that these variables may have a limited impact on the odds of a household having a limited dietary diversity. Second, there may be other variables that better explain these relationships than the independent variables provided here.

Table 23. Odds Ratios for Household Vulnerability Characteristics and HDDS Scores

Variables	Odds Ratio	95% Confidence Interval		Fisher's Test	Chi-Square
		Lower	Upper	P-value	P-value
Household head sex	1.148	.947	1.392	.168	.159
Household head education	1.801	1.384	2.342	<.001	<.001
Household head employment	1.446	1.163	1.797	.001	.001
Informality of dwelling	2.032	1.290	3.200	.002	.002
Low household income tercile	2.164	1.645	2.848	<.001	<.001
Household size	.756	.626	.913	.004	.004
Chronically ill members	.838	.703	.999	.050	.049

(P-values are estimated using a 2-Sided Fisher's Exact Test and an Asymptotic 2-Sided Pearson's Chi-Square Test)

Every social vulnerability variable included in the cross-tabulation with HFIAP scores demonstrated a statistically significant relationship according to the Fisher's Exact Test and Pearson's Chi-Square (independent of other variables). Low income appeared to have a particularly significant predictive relationship with HFIAP score distributions. The odds of low income households being categorized as food insecure on the HFIAP was 4 times greater than for households with middle or high income (independent of other variables). Households which were informally built also had approximately 3.3 times greater odds of being categorized as food insecure on the HFIAP when compared to other households (independent of other variables). In addition, the education level and employment status of the household head was significantly associated with HFIAP scores. Households whose heads did not have any amount of formal education had 2.8 times greater odds of being categorized as food insecure on the HFIAP compared to other households (independent of other variables). Households with unemployed household heads had twice the odds of being categorized as food insecure on the HFIAP compared with households whose heads were employed (independent of other variables).

Table 24. Odds Ratios for Household Vulnerability Characteristics and HFIAP Scores

Variables	Odds Ratio	95% Confidence Interval		Fisher's Test	Chi-Square
		Lower	Upper	P-value	P-value
Household head sex	1.421	1.141	1.769	.002	.002
Household head education	2.803	1.939	4.051	<.001	<.001
Household head employment	2.000	1.528	2.618	<.001	<.001
Informality of dwelling	3.269	1.623	6.586	<.001	<.001
Low household income tercile	4.269	2.933	6.213	<.001	<.001
Household size	1.580	1.276	1.958	<.001	<.001
Chronically ill members	1.966	1.612	2.398	<.001	<.001

(P-values are estimated using a 2-Sided Fisher's Exact Test and an Asymptotic 2-Sided Pearson's Chi-Square Test)

All the social vulnerability variables in this investigation demonstrated a statistically significant distribution (on the Fisher's Exact Test and Pearson's Chi-Square) in their cross-tabulation with MAHFP scores, with the exception of household size (independent of other variables). The odds of low income households having inconsistent monthly food provisions were 3.6 times greater than middle and high income households (independent of other variables). The informal construction of the dwelling in which a household resides also appears to have a significant impact on the distribution of households across MAHFP scores. Households residing in informally constructed dwellings had approximately 2.8 times greater odds of going without consistent monthly food provisions when compared to other households (independent of other variables). These calculations indicate that most of the social vulnerability indicators included in this investigation are significant predictors of MAHFP scores (as determined by odds ratio and Fisher's Exact Tests calculations and independent of other variables). These findings need to be corroborated with further statistical tests to determine if these relationships hold up when the other variables included in this investigation are taken into consideration.

Table 25. Odds Ratios for Household Vulnerability Characteristics and MAHFP Scores

Variables	Odds Ratio	95% Confidence Interval		Fisher's Test	Chi-Square
		Lower	Upper	P-value	P-value
Household head sex	1.289	1.060	1.567	.012	.011
Household head education	1.770	1.361	2.303	<.001	<.001
Household head employment	1.850	1.485	2.303	<.001	<.001
Informality of dwelling	2.772	1.747	4.400	<.001	<.001
Low household income tercile	3.644	2.746	4.834	<.001	<.001
Household size	1.174	.971	1.418	.099	.097
Chronically ill members	1.569	1.312	1.875	<.001	<.001

(P-values are estimated using a 2-Sided Fisher's Exact Test and an Asymptotic 2-Sided Pearson's Chi-Square Test)

Regression Statistics

The binary logistic regression analysis relating the social vulnerability variables to the HDDS demonstrates some limited and paradoxical relationships between these variables and dietary diversity. Two common indicators of food insecurity were found to statistically reduce the odds of limited household dietary diversity. In spite of these paradoxical observations, a Hosmer and Lemeshow Test suggested that the model is not a poor fit to the data included in this analysis ($x^2(8) = 11.483, p = 0.176$). However the pseudo R^2 values indicate that there is not a large difference between the likelihood of this model and the likelihood of the null model in predicting the dependent variable. A Cox and Snell R^2 test demonstrated a R^2 value of 0.046 and a Nagelkerke R^2 test demonstrated a value of 0.061. The discrepancy in these tests suggests that the model has limited additional value in predicting the dependent variable compared to the null model. That said, this model accurately categorized 59.7% of cases according to the HDDS variable while the null model accurately categorized only 54.6% of cases (both of these tests were performed at the 0.5 cut-off). The highest Pearson's r correlation coefficient observed among the independent variables was -.214, suggesting that multicollinearity may not have been a factor in this regression model. This was corroborated by the fact that all variables included in this investigation demonstrated Tolerance values between .699 and .943 and VIF values between 1.058 and 1.433.

Among the variables included in this model, the employment status of the household head variable, the low household income variable, the household size variable and the chronically sick household members variable were significant predictors of the HDDS variable. Holding other variables in the model constant, households with unemployed household heads had 1.456 times greater odds of having less dietary diversity than households with employed household heads. Households with a low income also had almost twice the odds of having limited dietary diversity when compared to middle and high income households, holding other variables in the model constant.

As was observed in the previous cross-tabulations, this regression model also presents some paradoxes. In particular, household size and the presence of chronically ill household members appear, based on this model, to be associated with greater dietary diversity. Households with more than five members had 30% less odds of having a limited dietary diversity and households with chronically ill household members had 25% less odds of having a limited dietary diversity (holding other variables in the model constant). These regression results need to be interpreted with care, however, as the upper limit of the 95% confidence interval for these estimates are both within .035 of 1, suggesting that these factors do not significantly increase or decrease the odds of a household having limited dietary diversity.

Table 26. Household Social Vulnerability Indicators and HDDS Binary Logistic Regression Results

Variables	B	S.E.	Wald	df	P value	Exp(B)	95% C.I.for EXP(B)	
							Lower	Upper
Household head sex	-.263	.161	2.682	1	.102	.768	.561	1.053
Household head education	.338	.220	2.366	1	.124	1.403	.911	2.159
Household head employment status*	.375	.179	4.385	1	.036	1.456	1.024	2.068
Informality of dwelling	.264	.349	.570	1	.450	1.302	.657	2.580
Low income tercile**	.665	.160	17.208	1	.000	1.944	1.420	2.662
Household size >5*	-.352	.162	4.742	1	.029	.703	.512	.965
Chronically sick member(s)*	-.296	.150	3.884	1	.049	.744	.554	.998
Constant	-.215	.117	3.378	1	.066	.806		

* p<.05
** p<.01

The regression model relating the social vulnerability variables with the HFIAP is not a reliable model for prediction. To begin, the Hosmer and Lemeshow Test demonstrated a statistically significant result ($x^2(8) = 35.672, p < .001$), suggesting that this model does not fit the data very well. In addition the model demonstrated a Cox and Snell R^2 value of .095 and a Nagelkerke R^2 value of .135, giving further evidence that the independent variables in this model do not significantly increase the likelihood of this model when compared to the null model. Finally, there was no difference in the degree to which this model was able to accurately categorize cases according to their HFIAP score when compared to the null model. Both models were 71.1% accurate in categorizing cases according to this HFIAP score (at the 0.5 cut-off). As such, this model should not be used to reliably predict HFIAP scores. The highest Pearson r correlation coefficient observed between the independent variables was -.202 between the sex of the household head and the education level of the household head, demonstrating that multicollinearity is likely not a concern in the interpretation of this model. This was corroborated by the fact that all variables included in this investigation demonstrated Tolerance values between .699 and .943 and VIF values between 1.058 and 1.433.

