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COMPOUNDING VULNERABILITY: A MODEL OF URBAN HOUSEHOLD FOOD SECURITY

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Abstract

The efficiency of the infrastructure systems in cities will define the extent to which dystopic visions of urban futures become a reality. At the level of the individual household, vulnerability to hazards in cities is defined, in part, by the ability to access essential resources and services. This discussion paper proposes a model to help explain the relationship between access to urban infrastructure systems and household vulnerability to food insecurity. Food access in cities is primarily achieved through food purchases, where households convert assets into food at retail locations. When a household falls into food insecurity through trading household assets for resources, it is often trapped by a host of resource deprivations that have occurred over time. In this manner, the process compounds the vulnerability of a household to food insecurity. The data used in this paper was collected from 2014 to 2016 by the Hungry Cities Partnership using a household food security baseline survey in four cities: Kingston (Jamaica), Maputo (Mozambique), Mexico City (Mexico), and Nairobi (Kenya).

Keywords

food security, vulnerability, urban infrastructure, urbanization, food access

This is the 12th discussion paper in a series published by the Hungry Cities Partnership (HCP), an international research project examining food security and inclusive growth in cities in the Global South. The five-year collaborative project aims to understand how cities in the Global South will manage the food security challenges arising from rapid urbanization and the transformation of urban food systems. The Partnership is funded by the Social Sciences and Humanities Research Council of Canada (SSHRC) and the International Development Research Centre (IDRC) through the International Partnerships for Sustainable Societies (IPaSS) Program.

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Introduction

Urban development has recently emerged as a significant priority in the new global sustainable development policy agenda, as evidenced by Sustainable Development Goal No. 11 and the Habitat III New Urban Agenda (Pieterse and Parnell 2017; Acuto and Parnell 2016). Cities are sustained by their infrastructure, institutions and service networks (Graham 2010) and without these infrastructure systems, cities would be concrete deserts devoid of resources. Humans caught in these environments would die of thirst or starve if they could not escape the city limits. Obviously, this dystopian vision of urban life has more often been imagined than observed (except, perhaps, in cases of cities destroyed by natural disasters or conflict). Instead, the growing concentration of humans in cities is associated with synergies in the trade of goods, the transfer of information, and institutional governance (Pacione 2009). However, rapid urbanization is a double-edged sword. The close living quarters of urban life increase the chances of disease transmission, the toll of natural disasters, and the strain on infrastructure in the city (Wisner et al 2004).

The efficiency of the infrastructure systems in cities will define the extent to which dystopic visions of urban futures become a reality. At the level of the individual household, vulnerability to hazards in cities is defined, in part, by their ability to access essential resources and services. In Southern Africa, recent studies have demonstrated how inconsistent access to urban infrastructure among urban households increases their vulnerability to food insecurity (Frayne and McCordic 2015, McCordic 2016, 2017, McCordic and Frayne 2017). The explanatory challenge that remains is how the relationship between urban infrastructure and food security actually occurs. This discussion paper proposes a model to help explain the relationship between access to urban infrastructure systems and household vulnerability to food insecurity. Some elements of the model are empirically tested with data from household surveys collected by the Hungry Cities Partnership in Kingston (Jamaica), Mexico City (Mexico), Maputo (Mozambique), and Nairobi (Kenya). However, the model still needs further empirical validation with additional data.

Conceptual Basis of the Model

Infrastructure networks in cities play an important role in determining household vulnerability to hazards. For the purposes of the model developed in this paper, the resources provided by these networks are labelled "infrastructure resources." The best definition for this term is the associated notion of "public capital", which are publicly-owned resources that facilitate private productivity (e.g. water, electricity, sanitation, education or healthcare) (Arslanalp et al 2010). In this paper, infrastructure resources are viewed as the output of predominantly public works. In some cities, infrastructure resources are the output of private or informal enterprises as well. For example, the privatization of infrastructure resources has accompanied neoliberal models of governance in many cities in the Global South (McDonald 2016). In cases where government agencies or the private sector fail to produce these resources, the informal economy may become a provider (Ahlers et al 2013). The initial production costs of infrastructure resources are large but cost decreases incrementally with each additional resource that is produced.

