GENETICS: An Urban Stability Framework

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Abstract: Global urbanization is occurring at an increasing rate, creating cities with unprecedented population density, size, and scale, stressing already vulnerable systems. Cities also serve as the site of new and increasingly critical factors for modern society across the social, political, and economic domains. At some point, these population centers will likely experience crises that demand external support, but there are few tools available to effectively evaluate a city's stability and resilience to these crises.

It is critical that planners have a framework that can be applied when evaluating urban environments from which they may draw reasonable conclusions regarding decision-making. Existing US Department of Defense (US DoD) frameworks for analysing city environments are ill-suited to evaluate the upcoming urban stability issues cities will be facing in the twenty-first century and beyond. This study highlights important factors affecting the stability of future cities and emphasizes the growing importance of human dynamics and people's expectations regarding urban situations and contexts. Dense urban environments are the hubs of technological opportunities and complications, increasingly interconnected international relations, and other significant risks and opportunities that impact and threaten urban stability.

The study offers a process to evaluate a city's stability through three resilience dimensions - adaptive capacity, coping capacity, and expectancy benchmarks (or ACE) - and introduces an overarching taxonomy to comprehensively assess the city as a system-of-systems known as GENETICS. The GENETICS stability factors - Governance, Economics, Natural Environment, Energy, Technology and Communication, Culture, and Security – assessed across the ACE resilience dimensions, provides planners and decision-makers the ability to make informed decisions regarding urban stability.

Key Words: Urban Resilience; Urban Security; Urban Systems; Urbanization

1. Introduction

The increasing urbanization of the world's population is creating cities with unprecedented population sizes and densities generating increasingly complex environments. In turn, both acute and chronic stressors will stress the stability of cities worldwide. Although major urban environments vary in a multitude of ways, their relative importance vis-à-vis the economy, culture, and political structure of nations means that urban stability increasingly represents national stability. Major cities face unique difficulties and vulnerabilities that will be tested in the coming years, and these trials will represent some of the most important events for state and non-state organizations to properly analyze and respond to in order maintain urban stability.

What factors define and impact the resilience and stability of urban environments? To better understand, and visualize, urban stability in a diverse range of urban environments, we introduce the GENETICS (Governance, Economic, Natural Environment, Energy, Technology and Communication, Infrastructure, Culture, and Security) Framework. Along with attributing a score to a city's resilience dimensions of adaptive capacity, coping capacity, and expectancy benchmark (an ACE Score), GENETICS helps answer the pressing questions regarding how to focus resources and analyze risk in a dense urban environment.

Each factor defined in GENETICS helps a policymaker or analyst understand the unique features that exist within a city. While no taxonomy could capture every feature of a city, GENETICS is designed to assess the city as a system, which enables focusing limited resources for maximum benefit. The remainder of this

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short paper briefly assesses the current urban resilience literature, refines key definitions, and then outlines the GENETICS stability factors and the three resilience dimensions (adaptive capacity, coping capacity, and expectancy benchmarks). The ACE resilience dimensions are supported by criteria that can help define whether these dimensions are positively, neutrally, or negatively impacting urban stability. As every city and urban environment is different, this tool does not rank or compare cities. Efforts to create this type of comparison exist, but they do not account for contextual factors that influence a city's stability. Instead, this tool is designed to understand the factors influencing urban stability within a city's broader context. GENETICS and the ACE dimensions refocus the conversation around urban stability to the most critical factors and will help make more informed, practical decisions in response to future disruptions.

2. Literature Review

The concept of urban resilience has received extensive attention over the past decade, particularly concerning the effects of climate change and increasing urbanization. There is a broad range of what the literature includes to evaluate resilience, or even in the basic definition of what resilience means. Two key themes and gaps are highlighted below to understand the context for an evaluation of urban stability.

a. Theme 1: Multiple definitions of resilience and resilience indicators

Whether for academic, public, or proprietary use, the concept of urban reslience shares one commonality: that there is no unified definition of urban resilience or how to measure it! Before assessing concepts developed by the United Nations (UN) and others, it is imperative to understand the historical context of the term resilience. Its original use is typically attributed to ecologist C.S. Holling, who in 1973 defined resilience as an ecosystem's ability to maintain basic functional characteristics in the face of disturbances (Holling 1973, pp. 1–23). Recognizing ecosystems have multiple stable states and are constantly changing, Holling later distinguished between static "engineering" resilience, which referred to a system's ability to return, or bounce back, to its previous state, and a dynamic "ecological" resilience, which focused on how a system maintained key functions when perturbed (Holling 1996). As analysis of urban resilience has gained popularity, the concept and supporting definitions have evolved beyond Holling's original concept.