Among the independent variables included in this model, the informality of the household dwelling, a low household income, a household size greater than 5 and the presence of chronically sick household members were all demonstrated as statistically significant variables in the prediction of the HFIAP dependent variable. Households with a low income had approximately 3.6 times greater odds than households with a higher income in having limited food access in the previous 4 weeks (controlling for other variables in the model). The informality of a household's dwelling also increased the odds that the household would have limited food access in the last 4 weeks by approximately 3 times (controlling for other variables in the model). Large households and households with chronically sick members demonstrated increased odds of having limited food access by 1.771 and 1.431 times respectively (again controlling for other variables in the model).

Table 27. Household Social Vulnerability Indicators and HFIAP Binary Logistic Regression Results

Variables	B	S.E.	Wald	df	P value	Exp(B)	95% C.I.for EXP(B)	
							Lower	Upper
Household head sex	-.018	.184	.009	1	.923	.983	.686	1.408
Household head education	.312	.284	1.209	1	.272	1.367	.783	2.385
Household head employment status	.190	.218	.755	1	.385	1.209	.788	1.854
Informality of dwelling*	1.135	.549	4.274	1	.039	3.113	1.061	9.134
Low income tercile**	1.292	.216	35.718	1	.000	3.641	2.383	5.563
Household size >5**	.571	.190	9.018	1	.003	1.771	1.219	2.571
Chronically sick member(s)*	.358	.169	4.466	1	.035	1.431	1.026	1.994
Constant	.172	.125	1.907	1	.167	1.188		

* p<.05
** p<.01

The logistic regression model relating the social vulnerability indicators to MAHFP scores demonstrated inconsistent evidence regarding the model's fit to the data. This model demonstrated an insignificant Hosmer and Lemeshow Test ($x^2(8) = 5.696, p = 0.681$), suggesting that the model may fit the data. The model also demonstrated a Cox and Snell R^2

value of 0.109 and a Nagelkerke R^2 value of 0.148, which suggests that the model does not have a significantly greater likelihood of predicting the dependent variable when compared with the null model. That said, the model accurately categorized 67.2% of cases compared with the 59.6% of the cases accurately categorized by the null model (at the 0.5 cut-off). The highest Pearson's r correlation among the independent variables in the model was -.214 between the sex of the household head and the education level of the household head, suggesting that multicollinearity was not a bias in this model. This was corroborated by the fact that all variables included in this investigation demonstrated Tolerance values between .699 and .943 and VIF values between 1.058 and 1.433.

The regression model relating the social vulnerability indicators to MAHFP scores only demonstrated three significant predictors of MAHFP scores: household head employment status, the informality of the dwelling's construction, and the low income of the household. Households with unemployed household heads had 1.4 times greater odds of going without consistent monthly food provisions over the last year (holding other variables constant in the model). Households informally constructed also had 2.5 times greater odds of having inconsistent monthly food provisions over the last year (holding other variables constant). Finally, low income households had 3.3 times greater odds of having inconsistent monthly food provisions over the last year compared to higher income households (holding other variables constant).

Table 28. Household Social Vulnerability Indicators and MAHFP Binary Logistic Regression Results

Variables	B	S.E.	Wald	df	P value	Exp(B)	95% C.I.for EXP(B)	
							Lower	Upper
Household head sex	-.113	.168	.448	1	.503	.893	.642	1.243
Household head education	.260	.228	1.305	1	.253	1.297	.830	2.025
Household head employment status*	.368	.185	3.964	1	.046	1.444	1.006	2.074
Informality of dwelling*	.929	.371	6.271	1	.012	2.533	1.224	5.241
Low income tercile**	1.191	.164	52.506	1	.000	3.291	2.384	4.541
Household size >5	.301	.167	3.243	1	.072	1.352	.974	1.876
Chronically sick member(s)	.299	.156	3.668	1	.055	1.349	.993	1.832
Constant**	-1.141	.131	76.359	1	.000	.319		

* p<.05
** p<.01

Comparison of Models

The models relating inconsistent infrastructure access variables, social vulnerability variables and food insecurity demonstrated different model test statistics. Both of the models relating inconsistent infrastructure access and social vulnerability variables to the HDDS demonstrated an insignificant Hosmer and Lemeshow Test, although both models also demonstrated low R^2 values (with the inconsistent infrastructure access regression model demonstrating the higher values of the two). The inconsistent infrastructure access model also accurately categorized 61.9% of cases according to HDDS scores (compared to the 57.9% of cases categorized by the null model). The social vulnerability model accurately categorized 59.7% of cases (compared to 54.6% of cases accurately categorized by the null model). Both of these analyses were performed at the 0.5 cut-off. These statistics demonstrate that there is little difference between these models in the extent to which they fit the data being modelled and indicate that neither model is a particularly good predictor of household dietary diversity.

The model relating the inconsistent infrastructure access variables to the HFIAP and the model relating the social vulnerability variables to the HFIAP demonstrated very different model test statistics. The inconsistent infrastructure access model demonstrated an insignificant Hosmer and Lemeshow Test while the social vulnerability model demonstrated a significant Hosmer and Lemeshow Test. This finding suggests that there is less evidence that the inconsistent infrastructure access model is a poor fit to the data than the social vulnerability model. The inconsistent infrastructure access model also demonstrated significantly higher R^2 values when compared to the social vulnerability model. These test statistics demonstrate that the inconsistent infrastructure access model appears to be a much better fit of the data than the social vulnerability model. While the social vulnerability model only accurately categorized 71.1% of cases (at the 0.5 cut-off), and there was no difference in this accuracy percentage compared with the null model, the inconsistent infrastructure access model accurately categorized 74.5% of cases (compared to the 71.2% of cases accurately categorized by the null model) at the 0.5 cut-off. The differences in these test statistics across the two models indicate that the inconsistent infrastructure access model was a superior predictive model than the social vulnerability model.

The differences between the model test statistics for the models relating inconsistent infrastructure access and social vulnerability to the MAFHP were limited. Both models demonstrated an insignificant Hosmer and Lemeshow Test and low R^2 values, giving inconsistent evidence that either model was a poor fit to the data collected in this investigation. The inconsistent infrastructure access model accurately categorized 69.1% of cases (compared to the 61.4% of cases accurately categorized by the null model) at the 0.5 cut-off. The social vulnerability model accurately categorized 67.2% of cases (compared with the 59.6% of cases accurately categorized by the null model) at the 0.5 cut-off. These model test statistics demonstrate that there are limited differences in data fit between these two models, suggesting that neither model is a particularly superior predictive model of the MAHFP.

Of all the regression models compared here, the inconsistent infrastructure access model predicting HFIAP scores was the superior model in terms of both data fit and predictive ability in its own right and in comparison with the social vulnerability regression models created here. Using the log-odds from this model, it is possible to design a regression equation to predict HFIAP scores. Expressed in one way, that equation would read as:

Equation 14. Regression Equation Relating Inconsistent Infrastructure Access to the HFIAP

$$\ln\left(\frac{P(HFIAP > 1)}{\left(1 - P(HFIAP > 1)\right)}\right) = -0.161 + 0.739X_1 + 0.950X_2 + 1.169X_3 + 1.346X_4$$

Where, the natural logarithm of the probability that a household will score greater than 1 on the HFIAP (demonstrating any form of insecure food access in the scale) is equal to the sum of the constant and the log-odds that an increase of 1 in each inconsistent infrastructure access variable will increase a household's score on the HFIAP. The inconsistent infrastructure access variables can be read as X_1= household access to water, X_2= household access to electricity, X_3= household access to medicine or medical care, and X_4= household access to a cash income. As a reminder, each of these variables is binary where a 0 represents consistent household access to the infrastructure resource or service in the last year and a 1 represents inconsistent or no household access to the infrastructure resource or service in the last year. While this equation is an accurate representation of the regression model, it is does not lend itself to easily calculating the probability of a household scoring greater than a 1 on the HFIAP. In order to facilitate this calculation, the equation can be reconfigured and expressed as the following:

Equation 15. Reconfigured Regression Equation Relating Inconsistent Infrastructure Access to the HFIAP

$$P(HFIAP > 1) = \frac{e^{-0.161+0.739X_1+0.950X_2+1.169X_3+1.346X_4}}{1 + e^{-0.161+0.739X_1+0.950X_2+1.169X_3+1.346X_4}}$$

Using the survey data collected in Maputo, this equation demonstrated 75% accuracy in categorizing households according to their HFIAP score (to be specific, whether the household scored a 1 or greater than a 1 on the HFIAP). The regression equation was 77% sensitive to food insecurity, accurately categorizing 77% of households which were categorized as food insecure on the HFIAP, while demonstrating a lower specificity score, accurately categorizing 67% of food secure households. These scores are reflected in the false positive and false negative rates for this equation. The regression equation demonstrated a false positive rate (the rate of falsely predicting household food insecurity) of 14% and the regression equation demonstrated a false negative rate (the rate of falsely predicting food security) of 45%. In other words, the equation made fewer errors in categorizing households which were food insecure and demonstrated more errors in categorizing households which were food secure. Together, these scores demonstrate that this equation has a bias towards the prediction of household food insecurity rather than household food security.