Infrastructure resources are primarily accessed through an exchange of household assets. When accessed, infrastructure resources are not consumed in their entirety by households. In the model, assets are treated as any social, monetary or physical goods and services that can be legally exchanged for access to resources. When assets are limited, households can trade access to different resources by shifting the expenditure of assets from one resource to another. Thus, as assets become limited, households may trade, for example, food access for access to other resources. During the exchange of household assets for resources, the vulnerability of urban households can change. Vulnerability is defined in this paper as increased odds of experiencing the impact of a hazard. Hazards are simply future events that have the potential to impact humans negatively. Vulnerable households, therefore, have disproportionately greater odds of experiencing the impact of a hazard (in the form of loss or degradation to human life or assets) (Birkmann 2006).

As a household loses consistent access to a growing number of resources, the odds that it will experience food insecurity increase. Food security is commonly defined as existing when "all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (FAO 2008: 1). This definition is predicated on four pillars of food security: food availability, food access, food utilization, and the stability of these pillars over time. Food access in cities is primarily achieved through food purchases, where households convert assets (monetary and otherwise) into food at retail locations (Crush and Frayne 2011). When a household falls into food insecurity through trading household assets for resources, it is often trapped by a host of resource deprivations that have occurred over time. In this manner, the process compounds the vulnerability of a household to food insecurity.

Inconsistent or non-existent access to some resources has a stronger relationship with food insecurity than others. In other words, food access is more likely to be a trade-off for access to some resources rather than others. Food access trade-offs can occur when the value of the resource being sought in the trade-off escalates due to some latent household vulnerability. For example, the importance of access to medical care rises when a household member is seriously ill. Escalation in the value of a resource can also occur when access to other resources is contingent upon it. For example, the strong relationship between access to cash income and food likely occurs because food is predominantly purchased rather than grown or given in cities, necessitating a cash income for household food access (in other words, food access is contingent on cash income access). In this example, households may choose to go without food in order to shore up the availability of cash for other purchases (or to access other infrastructure resources). Table 1 lists a series of conjectures underlying the Compounding Vulnerability Model (CVM) together with the figures that elaborate each hypothesis.

TABLE 1: Posited Links Underlying the Compounding Vulnerability Model

If:

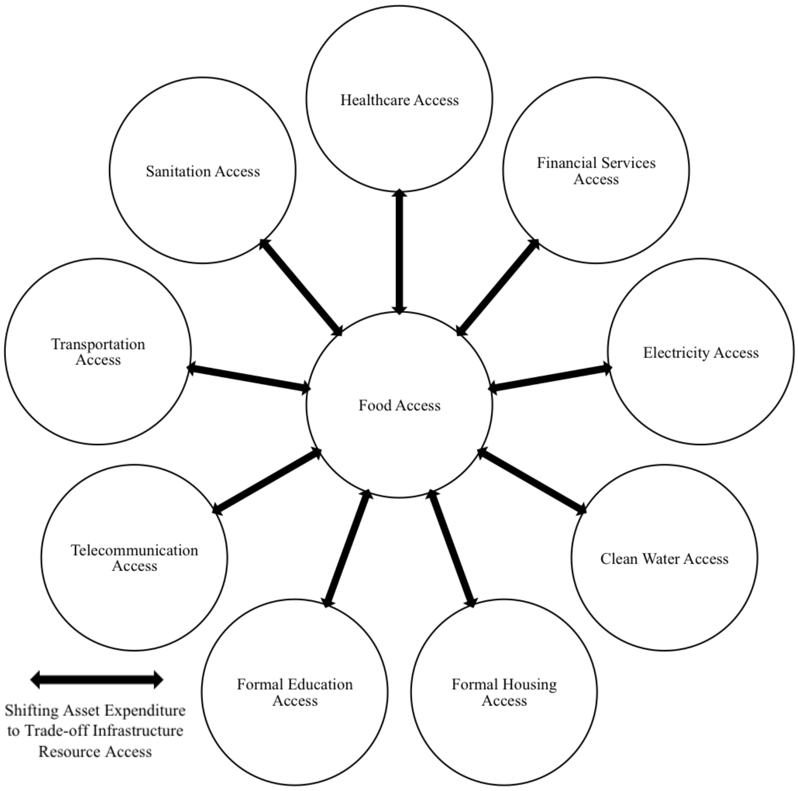
- Households have a finite number of assets at any one moment.
- Households can exchange assets to access any affordable infrastructure resource.
- Household access to infrastructure resources exists within a contextually defined interaction of vulnerabilities and hazards.