The UN has produced numerous resiliency assessment tools (UN-Habitat 2018), (Gencer 2017) and has sponsored research through the United Nations University Centre for Policy Research (UNU CPR) to develop urban resilience concepts. An October 2016 UNU Working Paper emphasizes a distinction between resilience and vulnerability, with resilience representing the key factors that enable "a city to maintain its core functions in the wake of shocks and stresses" while vulnerabilities are the the "key risks that when realized can lead to the instability of a city to fulfill its core functions" (Boer et al. 2016). Resilience is further defined "as a means of preventing, recovering from, and adapting to human and naturally induced threats while maintaining core functions" (Boer et al. 2016).

A second UNU CPR publication from December 2016 further reviews the literature and highlights the evolutions of the term resilience: from a term that implies a return to a pre-crisis status quo to recognizing the new equilibrium following a shock or stress could result in a new, and sometimes improved, status (Patel and Nosal 2016). This idea of returning to an improved status following a stress or shock is echoed elsewhere, most notably by Nassim Nicholas Taleb in technical papers and his eponymous book on the subject, *Antifragile* (Taleb 2012), (Taleb and Douady 2012).

The UN's Office for Disaster Risk Reduction (UNDRR) produced a framework that conceptualized resilience as a function of supporting components, instead of a standalone end state. In a 2014 assessment of the "Making Cities Resilient" campaign, resilience is defined as a function of resistance, coping capacity, recovery, and adaptive capacity. These terms are incorporated, and adapted, in the GENETICS framework, as outlined in subsequent sections.

Another important distinction regarding urban resilience lies not in the term resilience, but in the understanding the urban system, how that system's equilibrium is defined (for who, by who, over what period of time, etc), how it adapts, and how to understand the dynamics of the city as a bounded system or even an ecosystem (Meerow and Newell 2019, pp. 309–329), (Meerow et al. 2016, pp. 38–49), (Pickett et al. 2001, pp. 127–157). A more comprehensive, systems-oriented concept for urban resilience results:

Urban resilience refers to the ability of an urban system-and all its constituent socio-ecological and socio-technical networks across temporal and spatial scales-to maintain or rapidly return to desired functions in the face of a disturbance, to adapt to change, and to quickly transform systems that limit current or future adaptive capacity (Meerow et al. 2016).

b. Theme 2: A city-specific context gap

Measuring a city's resilience is imperative, but the breadth of definitions results in similarly varied measurement strategies. Some tools apply a common framework to cities across the globe to score and then rank cities on a resiliency scale (Da Silva 2014), (Barkham 2014), (UN-Habitat), (Schlör et al. 2018, pp. 382–392). These macro-level, top-down tools are of limited use, as they fail to fully account for the context of different cities. Additionally, many of these tools are proprietary, so while they are informative, they aren't immediately available to analysts.

Understanding each city's identity before assessing its resilience is clearly important, but the city-specific literature is sparse. The Resilience Alliance, an international, multidiscplinary research organization exploring socio-ecological systems building on Holling's work, developed their own Measurement Framework, which incorporates tipping points and thresholds within the urban system (Resilience Alliance), (Yamagata and Maruyama 2016, pp. 207–237). Building on the systems-oriented approach, a review of Complex Adaptive Systems (CAS) theory further introduced the value of understanding a social system's identity (Luhmann 2005). The creation of identity is known as schemata, which includes variables of identity, internal rules, and the perception of the external environment and rules of coevolving in this environment (Anderson 1999, pp. 216–232). The majority of the contemporary urban resilience literature only refers to perceptions or expectations when discussing security (Moser and Horn 2011), (Norton 2003, pp. 97–106), (Norton 2010, pp. 51–77), social cohesion (Boer et al. 2016), (Organisation for Economic Co-operation and Development 2011) or environmental regime shifts (Resilience Alliance), which is inherently limiting, given the urban resilience domains identified in Table 1.

Domain	**Synonyms or sub-categories**
Social	Human Capital, Lifestyle and Community Competence, Society and Economy, Community Capital, Social and Cultural Capital, Population and Demographics Environmental, Risk Knowledge
Economic	Economic Development, Society and Economy
Institutional	Governance, Organized Governmental Services, Coastal Resource Management, Warning and Evacuation, Emergency Response, Disaster Recovery
Physical	Physical Infrastructure, Infrastructural , Land Use and Structural Design
Natural	Ecosystem

Table 1: Domains and their synonyms or sub-categories of community disaster resilience (Ostadtaghizadeh et al. 2015)

3. Refining Definitions

Building on the introduction of various resiliency concepts, and acknowledging the many other remaining but unmentioned competing definitions, this section consolidates and clarifies the supporting terminology for GENETICS and how it evaluates urban stability. GENETICS incorporates UNISDR's terminology (coping capacity and adaptive capacity) and adds one final resilience dimension (expectancy benchmarks) to understand a city's identity more comprehensively to assess its overall stability.