While these comparisons demonstrate the differences between the two groups of independent variables as explanations of the three food security measures, further analysis is needed in order to compare the relative explanatory value of each individual variable included in this analysis. In particular, this comparison needs to take into account the influences of other variables by holding the values for the rest of the variables constant in these comparisons. As such, these variables need to be included in overall regression models in order to effectively compare the importance of each independent variable in their relationship with the three food security measures.

Comparison of Variables

The following binary logistic regression models are not meant to be used in the design of regression equations to predict household food insecurity. Instead these models are meant to allow for a comparison of independent variables in such a way that holds the influence of all other variables in the model constant. By doing so, these models facilitate a better comparison of the significance for each variable in determining household food insecurity. As is indicated in this section, some of the models may demonstrate significant Hosmer and Lemeshow values, low pseudo R^2 values, or other factors that may bias the overall model's predictive validity. For this reason, these models are only used as a platform to compare the relative relational strength of each of the independent variables in this investigation against the three dependent variable food security measures in such a way that controls the impacts of other variables in the equation. These models are therefore not meant to be used to predict food insecurity, only to compare the strength of relationship among the independent variables in the regression model with the dependent variables (the HDDS, HFIAP, and MAHFP).

The regression model analyzing the relationship between all independent variables in this investigation (both inconsistent infrastructure access and social vulnerability variables) and the HDDS dependent variable demonstrated some problematic model test statistics. A Hosmer and Lemeshow Test demonstrated a significant p-value at the .05 level ($x^2(8) = 18.209, p = 0.020$), suggesting that the model has a poor data fit. The model also demonstrated a Cox and Snell R^2 value of 0.069 and a Nagelkerke R^2 value of 0.093, suggesting that this model is not a very superior predictive model compared to the null model. This model also accurately categorized 62.5% of cases according the HDDS variable categories. The null model accurately categorized 55.0% of cases (both at the 0.5 cut-off) according to the HDDS variable. The highest Pearson's r correlation coefficient observed among the independent variables in this model was a -.425 between access to water and electricity. These model test statistics suggest a poor model fit and may also suggest multicollinearity (although Tolerance and VIF statistics for these variables suggest that this may not be the case). All variables included in this investigation demonstrated Tolerance values between .699 and .943 and VIF values between 1.058 and 1.433

The regression model indicates that only three variables are significant predictors of HDDS scores (holding all other variables in the model constant): low household income, a large household size, and the consistency of access to a cash income. That said, the impact of these variables on HDDS scores is qualitatively different across each variable. Households with low income had 1.643 times greater odds of having lower dietary diversity compared to households with higher income, holding other variables in the model constant. Households with inconsistent/no access to a cash income had approximately twice the odds of having a low dietary diversity, holding other variables in the model constant. The relationship between household size and dietary diversity was significantly different. The model indicated that households with more than five members had about 36% less odds of having low dietary diversity compared with smaller households, holding all other variables in the model constant.

Table 29. Household Infrastructure Access and Social Vulnerability Indicators and HDDS Binary Logistic Regression Results

Variables	B	S.E.	Wald	df	P value	Exp(B)	95% C.I.for EXP(B)	
							Lower	Upper
Household head sex	-.242	.165	2.147	1	.143	.785	.568	1.085
Household head education	.237	.228	1.081	1	.299	1.267	.811	1.981
Household head employment status	.359	.184	3.788	1	.052	1.432	.997	2.055
Informality of dwelling	.039	.384	.010	1	.920	1.040	.490	2.207
Low income tercile**	.496	.168	8.753	1	.003	1.643	1.182	2.282
Household size >5**	-.451	.167	7.258	1	.007	.637	.459	.884
Chronically sick member(s)	-.268	.155	2.987	1	.084	.765	.564	1.037
Consistent access to clean water	-.261	.181	2.078	1	.149	.770	.540	1.098
Consistent access to electricity	.208	.173	1.436	1	.231	1.231	.876	1.729
Consistent access to medical care	.034	.201	.028	1	.867	1.034	.698	1.532
Consistent access to cash income**	.709	.178	15.764	1	.000	2.031	1.432	2.882
Constant*	-.394	.136	8.380	1	.004	.674		

* p<.05
** p<.01

The regression model analyzing the relationship between all the indicators included in this investigation and HFIAP scores demonstrated predominantly strong model data fit test statistics. The one exception was the Hosmer and Lemeshow values observed for this model. The Hosmer and Lemeshow test demonstrated a significant chi-square value ($x^2(8) = 24.117, p = 0.002$), suggesting a poor model fit. That said, a Cox and Snell R^2 test demonstrated a value of 0.229 while a Nagelkerke R^2 test demonstrated a value of .327 (the highest values observed for these tests so far in this investigation). In addition, this model accurately categorized 78.0% of cases (again the highest value observed for any model in this investigation) while the null model accurately categorized 70.8% of cases (at the 0.5 cut-off), suggesting an even better model fit than the HFIAP model designed using only the inconsistent infrastructure access variables. These test statistics demonstrate that this model may be a reliably predictive model (given how conservative the Hosmer and Lemeshow test can be under certain conditions). The highest Pearson's r correlation coefficient observed among the independent variables in this model was a

-.428 between the access to water and access to electricity variable (which may suggest multicollinearity, again; however, the Tolerance and VIF values for this model suggest that this is not the case). All variables included in this investigation demonstrated Tolerance values between .699 and .943 and VIF values between 1.058 and 1.433.

The model relating all indicators to HFIAP scores demonstrated that six variables were significant predictors of HFIAP scores: low income, household size, and access to electricity, water, medical care and a cash income. The model indicated that households with low income had approximately 3 times greater odds of being categorized as food insecure on the HFIAP compared with higher income households, holding other variables in the model constant. Households with inconsistent access to either electricity or medical care also had approximately 3 times greater odds of being categorized as food insecure on the HFIAP (holding other variables in the model constant). Access to water and a cash income also increased the odds of a household being categorized as food insecure on the HFIAP by approximately 2 (holding other variables in the model constant). Households that had more than 5 members had approximately 67% greater odds of being categorized as food insecure, holding all other variables constant.

Table 30. Household Infrastructure Access and Social Vulnerability Indicators and HFIAP Binary Logistic Regression Results

Variables	B	S.E.	Wald	df	P value	Exp(B)	95% C.I.for EXP(B)	
							Lower	Upper
Household head sex	-.012	.201	.003	1	.953	.988	.666	1.466
Household head education	.165	.311	.283	1	.595	1.180	.641	2.170
Household head employment status	.247	.237	1.085	1	.298	1.280	.805	2.035
Informality of dwelling	.324	.680	.227	1	.634	1.383	.364	5.248
Low income tercile**	1.153	.238	23.499	1	.000	3.169	1.988	5.052
Household size >5*	.513	.210	5.952	1	.015	1.671	1.106	2.524
Chronically sick member(s)	.178	.188	.897	1	.344	1.195	.826	1.729
Consistent access to clean water*	.617	.250	6.101	1	.014	1.853	1.136	3.024
Consistent access to electricity**	1.132	.211	28.801	1	.000	3.103	2.052	4.692
Consistent access to medical care**	1.148	.350	10.724	1	.001	3.151	1.585	6.263
Consistent access to cash income**	.738	.248	8.880	1	.003	2.091	1.287	3.397
Constant**	-.620	.154	16.158	1	.000	.538		

* p<.05
** p<.01

The regression model relating all indicators in this model to the MAHFP demonstrated some solid model test statistics, which indicate that this model may have a good fit to the data collected in this investigation. A Hosmer and Lemeshow test demonstrated an insignificant chi-square value ($x^2(8) = 9.507, p = 0.301$). The model also demonstrated a Cox and Snell R^2 value of 0.184 and a Nagelkerke R^2 value of 0.248. These test statistics give little evidence that the model is a poor fit to the data included in this investigation. The model also accurately categorized 69.9% of cases while the null model only accurately categorized 59.8% of cases (both at the 0.5 cut-off). The highest Pearson's r correlation coefficient observed among the independent variables in this investigation was -.429 between access to water and electricity. As mentioned before, the VIF and Tolerance values for these variables suggest that multicollinearity was not a factor among the independent variables in this model. All variables included in this investigation demonstrated Tolerance values between .699 and .943 and VIF values between 1.058 and 1.433.

