Developing a Socio-Economic Resilience Index (SERI) Model and an Integrated Urban Services Resilience Index (IUSRI) Model using a System Dynamics Approach: The Case of Pasig City

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Introduction

Assessing resilience requires an approach that is (1) holistic or multidimensional, (2) measurable or quantifiable, (3) dynamic, and (4) useful for benchmarking with targets, standards, or comparing with other system context. To address the need for a resilience tool that meets the four criteria, we developed an **Integrated Urban Services Resilience Index (IUSRI) Model** using system dynamics. The IUSRI Model takes the **Urban Ecosystem Resilience Index (UERI) Model** (Campos, Litam et al. 2020), which covers ecosystem services, and supplements it with the **Socio-Economic Resilience Index (SERI) Model.**

Model Development

The IUSRI model is composed of two main models, the UERI and the SERI (Figure 1). The UERI simulates four categories of urban ecosystem services: provisioning (electricity, water, food), regulating (solid waste and wastewater, air quality and carbon emissions, and rain-water conveyance), supporting (land use change) and cultural services (greenspaces). The supporting services are input to the other three sub-systems, which then directly contribute part of the overall IUSRI score. More details can be found in the posters and technical report by Campos, Litam et al. 2020). The SERI includes the demographic, social, and economic dimensions (Table 1).

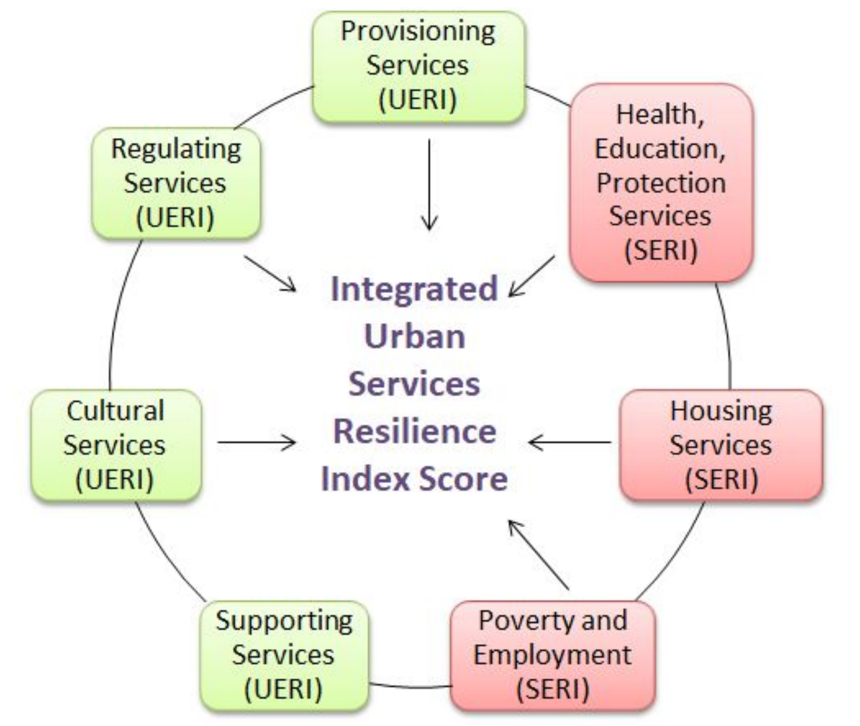

Figure 1. Model components: the IUSRI comprises of sub-models from the UERI and the SERI (adapted from Feofilovs, Romagnoli, Gotangco et al. 2020)

In both the UERI and SERI, key indicators in each subsystem were given resilience scores that represent how they compare to ideal or target values (Table 2). These ideal values are based on demand (as driven by population growth), national and LGU targets, or global standards. Selected indicators were also given self-sufficiency scores that represent how much of the capacity served is provided within the city. The SERI and UERI scores are averaged to produce the IUSRI.