UNISDR defines adaptive capacity as "the ability to plan, prepare for, facilitate, and implement adaptation options," typically targeted towards unanticipated threat. UNISDR augments this concept with coping capacity, defined as "the ability of a city to avoid irreparable damage from which it is unable to recover." Coping capacity focuses on a city's ability to resist a disturbance (without necessarily measuring that resistance) relative to the original state. Where coping capacity refers to the ability of the city to resist a disruption, adaptive capacity refers to its ability to change, either as a preemptive measure to mitigate disruption or as a consequence of it. Together, these two terms highlight a city's ability to address a current stressor and its flexibility to address future stressors.

GENETICS requires an assessment a city's schemata to fully understand its stability. To do so, the final resilience dimension is the expectancy benchmark, defined as "the collective belief of the urban population of the city's ability to maintain a standard of living within a certain range in response to disturbances." Though highly intangible and currently impossible to measure precisely, expectancy benchmark highlights that within any city, the population has certain expectations as a product of their shared experiences, culture, history, and circumstances. These experiences create an expectation of a certain quality of life before, during, and after a disruption, and these expectations are different in different cities.

Urban stability, therefore, is an overarching concept defined specifically by three dimensions: adaptive capacity, coping capacity, and expectancy benchmark. Thus, urban stability is a measure of a city to maintain order and governance of the population across the resilience dimensions (and the stability factors of GENETICS) without devolving into lawlessness or chaos. While cities are inherently complex systems, the GENETICS approach with the three resilience dimensions enable analysts to deconstruct the system. In doing so, GENETICS enables decision-makers to quickly determine what components of a city need additional resources. These three dimensions are especially practical as each relates to a common but distinct idea: that adaptive capacity generally relates to structural or policy changes that may require less physical resource support, coping capacity relates more towards the physical or tangible aspects of a city, and expectancy benchmark incorporates the often overlooked social, human element of a city.

4. GENETICS: A Method

The GENETICS stability factors were chosen by considering existing frameworks as well as noting which concepts were underdeveloped or entirely omitted. Listed in order, the eight stability factors of Governance, Economic, Natural Environment, Energy, Technology and Communication, Infrastructure, Culture, and Security form a useful acronym: GENETICS. Using GENETICS provides a variety of benefits beyond just a helpful acronym. In particular, the word genetics associates the evaluation a city's stability with biology more broadly and 'living' systems more specifically.

a. Scoring A Stability Factor

Each city around the world confronts a disruption from a different starting point of culture, development, and resources, making it challenging to assess urban stability objectively and quantitatively. Therefore, instead of applying a numeric score (which inherently suggests a ranking and comparison between cities), GENETICS limits evaluation outcomes to one of three options: Positive, Negative, or Neutral. These options are then applied to each of the three dimensions, collectively creating an ACE (Adaptive, Coping, Expectation) Score for each stability factor.

Figure 2 below demonstrates a way to assess the Security stability factor. Ultimately, the intent of scoring a stability factor across the resilience dimensions is to enable a planner or decision-maker to allocate limited resources to a particular factor and its contributing criteria or metric. For example, if Security was weighted as Negative overall while the other factors remained Positive or Neutral, naturally the outcome is directing additional attention and resources towards Security. Then, based on the criteria and its supporting metrics, it becomes clear where and why Security requires more attention, which can trigger additional planning on how to mitigate and accommodate the issues that give rise to its elevated weighting.

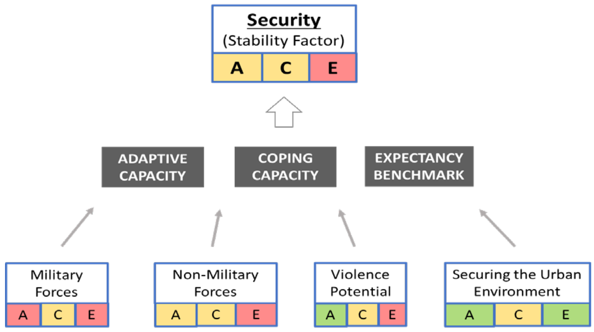

Figure 2 – An example Security Stability Factor outcome

While GENETICS attempts to provide a comprehensive, city-wide assessment, it must be acknowledged that, especially within expectancy benchmark, the population is unlikely to be a homogenous population. Although an overwhelming majority may exist, fractional groups may hold dramatically different expectations based on their unique circumstances and experiences. This consideration must be factored into the overall score, either solely through considerations of refined subset factors and assessments, or also through adjustment of the overall assessment of the expectancy benchmark itself.