The model relating all variables to the MAHFP demonstrated that only four variables were significant predictors of the MAHFP: household head employment status, low household income, access to medical care and access to a cash income. Low income and inconsistent/no access to a cash income both increased the odds of households going without monthly adequate food provisions by 2.7 times (holding other variables in the model constant). Inconsistent/no access to medical care increased the odds of a household going without monthly adequate food provisions by 1.7 times (holding other variables in the model constant). Households with unemployed household heads had approximately 50% greater odds of going without monthly food provisions when compared to households with employed household heads (holding other variables in the model constant).

Table 31. Household Infrastructure Access and Social Vulnerability Indicators and MAHFP Binary Logistic Regression Results

Variables	B	S.E.	Wald	df	P value	Exp(B)	95% C.I.for EXP(B)	
							Lower	Upper
Household head sex	-.080	.179	.200	1	.655	.923	.650	1.310
Household head education	.020	.246	.006	1	.936	1.020	.630	1.651
Household head employment status*	.416	.197	4.467	1	.035	1.515	1.031	2.228
Informality of dwelling	.578	.430	1.805	1	.179	1.782	.767	4.143
Low income tercile**	.998	.176	32.142	1	.000	2.714	1.922	3.833
Household size >5	.179	.178	1.006	1	.316	1.196	.843	1.696
Chronically sick member(s)	.224	.167	1.804	1	.179	1.251	.902	1.734
Consistent access to clean water	.305	.192	2.521	1	.112	1.356	.931	1.975
Consistent access to electricity	.057	.188	.092	1	.762	1.059	.732	1.531
Consistent access to medical care**	.590	.209	7.967	1	.005	1.804	1.198	2.717
Consistent access to cash income**	1.005	.185	29.677	1	.000	2.733	1.903	3.923
Constant**	-1.572	.162	94.470	1	.000	.208		

* p<.05
** p<.01

Results Summary

All of the social vulnerability variables included in this investigation demonstrated a statistically significant relationship with the household food insecurity measures independently (according to the chi-square and fisher's exact tests), with the exception of the female-headed household variable and the household size variable. Female headed households did not demonstrate a statistically significant relationship with HDDS, while larger households did not demonstrate a statistically significant relationship with the MAHFP in the odds-ratio calculations. These calculations also demonstrated paradoxes, where larger households and households with chronically ill household members had reduced odds of having limited household dietary diversity (although the reduction in odds was small). The presence of the remaining social vulnerability variables increased the odds of a household becoming food insecure independently in the odds ratio calculations. In the regression analyses, only the low income tercile variable significantly increased the odds of household food insecurity across the three food insecurity measures. Among the remaining independent social vulnerability variables, the independent variables which significantly predicted food insecurity varied by household food insecurity measure.

The analyses completed in this chapter also included a comparison of regression models and independent variables. The comparison of regression models demonstrated that, among the inconsistent infrastructure access and social vulnerability regression models in this investigation, the inconsistent infrastructure access model predicting the HFIAP is the most reliable and predictive model (as determined by Hosmer and Lemeshow Tests and pseudo R^2 values). In other words, this model fit the data collected in this survey well and was a better predictor of food insecurity than the other models reviewed here. The regression equation that was built from this model demonstrated 75% accuracy in categorizing households in Maputo according to their HFIAP score. The equation demonstrated a bias towards the prediction of household food insecurity at the cost of accurately predicting household food security. The independent variable comparisons presented in this chapter demonstrate that, holding social vulnerability variables constant, inconsistent social and physical infrastructure access is a significant predictor of the HFIAP (significantly increasing the odds of a household experiencing reduced food access) while inconsistent social infrastructure access is a significant predictor of the MAHFP (significantly increasing the odds of a household experiencing reduced long term food access). Among the inconsistent infrastructure access variables, only inconsistent access to a cash income significantly increased the odds of a low HDDS score.

Chapter Seven: Conclusions

Summary of Findings

Before presenting the conclusions of this research in detail, it is important to make a note here on how to interpret the results of the analysis as a whole. As described in the methods section, the progression of analyses was intentional. *First*, each independent variable was assessed as a significant predictor of each food security measure (independent of all other variables). In this stage of analysis, each independent variable was found to be a significant predictor of at least one of the food security measures. This was especially true of the HFIAP, of which all the independent variables in this investigation (both inconsistent infrastructure access variables and social vulnerability variables) were found to be significant predictors (in that each independent variable significantly increased the odds of household food insecurity). *Second*, these independent variables were assessed in two groups (inconsistent infrastructure access variables and social vulnerability variables) to compare how well each group of variables predicted the three measures of food insecurity. In this stage of analysis, there was inconsistent evidence to suggest that the group of inconsistent infrastructure access variables was a better predictor of food insecurity than the group of social vulnerability variables, with the exception of the HFIAP. The inconsistent infrastructure access model of the HFIAP was found to be the superior model when compared to the social vulnerability model of the HFIAP. This model was so superior, in fact, that the regression equation developed from this model demonstrated that the four inconsistent infrastructure access variables (access to water, electricity, medical care and a cash income) categorized households according to HFIAP scores with 75% accuracy among the sampled households in Maputo. This means that if one only knew how the sampled households responded to the four questions about inconsistent infrastructure access in the survey; it would be possible to predict whether a given surveyed household was categorized as food insecure on the

HFIAP with 75% accuracy. *Third*, each independent variable was included in a regression model to predict the three food security measures. This was done in order to compare the relative importance of these variables as predictors of the food insecurity scores when all the other independent variables in this investigation were held constant. In other words, is the impact of each independent variable on food insecurity still significant when all other variables in this investigation are held constant? In this stage of analysis, inconsistent infrastructure access remained a significant predictor of the HFIAP and inconsistent social infrastructure access remained a significant predictor of the MAHFP while many of the social vulnerability variables became insignificant predictors when the inconsistent infrastructure access variables were held constant. This means that, relative to all the variables in this investigation and controlling for the impact of all of these variables (including income poverty), inconsistent access to infrastructure increased the odds that a household would have limited short-term and long-term food access among the sampled households in Maputo.

The development of the regression equation to predict household food access (as determined by the HFIAP score of a given household) among the sampled households in Maputo represents one of the most significant findings in this investigation. This equation demonstrates how well inconsistent infrastructure access can predict household food access among the sampled households in this city. This finding is also likely the most immediately useful output of this research. If the results of this study are validated by future research, it may now be possible to infer household food access by mapping out inconsistent infrastructure access in Maputo. This equation is a novel contribution to food insecurity research. The equation demonstrates that urban household vulnerability to food insecurity in Maputo may be a function of factors related to urban planning and design in addition to income poverty. As such, this equation demonstrates that there are urban environmental factors which might determine that household's vulnerability to food insecurity in addition to the demographic characteristics of a household (even when those characteristics include low household income).

The results of this investigation indicate that a lack of consistent household access to social and physical infrastructure was associated with increased household sensitivity to food insecurity and therefore may have influenced the vulnerability of that household to food insecurity among the sampled households in Maputo (given that this relationship was not falsified by this investigation). This relationship was not uniform across measures of food insecurity, as demonstrated by the regression analyses which included all independent variables. While inconsistent social and physical infrastructure access was a significant predictor of household food access (via the HFIAP) and social infrastructure was a significant predictor of long-term food access (via the MAHFP), inconsistent infrastructure access played a less significant role in predicting household dietary diversity (via the HDDS) among the sampled households. Interestingly, only access to a cash income was a significant predictor of household dietary diversity among the inconsistent infrastructure access variables in these analyses (and holding all other variables in the model constant). Other indicators like household size and household income was a more significant determinant of household dietary diversity in this analysis. In all of these findings from the regression analyses including all independent variables, low household income was controlled for.