Then:

- Households can maintain access to some infrastructure resources by shifting the expenditure of assets on one infrastructure resource to another (Figure 1).
- Inconsistent access to one infrastructure resource tends to co-occur with inconsistent access to other infrastructure resources, demonstrating a static compounded vulnerability (Figure 2).
- The more infrastructure resources that a household has inconsistent access to, the greater the odds that the household is food insecure (Figure 3).
- The loss of consistent access to one infrastructure resource is associated with increased odds of losing consistent access to another infrastructure resource, demonstrating a dynamic compounding cycle of vulnerability (Figure 4).

The household exchange of assets for infrastructure resource access and trade-offs is demonstrated in Figure 1. Food access is placed at the centre of the web, although this positioning does not mean that it has greater value than the other resources represented. Based on the value of the resources provided by an infrastructure network, food access can be traded off for access to any of the other infrastructure resources. Trade-offs in resource access are necessitated by having insufficient assets to secure consistent access to all infrastructure resources. This situation has negative effects on the vulnerability context of urban households, making them more susceptible to the impacts of hazards.

FIGURE 1: Household Asset Trade-Offs on Food Access



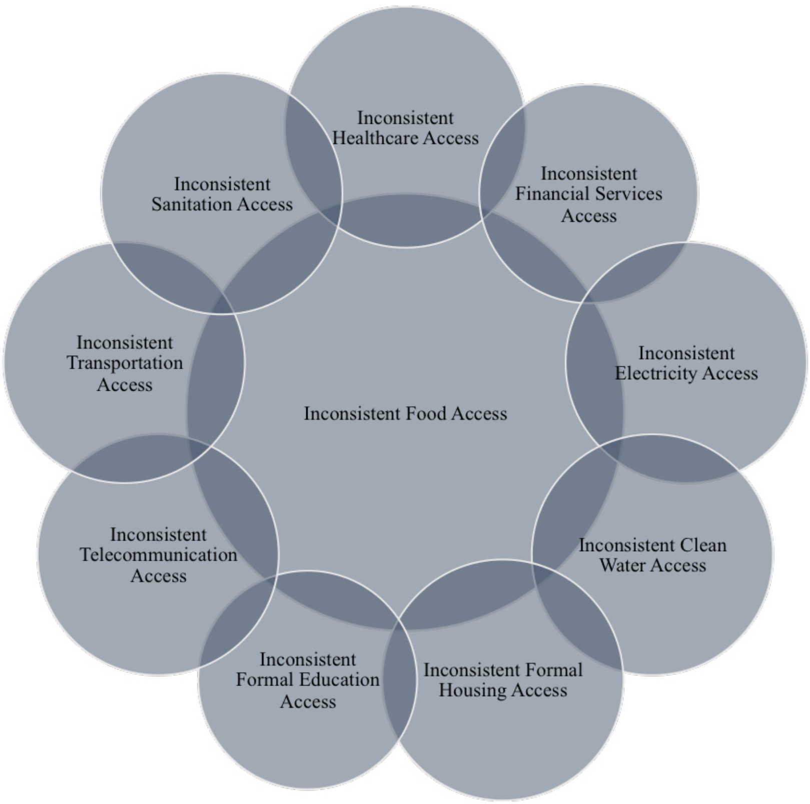
Inconsistent access to infrastructure resources tends to co-occur among poor households (Figure 2). Rather than assuming that this co-occurrence is simply a symptom of poverty, the model conceptualizes poverty as a multi-dimensional phenomenon. This approach to urban poverty is certainly not unique (Mitlin and Satterthwaite 2013). Many poverty measures either rely on an objective proxy (like income or expenditure) that is amenable to more powerful statistical modelling or the correlated influence of multiple measures of deprivation to create an overarching poverty measure. The very fact that different dimensions of resource deprivation are often correlated sufficiently to produce an overarching measure indicates an important insight: *households that go without one resource may have an increased chance of going without another resource.* This relationship is not deterministic or necessarily causal. Instead, the loss of resource access is associated with a change in the risk of further loss of resource access. A household may lose access to a resource without losing access to further resources and may be able to regain that lost access over time. However, escaping further resource access loss becomes more difficult as more resources are lost (because the risk of further resource loss increases with each lost resource). The implications of this phenomenon for household vulnerability are significant. If resource access deprivation has the tendency to co-occur (or correlate) among different kinds of resources, then households may be faced with a host of resource deprivations that need to be mitigated to escape poverty.

