ESPON

EUROPEAN UNION

Co-financed by the European Regional Development Fund

Inspire Policy Making with Territorial Evidence

// CApabilities and Performance Assessment of City (CAPAcity) dynamic model for potential investment and development.

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INTRODUCTION

Introduction

- Managing urban areas for sustainable **capital and territorial redevelopment** and cohesion is a top priority for urban and regional policy makers in Europe.
- Urban comprehensive carrying capacity (UCCC) is an important conceptual foundation that guides local governments towards **sustainable urban development**
- The methodological issues in UCCC monitoring and evaluation have been studied in depth, leaving behind the need to elaborate on the path to **innovative applications**, which is of high importance in the emerging framework of **smart cities**.
- A framework is proposed to address this need by **managing the data, monitoring the policy impacts and resulting territorial capacities** (based on the **attractiveness** of an area), thus supporting the generation of **smart and efficient** solutions and the creation of citizen friendly environments.
- It also enables authorities and actors, through a process centric approach to assess urban development scenarios, concerning interconnected **risk factors** and related impacts and losses.

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MAIN CONCEPTS-INNOVATION

Main Concepts- Innovation (1/3)

1. Urban Areas Attractiveness Indicator

One of the basic goals of the proposed is to evaluate the **attractiveness** of different areas (in city/region scale, cities for our case) and create an attractiveness index .

The attractiveness is based on two indicators :

- **Urban Comprehensive Carrying Capacity** : UCCC reflects the *potential* that could be reached by urban development.
- **Smartness** quotient : A 5- dimension Urban **Smartness** quotient is developed. It functions as a **weigh**t of high importance for the **final UCCC evaluation.**

Main Concepts- Innovation (2/3)

2. System of Systems

- City departments/authorities frequently **work in silos** when they are trying to solve city problems.
- For example, transport is dealt with by transport planners and energy is dealt with by energy managers.
- In reality, the problems that these sectors face are **interconnected** and an **integrated approach** has clear benefits.
- For instance, the density and spatial concentration of housing can negatively affect access to services and service efficiency (e.g. transportation, energy, water and waste management).
- This research proposes a **SoS integration** architecture by shifting the analysis from **function-oriented to process-oriented** integration, connecting systems to deliver higher efficiency/effectiveness in cities development .

Main Concepts- Innovation (2/3)

This network of systems, interconnections and flows can be described as a **system of systems**