Dimension	Subsystems
Demographics	Population
Social	Health, Education, Protection, and Housing
Economic	Poverty and Employment
Shock (Pandemic)	Integrated into other subsystems

Table 1. Subsystems of the SERI

Index	Equation	Implications		
		< 1	= 1	> 1
Resilience score	$= \frac{Actual\ capacity}{Ideal\ capacity}$	Ideal capacity not met	Ideal capacity met	Ideal capacity exceeded
Self-sufficiency score	$= \frac{In\ city\ capacity}{Actual\ capacity}$	Actual capacity partly served outside city	Entire actual capacity served in city	*not applicable*

Table 2. Interpretation of model index scores

The conceptualized subsystems are translated into quantitative stock-and-flow (SF) models on a system dynamics modeling platform (Vensim PLE) to simulate changes in the indicators over time.

The scope of the SERI dimensions includes the following:

1. **Demographics**: The population is broken down into age brackets: children, fertile population, and old population. Ideal values for indicators in the health, education, and business subsystems depend on the population age structure: health needs are greater for the aged, education needs are mostly for the young, and business employment is for the working age population.
2. **Social**: Capacity in the health, education, and protection subsystems are operationalized as the personnel and assets that the LGU needs to employ in providing these services. Table 3 shows the specific personnel and assets used as capacity indicators for each subsystem. The housing subsystem covers the LGU's provision of in- and off-city low-cost housing for informal settler families.
3. **Poverty and Employment**:Capacity in the employment sector is indicated by the number of jobs available, given the growth of business vs. the growth of working age population.Data from the Philippine Statistics Authority are used to characterize the changes in poverty incidence, which is then used to estimate the annual aggregate amount that its poor constituents fall short of reaching the poverty threshold.

Subsystem	Personnel	Assets
Health	Doctors Nurses Midwives	Hospital beds
Education	Teachers	Classrooms Seats
Protection	Policemen Firemen	Firetrucks

Table 3. Personnel and assets representing service capacity of the Health, Education, and Protection subsystems

4. **Shock (Pandemic)**: A simplified treatment to estimate the effects of COVID-19 is incorporated in the health subsystem in terms of (a) the number of patients that doctors and nurses attend to and (b) the hospital bed benchmark to account for the additional bed days. COVID-19 affects unemployment due to the lockdown.

Pandemic cost impacts within the LGU were also estimated for online learning peripherals, personal protective equipment (PPE) for health workers, financial aid through the Social Amelioration Program (SAP), and PhilHealth coverage for those hospitalized due to COVID-19.

The SERI model for each city was combined with its respective UERI model. The population subsystem from the SERI model connects to the population inputs in the UERI model, replacing the UERI model's non-age-disaggregated model.The sample simulations for the IUSRI combine the resulting resilience scores from the UERI and SERI to gauge the overall Urban Services Resilience scores of each city.