For all measures of household food insecurity in this investigation, low household income was a significant predictor among the sampled households. This finding was unsurprising given the extent of the background research literature that suggests that household income is a significant determinant of household food insecurity. This finding demonstrates the critical role that income plays in determining household food insecurity among the sampled households in Maputo. Even when the various social vulnerability and inconsistent infrastructure access variables were taken into account, low household income was still a significant and strong predictor of all three measures of food insecurity among the sampled households. In other words, this case study does not rule out low household income as a predictor of household food insecurity, rather, this case study demonstrates that while low household income is still a significant predictor of household food insecurity among the sampled households in Maputo, it is not the only predictor. When low household income is controlled for, inconsistent infrastructure access is still a significant predictor of food insecurity.

It is interesting to note that the informality of the dwelling construction was not a significant predictor of the three food security scales in the regression models in spite of being a significant predictor of all three food security scales when assessed independent of the other variables. This finding suggests that the impact of the informality of the dwelling construction on food insecurity may be better explained by inconsistent infrastructure access and low income among the sampled households in Maputo (although this finding will have to be assessed by further research). Given that inconsistent infrastructure access was held constant in the odds ratio calculation for this finding, it appears that the impact of informality on household food security may have more to do with the inconsistent infrastructure access components of informality (potentially the informal area in which a household resides) as opposed to the hazard exposure resulting from the dwelling construction per se (the characteristics of the household itself). That said, further research is required to validate this conclusion.

The relationship between household access to clean water and household food insecurity was a surprising result of this investigation. Household access to water was only a significant predictor of household food access among the sampled households (holding all other variables in this investigation constant), in spite of the intuitive link between water and food insecurity in the regression analyses which included all independent variables. One potential explanation for this finding may be the unique situation of water access in Maputo. The main source of clean water in Maputo is via the formal water utility grid. Access to this grid can be expensive and service can be inconsistent. When access to the formal water grid is down and other informal water services are unavailable, households cope by accessing water from boreholes (Ahlers et al., 2013; Rusca & Schwartz, 2012). This water, however, is susceptible to contamination (Vicente et al., 2006). Thus, while a household may go without consistent access to clean water, there are multiple sources for household water access. These multiple sources allow a household to cope with inconsistent water access. In addition, inconsistent water access is a common occurrence among households in Maputo. It is also common for households to make use of bottled water for clean water access rather than relying on water utilities.

Knowledge Gap and Research Contributions

As of the time of this dissertation, there is limited published empirical evidence to demonstrate that inconsistent infrastructure access has any impact on urban household vulnerability to food insecurity. Although, this research builds upon the work by both Ogun (2010) and Canning & Bennathan (2000) which suggest that infrastructure can play a role in determining urban household poverty, this investigation took a different focus. The results of this investigation differentiate the extent to which inconsistent household access to different forms of infrastructure services (social and physical) are associated with household vulnerability to food insecurity among the sampled households in Maputo. This investigation also determined the differential predictive strength of common social vulnerability characteristics versus inconsistent infrastructure access variables in predicting urban household vulnerability to food insecurity among the sampled households. This approach facilitated the discovery of the relative importance of low household income compared with inconsistent infrastructure access in predicting household vulnerability to food insecurity. In summary of these contributions, this investigation demonstrated that inconsistent infrastructure access plays an important role in predicting household vulnerability to food insecurity among the sampled households in Maputo. Furthermore, the importance of inconsistent infrastructure access in predicting household vulnerability to food insecurity was not better explained by low income or other previously established social vulnerability variables (given that these variables were held constant).

Contributions to Urban Food Security Research

This investigation identified some of the key predictors of household food insecurity in a growing urban area within a developing nation. These predictors could provide a springboard for future research into the factors influencing the household food security outcomes of urban food systems. This is a key area of research, given the different urban food system designs and objectives reviewed by Morgan and Sonnino (2010). The predictors identified in this Maputo case study could help researchers better understand the challenges that may help to explain inequity in inconsistent urban infrastructure access and provide alternative household food security strategies that focus on the infrastructural supports for urban household food security. While the results of this investigation will need to be validated by future research, it appears that inequitable access to infrastructure may be an underlying mechanism to explain inequity in food access across cities. As such, this research could help to inform the design of sustainable food systems in cities by integrating factors external to a food system that facilitate food access.

If future studies are able to validate the claims made in this investigation, these predictors may be used to map households that are vulnerable to food insecurity in urban areas. In this application, these identifiers could serve as an aid in targeted urban food security interventions among cities in developing nations. In both of these applications, the indicators identified as significant predictors of household food insecurity in this investigation could help to identify households vulnerable to food insecurity where no information exists on household food insecurity.

This investigation also identifies a potential role for urban planning in managing the future of urban food security. Given the kinds of pressures that are projected to impact global food security (in the form of climatic events and growing human populations) (Godfray et al., 2010), efficient and effective urban food system designs will come to play a significant role in bolstering urban household food security. Planning cities in such a way that facilitates household access to both physical infrastructure services (via constructing water and electrical grids to incorporate future residential growth) and household access to social infrastructure services (via the effective governance of systems of institutions such as hospitals and banks) will become an increasingly important obligation. This focus on urban development builds from Bosher and Dainty's (2011) concept of built-in resilience by recommending the integration of multiple domains (social and physical infrastructure) in holistic urban planning.

Contributions to Social Vulnerability Research

This investigation demonstrated the methodological effectiveness of conceptualizing food insecurity as the impact of a hazard in determining household vulnerability to food insecurity. By conceptualizing food insecurity in this way, it was possible to use simple statistical methods to investigate food insecurity vulnerability. This conceptualization allows the discussion of food insecurity to shift from the assumption that low income households are uniformly affected by food supply shocks. Instead, there are household characteristics that either increase or decrease the likelihood of a household experiencing food insecurity. This approach also demonstrates that the hazard of food insecurity is not a completely natural process. The likelihood of household food insecurity is instead the result of both natural factors (such as famine, drought, or disease) and social factors (such as household income and inconsistent household infrastructure access).

This investigation gives further evidence that household sensitivity, as a measure of vulnerability, is a useful theoretical framework that is open to empirical falsification using regression analysis. While this was a narrow definition of vulnerability, the approach nonetheless facilitated an operationalization of vulnerability which could be easily tested using statistical analysis. This investigation also demonstrated the link between common social vulnerability indicators (indicators which had been previously established in social vulnerability literature) and household level food insecurity. While many of these indicators did not significantly increase the odds of household food insecurity in the regression models, some (such as household income, household size and household head employment) were validated by this investigation as significant predictors of food insecurity, even while inconsistent infrastructure access was held constant.