Additionally, the expectation assessment may have other considerations to incorporate such as the frequency and severity of disruption; a frequently repeated disruption will likely have a significantly different expectation benchmark from that of an unexpected or unprecedented disruption. So too will it be the case for a severe disruption, where a substantial increase in the magnitude of a disruption, even though it may have precedence in a less severe manner, will also have a significant effect on the overall expectation score.

b. Criteria and Metrics

Each factor within GENETICS is expanded individually with its own respective criteria and metrics. Criteria categorize the broader issues within each factor while metrics provide a more granular view. Decision-makers must incorporate both quantitative and qualitative data within metrics and criteria, as well as context-specific information and personal analysis from within each stability factor to adjust the overall scoring. Once the criteria and metrics for each stability factor are developed, they must be evaluated against the resilience dimensions to develop the overall urban stability evaluation.

Example criteria are summarized in Table 2 below, while the metrics need further development. Factors like Governance, Economics, and Security employ common criteria across the three ACE dimensions and are scored as noted in Figure 2. The remaining stability factors continue to assign a positive, negative, or neutral score to each ACE resilience dimension, but with more specified criteria.

Resilience Dimensions / *Stability Factors*	**Adaptive Capacity**	**Coping Capacity**	**Expectancy Benchmark**
Governance	Municipal Government, Provincial Governance, National Governance, International Presence		
Economics	Economic Structure, Market Connectivity, Financial Stability, Informality and Formality		
Natural Environment	Awareness, Flexibility, Form	Individual Threats, Long-term Threats	Expectations of Service, Predictability
Energy	Supply Modernization, Network Flexiblity	Demand Efficiency, Supply Responsiveness, Supply Diversity	Restoration, Reliability and Availability, Price
Technology & Communication	Social Awareness, Policy Making Efficiency	Prediction and Preparation, Community Response	Development, Citizen Participation, Governing Regulations
Infrastructure	Governance Environment, Operated and Managed Infrastructure	Institional Adaptation, Infrastructure Flexibility, Link Essentially	Operated and Personal Transportation Mode Shares
Culture & Society	Community Support, Health Care	Education and Knowledge	Identity and Culture
Security	Military Forces, Non-Military Forces, Violence Potential, Securing the Urban Environment		

Table 2: GENETICS stability factors with the ACE resilience dimension criteria

c. GENETICS Evaluation

Once all the stability factors are scored across the resilience dimensions, Figure 3 shows the overall GENETICS evaluation. While the color coding is fairly intuitive, the visualization includes extended limbs based on the positive, neutral, or negative score. Currently, the limb length is not associated with a magnitude of how good or how bad, but is more to quickly orient the viewer as to which limb is most unstable.

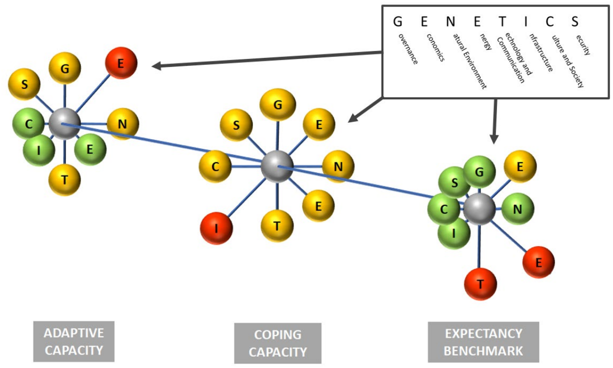

Figure 3: The GENETICS Framework

5. Summary and Way Ahead

This new taxonomy more uniquely and comprehensively assesses the context of a city to evaluate overall urban stability, but there's more work to do and limits to this approach. To highlight the key takeaways of the GENETICS approach: the three resilience dimensions (adaptive capacity, coping capacity, and expectancy benchmark, or ACE) derive an ACE score for each GENETICS stability factor (Governance, Economic, Natural Environment, Energy, Technology and Communication, Infrastructure, Culture, and Security). Combined, the GENETICS and ACE evaluations (positive, negative, or neutral) enable planners and decision makers to ask the right questions and allocate resources to facilitate urban stability.

There are a certainly many challenges with implementing the GENETICS approach for assessing urban stability. First, to validate the conceptual approach, case studies should evaluate events (after they have occurred) to see if GENETICS could have identified opportunities for planners to employ limited resources to prevent urban stability. Future work should also develop indices to formalize the criteria outlined earlier and their supporting metrics, and then use that data to facilitate a more rigorous analysis of the resilience dimensions and how they contribute to the stability factors. Incorporating more quantitative data would enable a more real-time employment of the GENETICS framework.

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