The relationship between assets and resource access may be apparent in cross-sectional data collected at one point in time (such as in a household survey). However, the mechanisms driving this relationship seem to describe a snowball-like process or a positive feedback loop. As households lose a resource, they increase their vulnerability (and their chance of experiencing a hazard impact). When an additional hazard impact occurs, the household loses another resource, further increasing household vulnerability. As a household continues to lose access to resources, its chances of losing access to more resources increases. These events are often the result of contextually-laden interactions of multiple shocks, vulnerabilities, oppressive structures, and socially constructed labels (Green and Hulme 2005). Instead of imposing a narrative to explain the exact causal mechanisms, the model simply acknowledges the empirical changes in risk that can occur when a household is deprived of access to a resource.

While more of a concept than an established theory, compounded vulnerability has been used in diverse social sciences to define how the confluence of impacts from institutions, demographic characteristics, and broader environmental processes can position humans as vulnerable (Morrow 1999; Peek and Stough 2010; Aolain 2011). The exchange of assets for access to infrastructure resources described in the model draws from Sen's (1981) Entitlement Theory. The model could be interpreted as showing how poor households convert limited endowments into entitlements (by shifting the way endowments are converted across entitlements) (Sen 1981). The model does suffer from some of the same limitations as Sen's approach. For example, it has difficulty explaining self-limiting food consumption behaviour independent of resource deprivation (Devereux 2001). That said, unlike Sen's theory, the model's predictions should still hold up when explaining food security under the strain of disease (which is viewed as a hazard impact event in this model).

Social vulnerability models also provided helpful insights and building blocks for the model. For example, the Pressure and Release model describes how vulnerabilities and hazards can interact at the point of hazard impact to produce a disaster. This model provided the basis for understanding how the risk of food insecurity can change with the loss of household access to a resource (Birkmann 2006). Theoretical insights into the feedback loops that can exist in social vulnerability are very helpful too. For example, Sustainable Livelihoods Theory theorizes a cyclical relationship between hazard impact events and the level of capital a household has command over. This relationship is mediated by transforming structures and processes which determine the effectiveness of household strategies to achieve better livelihood outcomes (Scoones 1998).

FIGURE 2: The Co-occurrence of Inconsistent Access to Multiple Infrastructure Resources



The following sections of the paper apply the model to household survey data collected in four cities across the Global South. The analysis has two main objectives: first, it seeks to demonstrate the change in odds of a household losing access to an additional infrastructure resource associated with inconsistent access to one infrastructure resource. Second, it seeks to demonstrate the change in odds of household food insecurity associated with the loss of consistent access to an increasing number of infrastructure resources.

Methodology

The data used in this paper was collected from 2014 to 2016 by the Hungry Cities Partnership using a household food security baseline survey in four cities: Kingston (Jamaica), Maputo (Mozambique), Mexico City (Mexico) and Nairobi (Kenya). The survey questionnaire measured household food security, food sources, poverty, and demographic data. In each city, the sampling strategy relied on forms of systematic sampling within randomly selected sub-districts in the city. The sample sizes for these surveys were also approximately stratified according to the population size of districts/sub-districts. The total sample size was then distributed across the selected sub-districts using proportionate allocation (Table 2).

TABLE 2: HCP Household Survey Sample Distribution

City	No. of households
Kingston	702
Maputo	2,071
Mexico City	1,210
Nairobi	1,414

The Compounding Vulnerability Model (CVM) was assessed via an analysis of relationships between variables drawn from these household surveys (Table 3). Food insecurity was measured using the Household Food Insecure Access Prevalence (HFIAP) scale (Coates et al 2007). The food security score derived from this scale is calculated using the ranked answers to nine multiple choice questions regarding the frequency with which households have experienced different forms of food access challenges in the previous month. The final food security ranking is given on a scale from 1 to 4, where a score of 1 represents food secure status and a score of 2 to 4 represents increasingly severe food insecurity. In this paper, the HFIAP score was collapsed in binary form to represent either food secure (a score of 1) or food insecure (a score of 2 to 4). This allowed for easier comparisons of odds ratios with the modelling approach used in the paper.