In addition to providing evidence for the validity of the theoretical framework used in this study, this study also provided evidence for the validity of the Access Model (Wisner et al., 2004) in explaining urban household vulnerability to food insecurity (when food insecurity is treated as the impact of a hazard). In particular, this study demonstrated that sampled households with inconsistent access to infrastructure in Maputo had increased odds of having limited food access. This finding provides external validity for the use of this model by demonstrating that the model was not falsified in the context of this case study of Maputo. If, on the other hand, the Pressure and Release model (Birkmann, 2006) is used to interpret the results of this investigation, a lack of investment in infrastructure may provide the root causes of household vulnerability to food insecurity. Comfort's (2006) case study of Hurricane Katrina provides external validity for this interpretation and Ogun's (2010) work suggest this may be a deductively sound conclusion. Future longitudinal research is still needed, however, to validate this interpretation of these results. Similar to the Access Model, the findings of this investigation may also lend a different perspective on the Process of Marginalization (Wisner & Luce, 1993). If inconsistent infrastructure access predicts household vulnerability to food insecurity, this might explain how a deteriorating physical environment can predispose a human population to the impact of a hazard. This interpretation is nuanced in the Holistic Model (Birkmann, 2006), where vulnerabilities to a hazard are determined by both hard (physical deterioration) and soft risk (socio-economic fragility), similar to this investigation's conceptualization of social and physical infrastructure. This interpretation is validated by the Sustainable Livelihoods Framework, which articulates the importance of different forms of social and physical capital in determining livelihood outcomes (Birkmann, 2006). That said, both of these models integrate a feedback loop which explains how adaptive coping and shocks can influence the vulnerability of a human population to a hazard impact (as described in the Onion Framework) (Birkmann, 2006). This interpretation is made clearer in both the BBC Framework and the Vulnerability Framework (Birkmann, 2006; Turner et al., 2003). These models together integrate the means by which multidimensional factors (social, economic, and environmental) can influence human vulnerability to hazard impacts over time by incorporating adaptive coping and exposure as mitigating factors in determining vulnerability. While these models validate the basic relationships observed in this investigation regarding the sensitivity of households to food insecurity, the models highlight important factors which can also influence this relationship. The impact of shocks and adaptive coping can mediate household vulnerability to food insecurity (as suggested by these models). That said, the cross-sectional nature of this investigation and the limited number of variables included here constrains the ability of this investigation to infer or test such relationships. In summary, while this investigation is externally validated by some features of these models, the models also describe the broader contextual factors which will need to be investigated in order to better situate the findings of this investigation in the social vulnerability literature.

Contributions to Interdisciplinary Research

Identifying the contributions of this research according to interdisciplinary and transdisciplinary literature is a challenge. While Lawrence (2010) observes that there is no standard definition of either transdisciplinary or interdisciplinary (except for the consensus that they are not identical terms), Huutoniemi (2010) suggests that transdisciplinary research is a more focused approach within the broader field of interdisciplinary research. Broadly speaking, interdisciplinary research involves the integration of knowledge and tools from multiple disciplines to inform the investigation of a research topic that lies between disciplines. Hadorn et al. (2007) suggests that transdisciplinary research is defined by its four foci: a real world problem focus, the integration of paradigms from different disciplines, a participatory approach, and a research product which integrates knowledge across disciplines. Stokols (2006) in particular notes the importance of maintaining a focus on solving real world problems within a participatory paradigm (which applies to both the epistemology and methodology in an investigation) in transdisciplinary research. The integration of disciplinary knowledge in order to develop a unifying knowledge product makes both transdisciplinary and interdisciplinary research an epistemological challenge, especially when it comes to assessing the contributions of that research (Klein, 2008). Every epistemology is deductively premised on assumptions regarding the nature of knowledge (Miller et al., 2008). When attempting to implement multiple epistemologies in research, those assumptions can conflict and create an internally incoherent research production (a research product whose methods contradict the epistemology it is predicated on).

This investigation draws from multiple disciplines and is also designed for action by informing policies regarding urban development and sustainability in order to solve a real-world problem. That said, this investigation is a cross-sectional and non-iterative research design which is action-oriented only in the application of the results. This research is also situated in two fields (food security and social vulnerability) that are at the intersection of different disciplines. In addition, this investigation draws tools and concepts from multiple disciplines in order to inform the defense of its thesis. Given that this investigation is at the intersection of disciplines of study and makes use of statistical and conceptual tools to inform the defense of its thesis, this investigation is likely better described as an interdisciplinary investigation rather than a transdisciplinary investigation (Hadorn et al., 2007; Huutoniemi, 2010). As an interdisciplinary investigation, this research provides two contributions to the field in the use of interdisciplinary models and methods.

This investigation demonstrated the usefulness of social vulnerability models as an explanation for household vulnerability to food insecurity, bridging the fields of food security and disaster risk reduction. The integration of these social vulnerability models allowed this investigation to take on a more nuanced understanding of the mechanisms involved in household vulnerability to food insecurity. Rather than conceptualizing the mechanisms which predispose households to food insecurity as causal (e.g. low household income causing food insecurity), this investigation reconceptualised those mechanisms as vulnerabilities (e.g. inconsistent infrastructure access increases the odds of food insecurity). By reconceptualising these mechanisms as vulnerabilities, this investigation was able to identify variables which increase household sensitivity to food insecurity while remaining outside an intuitive causal relationship with household food insecurity. As such, this reconceptualization of the mechanisms involved in household food insecurity contributes a more nuanced understanding of how household food insecurity can occur.

This investigation also demonstrates the usefulness of statistical modelling as a means of testing interdisciplinary theoretical frameworks for the purpose of informing action. The statistical tests involved in regression modelling presents a standardized procedure to weigh the influence of operationalized concepts in a theoretical model on an operationalized target of interest (in this case, household food security). This investigation therefore contributes to the growing literature that demonstrates the usefulness of statistical modelling as a means of both testing theoretical frameworks and informing policy. That said, the methodology used in this investigation was not able to represent dynamic relationships inherent to social processes (such as multi-scalar effects and feedback loops). Future development of methodologies to define these challenging relationships will be essential in order to develop a clearer interpretation of social processes like social vulnerability.

There is one aspect of this investigation which falls short of a “purist” approach to interdisciplinary investigations. Miller et al. (2008) highlight the importance of maintaining a pluralist epistemology in interdisciplinary research. A pluralist epistemology integrates multiple approaches to knowledge to inform the research methodology and the interpretation of the results. While this investigation is an interdisciplinary investigation, the analysis presented in this dissertation is still predicated on one epistemology (post-positivism). This epistemology informs the methods used in this investigation as well as the limitations of this research. While the choice of a post-positivist epistemology is valid in the context of this investigation (in that the final research product is internally coherent and defensible), there are many other equally valid epistemological approaches to interpreting the results from this investigation. Thus, this investigation does not discount alternative epistemologies, rather, this investigation made use of one epistemology which supported the methods used to defend the thesis.

Contributions to Theory

Using Popper's method of falsification (disproving the premises of knowledge) (Popper, 1935), this study demonstrates the extent to which the theoretical framework used in this investigation explains household food insecurity in Maputo. This framework is corroborated by the results of this investigation, which demonstrate that inconsistent infrastructure access does explain household food insecurity (household food access in particular) in Maputo. That said, this theoretical framework cannot be validated using only one case. Further empirical study will be required in order to test this theory.

This investigation also highlighted the role of access across both food security measures and inconsistent infrastructure access measures. The fact that inconsistent infrastructure access was a significant predictor of household food access measures (almost exclusively), demonstrates that there may be an overarching access phenomenon that may explain this relationship. In other words, inconsistent access to one resource may influence inconsistent household access to another resource. As an example, inconsistent household access to water may be associated with inconsistent household food access. One explanation for the influence of inconsistent access across these domains may be explained by household trade-offs of a fixed resource (household income), where a limited resource may cause inconsistent access in multiple domains.

Another explanation for this phenomenon may be a hierarchy of access needs, where, higher order needs (access to more important resources/services) are maintained while lower order needs (access to less important resources/services) may be sacrificed. If this were true, then the loss of a higher order need would only occur after lower order needs were sacrificed. In other words, the loss of a higher order need would necessarily occur along with the loss of a lower order need. For example, a household would first go without access to food before going without access to a cash income (as a self-limiting strategy).

The relationship between inconsistent access to infrastructure services and household food access may be better explained by the Access Model (Wisner et al., 2004). This model suggests that inconsistent access to resources increases the vulnerability of a household to the impacts of a hazard (like food insecurity). The Access Model, however, does not provide a clear explanation for how access to resources can be linked in the manner discussed here. This model may, however, provide a theoretical framework for future research on this phenomenon.

Contributions to the Sustainability of Socio-Ecological Systems

Sustainability was famously described in the 1987 Brundtland report as intragenerational and intergenerational equity (Brundtland, 1987). In other words, the Brundtland report suggested that sustainable development should meet the needs of the current and future generations equitably. Since that time, this sustainability term has been expanded to include a number of other criteria (see Gibson, 2005), but the original concept remains a helpful reference. Turner (2010) noted that parts of vulnerability and sustainability research share a synergistic relationship. Both of these areas of research investigate socio-ecological system interactions and the transfer of shocks across these two systems. Turner et al. (2003) furthermore suggested that these two fields share the investigation of climate change impacts on socio-ecological systems. As sustainability research continues to note the impending environmental hazards resulting from human activity, vulnerability research complements this research in the identification of vulnerable populations sensitive to those changes. Given these two complementary components of sustainability, this investigation makes two contributions to the sustainability of socio-ecological systems: the definitions of potential mechanisms underlying inequity and the identification of human vulnerabilities to natural hazards.