Results & Discussion

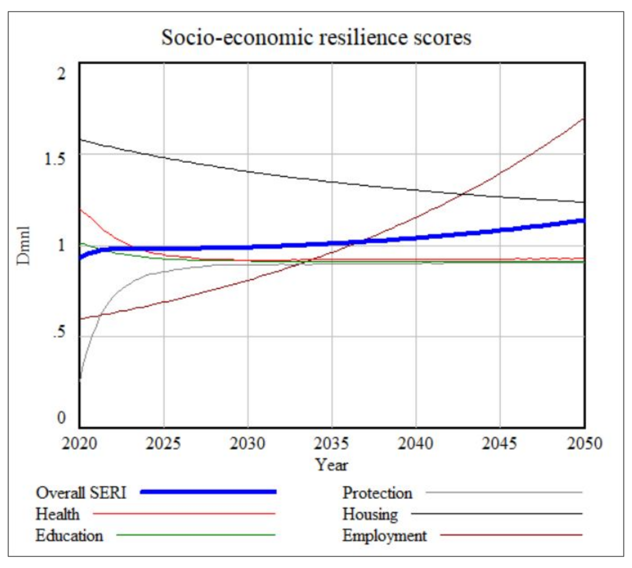

Figure 2. BAU Scenario: Overall SERI score

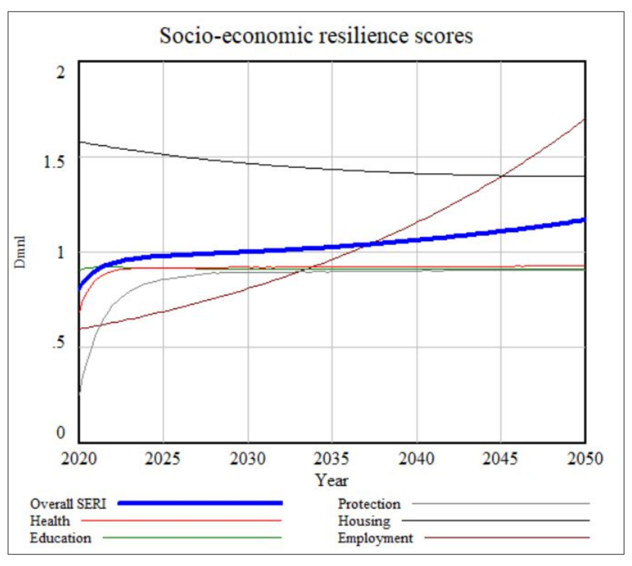

Figure 3. Priorities Scenario: Overall SERI score

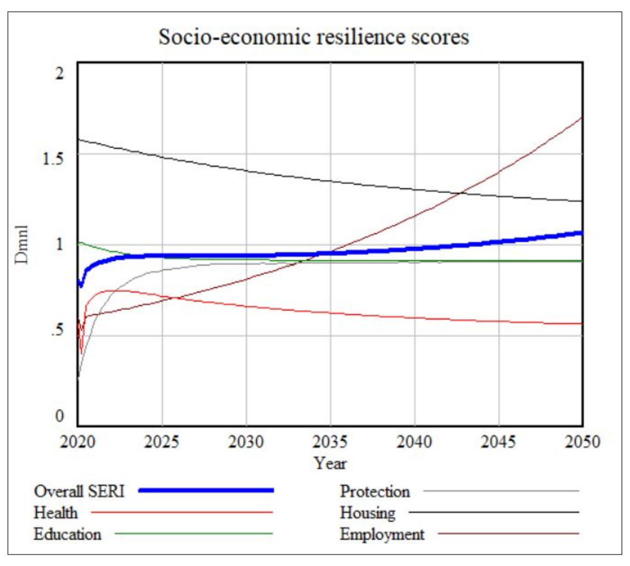

Figure 4. COVID-19 Scenario: Overall SERI score

The overall SERI scores show that Pasig City will reach the ideal resilience score in all three scenarios tested, albeit in later simulation years: the Business-As-Usual (BAU) case (Figure 2), the Priorities case (Figure 3) which include health, education, and housing improvements, and the COVID-19 case (Figure 4) which considers the BAU case with the COVID-19 impact on health and employment in 2020 (ideal capacity used hospitalization ratios instead of the 'ideal ratio to population' in order to capture the impact of COVID-19).