Access to infrastructure resources was measured by the consistency of household access to water, electricity, and healthcare in the previous year. These variables are represented as binary indicators of consistent or inconsistent access. These variables were also summed to represent an ordinal-level compounded vulnerability variable that indicates the number of inconsistently accessible infrastructure resources in the previous year. This variable is ranked from 0 (representing consistent access to water, electricity and healthcare) to 3 (representing inconsistent access to water, electricity and healthcare).

To establish changes in the probability of events occurring in these variables, odds ratios are used. Odds ratios indicate the change in odds of an event occurring given the occurrence of an event in another variable. Odds ratios greater than 1 indicate greater odds of an event occurring in one variable given the occurrence of an event in another variable (while a score of less than 1 indicates lower odds). These calculations were paired with a Pearson's chi-square test to give an indication of the chance that the relationship between any two categorical variables is random.

To determine the sequential change in odds of food insecurity associated with inconsistent access to each additional infrastructure resource, this investigation relied on binary logistic regression. This form of statistical modelling indicated the change in log-odds of food insecurity given inconsistent access to each additional infrastructure resource (when compared to households with consistent access to all the measured infrastructure resources). These log-odds were then exponentiated to indicate odds ratio values. These models did not control for any other variables. Each of these models were assessed using Omnibus tests of model coefficients and Nagelkerke R^2 values.

Data Analysis

As Table 4 indicates, inconsistent access to water, electricity and healthcare tends to co-occur among the households sampled in Kingston, Maputo, Mexico City and Nairobi. Households that went without consistent access to one of these infrastructure resources had increased odds of going without consistent access to others as well (when compared to those households that maintained consistent access to one of the infrastructure resources). There is also limited evidence to suggest that these relationships are random (given the low p-values observed in the Pearson's chi-square test of independence).

Inconsistent access to water, electricity and healthcare was also associated with increased odds of food insecurity in each of the four cities (Table 5). Except for the households sampled in Kingston, inconsistent access to healthcare was associated with the greatest increase in the odds of household food insecurity (when compared to the odds associated with inconsistent access to water or electricity and food insecurity).

Binary logistic regression modelling indicates that inconsistent access to an increasing number of infrastructure resources is also associated with

TABLE 3: Variable Descriptions

Variable	Level	Values	
Food security	Binary	Food secure	Food insecure
Water	Binary	Consistent water access	Inconsistent water access
Electricity	Binary	Consistent electricity access	Inconsistent electricity access
Healthcare	Binary	Consistent healthcare access	Inconsistent healthcare access
Compounded vulnerability	Ordinal	Consistent access to water, electricity and healthcare – inconsistent access to water, electricity and healthcare	

TABLE 4: Analysis of Inconsistent Access to Infrastructure Resources

Inconsistent access to:	Kingston		Maputo		Mexico City		Nairobi	
	OR	N	OR	N	OR	N	OR	N
Water and electricity	2.4**	677	12.1**	2,033	5.2**	1,196	6.3**	1,362
Water and healthcare	2.9**	668	4.3**	2,042	7.8**	1,195	3.7**	1,372
Healthcare and electricity	3.5**	665	5.1**	2,037	6.5**	1,197	4.3**	1,362

* p<.05 (2-sided Pearson's chi-square test)
** p<.01 (2-sided Pearson's chi-square test)

TABLE 5: Analysis of Inconsistent Access to Infrastructure Resources and Food Insecurity

Inconsistent access to:	Kingston		Maputo		Mexico City		Nairobi	
	OR	N	OR	N	OR	N	OR	N
Water	2.2**	679	5.0**	2,032	4.4**	1,188	2.8**	1,366
Electricity	4.7**	677	5.5**	2,027	2.6**	1,190	2.3**	1,356
Healthcare	4.0**	667	8.4**	2,039	8.0**	1,189	13.0**	1,366