This investigation contributes to the sustainability of socio-ecological systems by providing insights into the factors that determine urban food insecurity vulnerability in Maputo. By demonstrating the impact that inconsistent infrastructure access can have on household food security, this investigation highlights the important role of sustainable urban development that ensures equitable access to infrastructure for urban household food security. As such, this investigation contributes to sustainability by determining the factors that may underlie inequitable access in developing urban areas. Sneddon et al. (2007) notes that inequitable access to economic opportunities is on the rise and a threat to sustainable development and that inequity has not been solved by economic growth as Brundtland suggested. This investigation demonstrates that there are externalities to economic development (such as inconsistent infrastructure access, even when low household income is accounted for) which may explain why some households remain food insecure in addition to economic factors like household income.

This investigation also aided in the identification of human vulnerabilities to natural hazard impacts. Given the projected impacts of climate change on the already strained current food system (Brown & Funk, 2008), food shortages are set to become a more frequently occurring hazard facing the future urban population (Godfray et al., 2010; Morgan, 2009). This investigation demonstrated that, while the threat of food shortages is present, the impact of those food shortages will likely be uneven. If these results are validated in other cities, vulnerable urban households are much more likely to experience food insecurity due to their inconsistent access to infrastructure.

Given these contributions to sustainability research, it is therefore essential that the infrastructure within Maputo is designed in such a way that supports household access to essential resources like water, electricity, a cash income, and medical care in order to reduce the vulnerability of future urban populations to food insecurity. In relation to the theoretical framework of this investigation, food insecurity needs to be framed from a socio-ecosystem perspective which demonstrates how the impact of environmental threats to food production may be mitigated by infrastructure development. This approach conceptualizes food insecurity as the impact of an interaction between two systems (a hazard and a vulnerable population). In this conceptualization, infrastructure development mediates the impact of a hazard on a vulnerable population, thus household food security.

Contributions to Policy

Between 1984 and 2008, 16 tropical storms ranging in wind speed from 37 to 213 km/hr made landfall in Mozambique. Maputo risks an annual GDP of 18 million USD from the impact of rising sea levels and storm surges over the next 40 years (Neumann, Emanuel, Ravela, Ludwig, & Verly, 2013). The research provided in this dissertation may provide direction to disaster mitigation efforts in Maputo by describing the potential mechanisms through which households are made vulnerable to the impacts of natural hazards (specifically in regards to food insecurity). As such, this investigation suggests the relative importance of different indicators in determining household vulnerability to food insecurity as the result of these hazards. These findings have implications for policy development in Maputo, if interpreted correctly and if these findings are corroborated by further research.

The identification of household vulnerabilities to food insecurity contributes to policy action by giving windows of opportunity through which to intervene. The Holistic model (Birkmann, 2006) demonstrates that the identification of disaster risk can inform the management of disaster mitigation. By identifying the vulnerability characteristics that increase the sensitivity of households to food insecurity in Maputo, it is possible to begin building policies that can limit the presence of those vulnerability characteristics in an urban population in order to bolster household food security. That said, this investigation does not assume a causal connection between these vulnerabilities and the household experience of a hazard impact like food insecurity. As mentioned earlier, the causal mechanisms that give rise to the hazard of food insecurity (for example, climatic events, conflict, or food price volatility) are not within the boundaries of this investigation. This investigation only focused on the factors associated with household vulnerability. As such, the policy recommendations made here are exclusively in reference to limiting the vulnerability of households in Maputo food insecurity.

This research therefore contributes to public policy in Maputo by demonstrating the relationship between infrastructure and household food security in Maputo. In particular, this investigation distinguishes the different impacts of social versus physical infrastructure on household food insecurity. These insights demonstrate that infrastructure development in the city may be associated with broader impacts for household food security and demonstrate the potential relative returns on investment in different types of infrastructure. The analysis performed by Ogun (2010) made similar recommendations regarding the relative return on investment for investments on social infrastructure on urban poverty. Canning & Bennathan (2000) first attempted to describe the potential rate of return on investments in infrastructure. This investigation broadly validates the findings of both of those investigations within the context of Maputo and demonstrates that consistent household infrastructure access may reduce the likelihood of household food insecurity (if these findings are corroborated by future research). As a result, this research has the potential to redirect public funding for infrastructure development in Maputo in order to bolster food security among poor households in the city. The results of this research also have the potential to inform urban policy, disaster risk reduction policy, and food security policy in Maputo by demonstrating the characteristics of households vulnerable to food insecurity.

Some of the results of this investigation suggest that the impact of infrastructure on food insecurity may be inequitably high among female-headed households than among male-headed household in Maputo. The results suggest that the inequitable impact of being a female-headed household on food insecurity in Maputo might actually be mediated by access to income and infrastructure. This conclusion is drawn from the observation that female-headed households had significantly greater odds of being food insecure (according to the independent odds ratio calculations), but that variable became insignificant when income and inconsistent infrastructure access were controlled for. This means that the vulnerability of female headed households to food insecurity in Maputo might actually be determined by their inconsistent access to infrastructure services and low income (at least in regards to food access). While this finding should be assessed further in future investigation, these preliminary results suggest that investment in bolstering the access of female-headed households to infrastructure (through subsidies or social grants) might have a knock-on effect on the food security of those households.

This investigation also clearly demonstrated the impact of chronic illness on household food access in Maputo. Households in Maputo that contain members with a chronic illness had greater odds of having insecure food access when compared to other households. Interestingly, the regression analysis also indicated that the impact of chronic illness on household food access is statistically insignificant (using an alpha of .05) when the consistency of household access to medical care (in addition to the other variables in this investigation) is held constant. Given the two-tiered medical system in Maputo (private versus public) that favours wealthier patients, these preliminary findings suggest that investment in bolstering medical care access among poor communities may reduce the vulnerability of poor households to food insecurity (this conclusion will need to be corroborated by future research before implementation as this study only considered predictive relationships and not necessarily causal relationships). It seems that the greatest barrier to medical care access among Maputo households is medical cost and waiting times in triage at public hospitals. In which case, investment in building clinics in close proximity to poor neighbourhoods and subsidizing healthcare costs for poor households may have an impact on household vulnerability to food insecurity. Further research on this topic is required to validate this finding and to give more specific recommendations on the type of policy changes required to meet this goal.

This investigation does suggest that households in the informal areas of Maputo may be more vulnerable to insecure food access (given the impact of inconsistent access to electricity and water in these areas). The challenge of supplying infrastructure to these informal areas of

Maputo is not only in relation to the post-hoc nature of this development, but also in relation to maintaining consistency in the provision of infrastructure services. That said, power and water outages still occur within the formal areas of Maputo and, based on the findings from this investigation, may have an impact on household food access regardless of the formality of the area in which a household resides. Alternative energy sources such as solar power and alternative resource access such as rain water collection may reduce the load of household utilities use on formal utilities grids. It is possible that the provision of subsidies or tax rebates for these alternative infrastructure sources at the household level may reduce the load on these utilities, thereby limiting the number of power and water outages, and potentially having a knock-on effect for household food security. This suggestion also needs to be corroborated by further research before a causal mechanism can be inferred using the results of this investigation.

In addition to fostering alternative energy sources, the provision of infrastructure in informal settlements has been described as a predominantly private endeavor rather than public endeavor in Maputo (Baptista, 2013). Given the potential public good that bringing these infrastructure services (like water and electricity) seem to be, and the potential knock-on effects of access to this infrastructure for food security, it may be advisable to subsidize the cost or provide tax reimbursements for these private ventures. While it is in the best interests to the city to secure household access to infrastructure in Maputo, the challenge of maintaining a holistic planning vision for the city remains a challenge. Maputo is in the process of attempting to formalize many informal settlements through the provision of infrastructure and harmonizing land tenure (Cities Alliance, 2011). It will be interesting to follow how this process will impact household vulnerability to food insecurity in Maputo. That said, the results of this investigation, reinforce the necessity of this regularization program as it relates to bolstering infrastructure access.