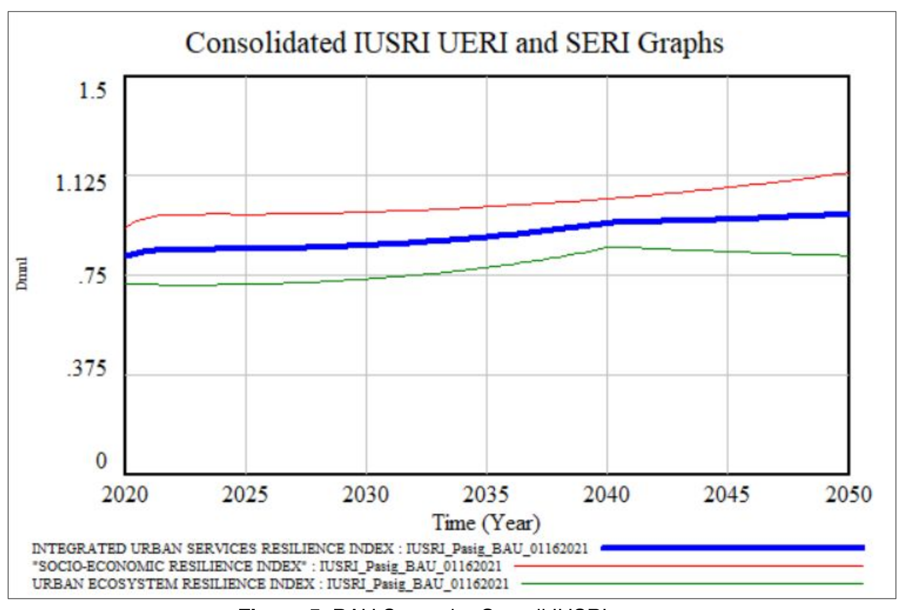

Figure 5. BAU Scenario: Overall IUSRI score

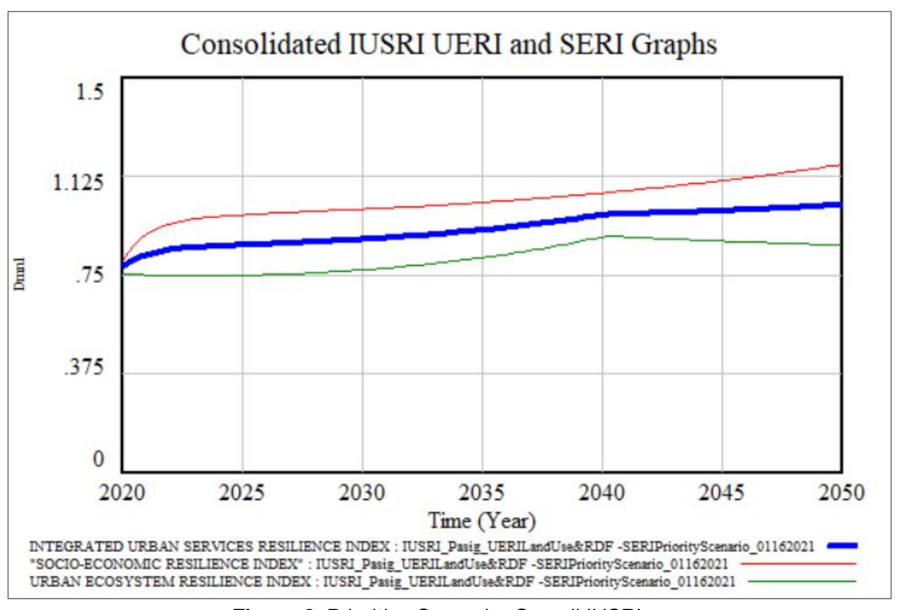

Figure 6. Priorities Scenario: Overall IUSRI score

The overall IUSRI scores were simulated in two scenarios: BAU case (Figure 5) which uses the BAU cases for both SERI and UERI, and the Priorities case (Figure 6) which uses the Priority case for SERI and the Land Use & RDF case for UERI. In both cases, the SERI score is higher than the UERI score, indicating that socio-economic services are more resilient than ecological services. The overall IUSRI scores for both cases are shown to be below the ideal resilience score and eventually reach this, but sooner in the Priorities case.

Policy Implication

Pasig City can best achieve a good resilience score by improving the overall ecosystem services resilience and the low components of the socio-economic services resilience. It is important that Pasig City is able set the right goals for ideal ratios and target capacities. In the health, education, and protection services that change following the goal-seeking model of growth, the targets need to be high enough to have a buffer and to account for the length of adjustment time needed. The targets also cannot be too high such that resources are unnecessarily expended on these when they could have been used for another purpose. For the housing and employment resilience scores that change following fixed growth rates, the City should plan for its expansion with consideration of self-sufficiency and of the factors that determine the need for housing and access to employment.

Recommendations

The IUSRI and SERI models can incorporate more feedbacks and interlinkages between subsystems to capture development constraints, such as carrying capacity and budget allocations. The service approach to resilience taken in these models has its limitations: other dimensions of city resilience are difficult to quantify and are not directly translatable into these various service capacities and targets. For example, mental health and general well-being, trust networks in the community, diversity, and inclusion. Other approaches will still need to complement the model developed here for holistic decision-making.

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