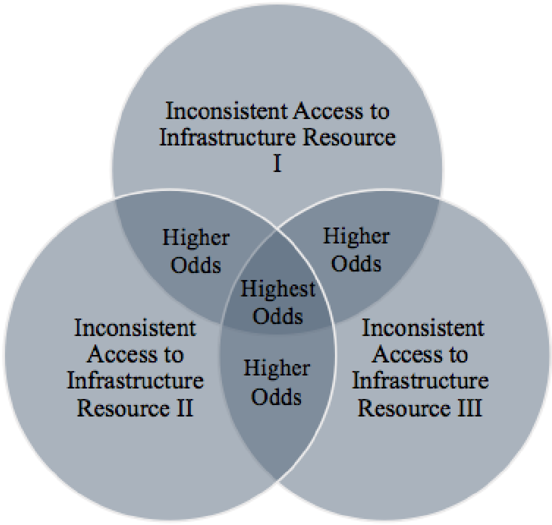
* p<.05 (2-sided Pearson's chi-square test)
** p<.01 (2-sided Pearson's chi-square test)

increasing odds of food insecurity (when compared to households with consistent access to all three infrastructure resources). While these results do not indicate very high Nagelkerke R^2 values (indicating that the binary logistic regression models do not significantly predict food insecurity better than null models), the models are meant to capture the kinds of changes in odds of food insecurity that occur with inconsistent access to an increasing number of infrastructure resources rather than comprehensively predict urban household food security (Table 6).

Together these results provide some important insights into the relationship between infrastructure resource access and food security in Kingston, Maputo, Mexico City, and Nairobi. First, inconsistent access to water, electricity and healthcare tend to co-occur. Inconsistent access to one infrastructure resource is also associated with increased odds of inconsistent access to additional infrastructure resources. As the households lose consistent access to an increasing number of infrastructure resources, the odds that those households are food insecure go up sequentially (Figure 3).

These findings suggest a process of compounding household vulnerability to food insecurity as households lose consistent access to an increasing number of infrastructure resources. This relationship is compounding because an increased vulnerability to food insecurity (in the form of inconsistent access to an infrastructure resource) appears to increase the odds of further vulnerability (inconsistent access to an additional infrastructure resource) as well as increasing odds of food insecurity. While the number of infrastructure resources considered in this paper is limited, these findings still give empirical support to the links posited in Figure 2 (on the co-occurrence of inconsistent access to infrastructure resources and food).

FIGURE 3: Static Compounded Vulnerability Odds of Household Food Insecurity



Implications for Future Research

The main limitation of this study is the cross-sectional nature of the data being analyzed. However, the changes in observed odds and probabilities may indicate longitudinal changes in household vulnerability. Based on the observed odds ratios, it appears that there may be a feedback loop between losing consistent access to one infrastructure

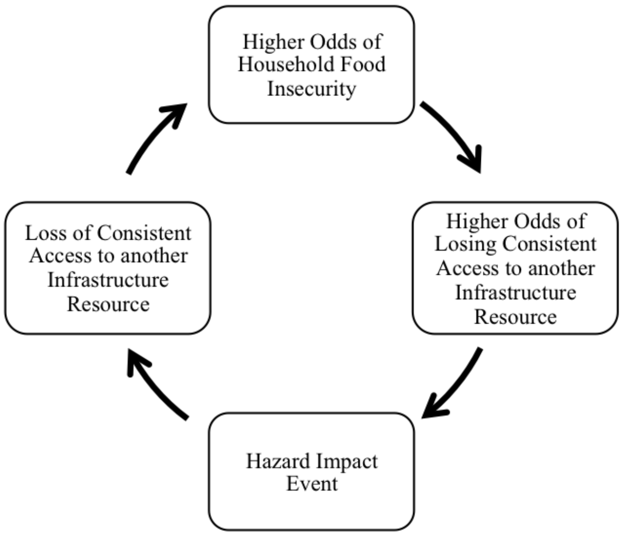
TABLE 6: Inconsistent Access to an Increasing Number of Infrastructure Resources and Food Insecurity

Inconsistent access to:	Kingston		Maputo		Mexico City		Nairobi	
	B	OR	B	OR	B	OR	B	OR
One infrastructure resource	1.058	2.9**	1.251	3.5**	1.238	3.4**	0.879	2.4**
Two infrastructure resources	1.924	6.8**	2.153	8.6**	1.696	5.5**	1.206	3.3**
Three infrastructure resources	2.846	17.2**	3.16	23.6**	2.585	13.3**	3.593	36.3**
Nagelkerke R^2	0.126		0.245		0.160		0.126	
Omnibus tests	61**		382**		153**		127**	

* p<.05
** p<.01

resource and losing consistent access to an additional infrastructure resource (Figure 4).