The development of a regression equation to predict household food access using the four infrastructure services included in this investigation is likely the most solid contribution to policy development in this dissertation. With this regression equation, Governments and NGO's may be able to infer household food insecurity vulnerability more quickly through a simple and quick forced answer survey of infrastructure access (regarding the consistency of household access to water, electricity, medical care, or a cash income). Governments and NGO's can also implement the equation by inferring inconsistent infrastructure access based on infrastructure availability in different areas of Maputo. This equation has the potential to also inform household food insecurity mapping in Maputo based on the availability of different infrastructure services, the comparison of average household income to medical care costs, and estimates of cash income access using employment figures. In general, this equation has the potential to facilitate quick estimations of household food insecurity using inconsistent infrastructure access during project monitoring, evaluation and planning.

Future Research

This work is novel and potentially ground breaking in that this investigation demonstrated that a lack of inconsistent urban infrastructure access can predict household food insecurity. As such, this research has the potential to serve as a springboard for further research into the influence of urban environment designs on urban household food insecurity. In addition, the implications of this research will become more important as urban populations continue to grow, along with informal settlements in the developing world (Parnell & Oldield, 2014; Parnell & Pieterse, 2014; Tacoli, Bukhari, & Fisher, 2013). These expanding informal settlements will necessitate further research into the unique dynamics of informality, especially in reference to effective food security interventions among within informal settlements. The following suggestions are a guide for how future research can build upon the results of this investigation (although the potential impact of this investigation on future research is not comprehensively contained within these suggestions).

Future qualitative research will be needed to confirm the impact of infrastructure on food insecurity (to provide external validity for these results) and to test the explanations developed in this research. In particular, qualitative research will be helpful in determining whether any of the explanations given in this research match what households claim is the reason for the impact of infrastructure on household food insecurity vulnerability. Future research should also attempt to distinguish the impact of different kinds of female-headship on household food insecurity. In a case study from Vietnam, Scott (2003) found that these different kinds of headship were associated with significantly different poverty outcomes and were mediated by access to social networks for support. These different kinds of household headship categories were masked in the female headship variable used in this investigation.

This research will also need to be confirmed by further modelling techniques. In particular, statistical network modelling can be used to confirm whether the independent variables observed in this investigation are conditionally dependent upon one another. The regression analyses in this dissertation suggested that the impact of some independent predictors (such as chronic illness) on household food insecurity was actually mediated by inconsistent infrastructure access (such as medical care access). In addition to further regression analysis of the interactions among the independent variables in this investigation, Bayesian network modelling may provide a means of testing whether these variables are actually conditionally dependent.

Similarly, computational modelling could also provide insight into the dynamic relationships that this investigation appears to infer. By incorporating the regression equation discovered here, future research could provide insight into how the spread of informal settlements could influence household vulnerability to food insecurity. In addition, the equation could be used to simulate the knock-on effects of infrastructure disruption due to climate hazards (providing a link between the social vulnerability research outlined here and the broader field of disaster risk reduction).

Future research could also include broader conceptual areas. One area of particular interest would be the impact of climate change on food supply and how that limited food supply could impact vulnerable urban households (as identified in this research). In addition, future research could take a more in-depth look at additional indicators of informality. One key infrastructural component that was left out of this investigation was household access to adequate sanitation. It would be fascinating to determine whether any additional infrastructure services predict household food insecurity and whether there is a hierarchy of infrastructure services in relation to maintaining urban household food insecurity.

Limitations

This investigation is based on survey research, meaning that every variable collected and calculated in this investigation was based on the report of survey respondents. This means that this research was reliant upon the recall and honesty of the survey respondents. In addition, due to the household scale of this investigation, this survey relied upon the ability of survey respondents to answer the survey questions on behalf of the entire household. This activity required survey respondents to not only recall information related to their own activities, but also the activities of others in the household. For this reason, only adults who confirmed that they could answer on behalf of the entire household were included in this survey. Preferably, the survey respondent was the head of the household. The measures of food insecurity used in this investigation made exclusive use of household-level survey scales. While these scales facilitated effective administration and have been externally validated. That said, these scales were only household level measures (demonstrating the limited ability of these scales to capture phenomena at lower or higher scales of measurement) and these scales are open to the same challenges as all survey scales. The exclusive use of binary variables in this investigation helped to limit the potential error resulting from inaccurate recall. In addition, the survey underwent rigorous statistical validation in the field to confirm that the survey data was collected accurately.

The theoretical framework for this investigation is based on the use of sensitivity to measure vulnerability. The exclusion of coping capacity (which was left out for methodological and logistical reasons), means that key coping mechanisms were not directly observed and assessed in this analysis. One example of an important coping mechanism not addressed in this investigation is social networks. Urban households may engage in remittances to ensure food access and this practice could mitigate the impact of other social vulnerabilities on household access to food. In addition, a note needs to be made about the intertwined nature of poverty and the findings of this investigation. Depending upon the definition of poverty, all of the indicators used in this investigation could be interpreted as proxies for poverty. This investigation did not rule out poverty as a causal mechanism for food insecurity. Instead, this investigation demonstrated that, relative to other indicators, inconsistent access to infrastructure appears to be an important determinant of household vulnerability to food insecurity.

Along this same line of discussion, the variables included in this investigation are also open to critique. The exclusive focus on household heads in the social vulnerability variables may have overlooked other more significant household member variables. In addition, the informality of dwelling construction ignored the informality of tenure. While the definition varies with different bodies of literature, informality is primarily defined according to land tenure rather than the unplanned nature of the dwelling construction. In addition, the chronic illness variable did not account for HIV/AIDS which this investigation was not able to record due to ethics constraints. In addition, the choice of low-income cut-off using the “bottom third” was informed by Wisner and Luce (1993) but the statistical importance of this variable may have been different if a different cut-off point was used (e.g. a cut-off representing 1 USD per day per household member). The same limitation applies to the definition of all the independent variables used in this investigation. Similarly, the gender of the household head was exclusively defined by the sex of the household head. Other conceptualizations of this variable (such as female centered households) include the marital status of the household head. If this approach was used in the context of this investigation, it is likely that different results could have been observed in this investigation. That said, each of these variables still empirically demonstrated a significant predictive relationship with at least one household food insecurity measure, demonstrating the usefulness of these variables as indicators of social vulnerability to household food insecurity.

This investigation was geographically restricted to Maputo. This means that the results and conclusions of this investigation cannot be generalized to other urban areas based on these results alone. In addition, this investigation is presented as a case study and the extent to which these results are representative of all Maputo residents cannot be confirmed by this investigation. This discussion also related to the sample sizes for each of the regression analyses in this investigation. While the number of events per variable did not drop below 20 for any of these regression analyses, the unwillingness of respondents to provide survey responses at some parts of the survey limits the generalizability of these findings. As a result, these findings will need to be confirmed by further analysis to determine how representative the findings are. While the conclusions of this investigation may have implications for the urban design of other cities, further empirical evidence will need to be collected before the presence of these relationships can be confirmed in those cities. That said, the results from the investigation by Frayne and McCordic (2015) using data from 2008 across Southern Africa suggest that inconsistent infrastructure access does predict urban food insecurity across the entire region. In addition, the same survey instrument has been applied in Western, Eastern, and Southern Africa recently as a part of the Hungry Cities Partnership, thus, there will be more opportunities in the near future to determine the extent to which this relationship can be generalized outside of Maputo.

Conclusion

The results of this investigation demonstrate the importance of inconsistent infrastructure access as a determinant of household vulnerability to food insecurity. As such, this investigation contributes to the existing body of knowledge regarding the determinants of household food insecurity in cities. This investigation demonstrates that, in addition to low household income, there are other ways in which a household can be vulnerable to food insecurity in Maputo. The conclusions of this case study demonstrate the potential importance of pro-active urban planning to limit the potential vulnerability of future urban households to food insecurity in Maputo. If this conclusion holds in other urban environments, then food insecurity interventions may need to focus on limiting current food insecurity prevalence but on mitigating the future vulnerability of humanity to food insecurity as well. Current projections demonstrate that humanity is going to continue moving into cities (United Nations, 2014). If the results of this study are validated by future research, the design of those cities will determine whether humanity is progressing to more resilient livelihoods or falling into an urban trap which will force greater vulnerability to food insecurity on urban households. The challenge which this case study leaves unanswered is this: How can humanity change the design of our cities to neutralize that trap and build resilience?

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