FIGURE 4: Dynamic Compounding Vulnerability to Food Insecurity



Future research will need to further empirically test the relationships highlighted in Figure 4. The Compounding Vulnerability Model hypothesizes that, with the loss of consistent access to a resource, households become more vulnerable to the impact of a hazard event (such as the loss of employment or a death in the family) because the household is less able to cope with the hazard event when it occurs. Behind this model, assets are being shifted and exchanged to secure access to different infrastructure resources. The loss of consistent access to infrastructure resources may limit the ability of a household to earn a higher income, gain further assets, or receive transfers.

Based on the hypothesized feedback loop in Figure 4 (and the empirical findings from this cross-sectional study), it appears that there is a larger phenomenon of compounding vulnerability experienced by poor urban households. If the loss of consistent access to infrastructure resources is associated with greater odds of losing consistent access to additional infrastructure resources, then this model may provide an additional explanation for chronic poverty. Poor households may be pulled into a situation of compounded vulnerability by losing access to more and more infrastructure resources until, to escape poverty, households are faced with the challenge of securing access to a host of resource-access deprivations. Underlying this model is the real-world interaction of vulnerabilities and hazard impacts that drive the pull and push of odds towards compounded vulnerability or resilience.

In the interests of providing a clear and testable framework for future longitudinal research, this relationship has been modelled in Figure 5. The hypothesized model of compounding vulnerability may explain the risk of household food insecurity (Figure 6). As the number of inconsistently accessible infrastructure resources increases (along with the odds of losing consistent access to additional infrastructure resources), the probability of a household becoming food insecure (trading food access to secure access to other resources) increases towards compounded vulnerability. Given the nature of odds and probability calculations for dichotomous (or binary) events, the reverse direction towards resilience should also hold true. If this model is further empirically validated, its implications for explaining how urban households fall into

FIGURE 5: Compounding Vulnerability Model of Urban Household Insecurity

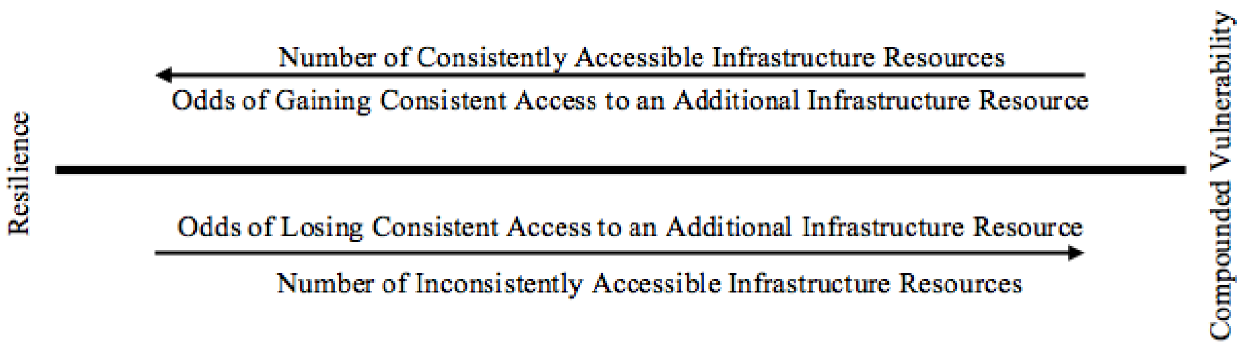
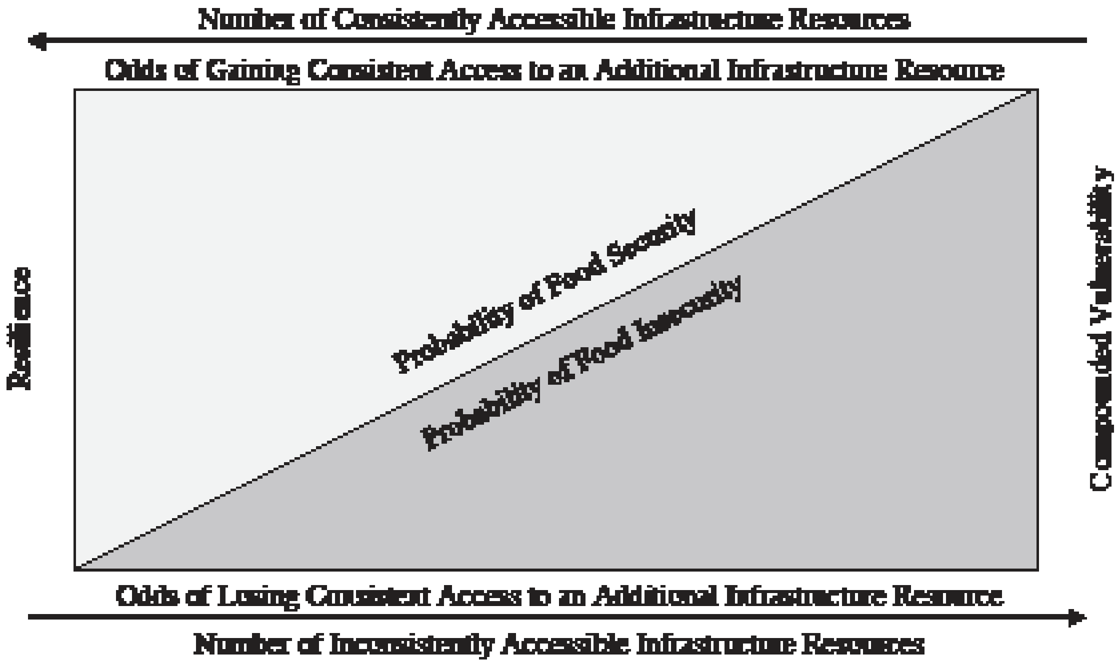


FIGURE 6: Compounding Vulnerability Model of Urban Household Food Security



food insecurity, and why households remain food insecure, may be quite helpful. If the mounting loss of consistent access to infrastructure resources is changing the vulnerability context of urban households, increasing the likelihood that a hazard impact will drive the household into food insecurity, then this model could help map urban household vulnerability. In addition, the compounding nature of vulnerability may explain why households that fall into food insecurity may remain in a chronic state of food insecurity.

This model is meant to define the differential pull of probability in determining household food security based on the loss or gain of access to infrastructure resources. Given that the model is based on risk estimates calculated using probability, the relationships defined by the model exist over the long-term and across the experiences of many households. This is an important point to highlight for two reasons. First, this model is not about causality, but rather the push and pull of probability, accepting the fact that there are several diverse causal mechanisms driving household food security with varying degrees of strength. Second, this model is not determinant; households may slip in and out of food insecurity, but as a household loses consistent access to a greater number of infrastructure resources, the chance of escaping food insecurity becomes increasingly unlikely.

While the model appears to show linear associations between variables, the straight lines in Figure 6 are merely there for explanatory simplicity. The exact curve of the lines is contextually defined given the exact interaction between the type and number of inaccessible infrastructure resources and the presence/absence of hazards. The only true assumption that this model makes about these relationships is that they are monotonic (i.e. consistently increasing or decreasing but not parabolic or hyperbolic).

The Compounding Vulnerability Model frames the dynamics underlying household food security in terms of risk, where the probability or odds of an event happening change according to the presence or absence of other factors. A key element of this theory is that the relationships between infrastructure resource access are measured independently of other factors. The nuanced and contextually defined causal mechanisms that drive vulnerability are assumed as an integral aspect of the model. If other factors like disease, low income, gender, or other contextually defined vulnerabilities are controlled for, the relationships observed in this model may become insignificant because changes in the vulnerability context of a household are a driving force behind this model.

Conclusion

All models are a simplification of reality. The selective attention of models makes them insensitive to nuance. As a result, this model has the potential to misinform if it is not rigorously tested against reality. For example, the model is premised on arguments deduced from cross-sectional survey data, yet a key domain of the model is the longitudinal feedback loop that probably drives households into greater or lesser risk of food insecurity. The notion of risk also usually indicates a timeline of occurrences that make prevalence calculations possible. For these reasons, the model still needs to be tested longitudinally to determine whether the risk of food insecurity does change based on the gain or loss of access to infrastructure resources. It is also important that the model is validated by the reports of households actually experiencing food insecurity. The true validation of this model will therefore be determined by the accounts of those who experience food insecurity.

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