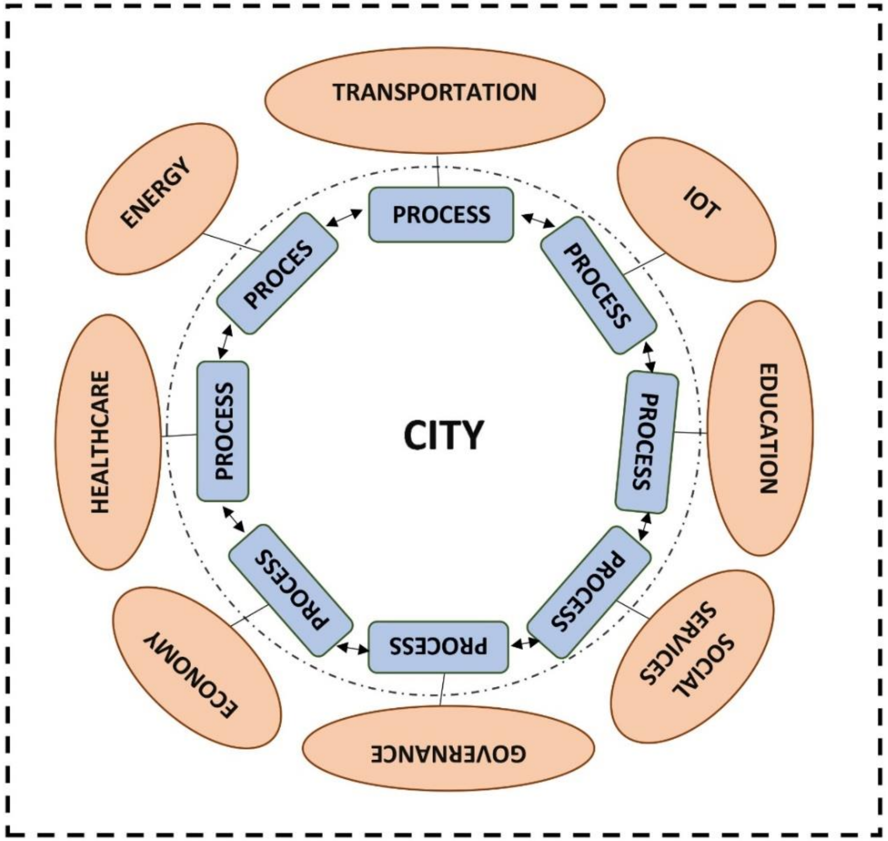

Figure 1: City as a system of systems

Main Concepts- Innovation (3/3)

3. STPA for Urban Area Development Risk Analysis

- Based on the SoS architecture , "Systems thinking" discipline is proposed to provides **skills** and **tools** designed to address **situations of complexity** and **uncertainty** which are difficult to grasp and manage and to which there are no simple answers.
- The STPA (System-Theoretic Process Analysis), a relatively **new hazard analysis technique** based on an extended model of accident causation (Leveson, MIT, 2012) , is proposed
- STPA assumes that **accidents** can also be caused by **unsafe interactions** of system components, none of which may have failed.
- **Hazard** is STPA is defined as "A system state or set of conditions that, together with a particular set of worst-case environmental conditions, will lead to an **accident (loss)**".
- The ultimate goal is to **eliminate** or, if not possible, **reduce** identified hazards during the system design activity, urban development scenarios at this case.

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METHODOLOGY

Methodology (1/7)

STEP 1: Target system definition

- As the methodology can be applied to urban environments with **different characteristics** and multiple scales, the first step defines the **specific target area(s)**.
- In each area an operational **comprehensive carrying capacity target system** is established based on area characteristics.
- A model for quantifying the UCCC of a city/area/zone based on **five factors**, including **infrastructure** carrying capacity, **environmental** carrying capacity, **economic** carrying capacity, **society** carrying capacity and **traffic** carrying capacity.
- Each factor contains is characterized by the criterion which includes **Demand and Supply,** which in turn are correlated with the respective **Indicators.**
- This work considers two types of indicators the **positive** and the **negative**, based on their attribute in relation to the urban comprehensive capacity.

Methodology (2/7)

STEP 2: Data collection

- Existing databases and tools function as valuable data sources for the urban areas.

- Sources : CityBench, ESA, Eurostat, EUREF, transport fleets and social networks

- Data on fundamental variables: GDP, places for rent, number of pedestrians, public transport access and quality, internet access and use, use of renewable energy sources .

Methodology (3/7)

STEP 3: Indicators Weight Assignment

- The weights of the indicators and factors are determined by the **entropy coefficient method**.
- Entropy is the measure of the disorder degree of the system, and it can measure the effective information provided by the data.
- A large difference between the evaluated objects on a particular indicator means that the entropy is smaller, which shows that when the indicators provide more effective information and the weight of the indicators should be larger
- On the contrary, the smaller the difference, the larger the entropy, which shows that the smaller the amount of information provided by indicators, the smaller the index weights.

Methodology (4/7)

STEP 4: Urban Comprehensive Capacity Assessment

- The **urban comprehensive carrying capacity A=A(Y)** of a city/area/zone adopts the integrated form:

$$\sum_{i=1}^{n} w_i Y_i \qquad (1)$$

The integrated assessment value of subsystem **i** adopts the evaluation model:

$$Y_i = \sum_{j=1}^{m} b_{ij} x_{ij} \qquad (2)$$

- where, **Yi** is the integrated assessment value of the **i** th factor
- **wi** is the weight of the **i**th factor;
- **n** is the integration index in the **i**th factor;
- **bij** is the weight of the **j**th indicator in the **i**th factor;
- **xij** is the evaluation value of the **j**th indicator in the **i**th factor;
- **m** is the evaluation index in the **i**th subsystem.

Table 1: Proposed Indicators for calculating UCCC

Target System	Factor	Criterion	Indicators
Urban comprehensive carrying capacity	Infrastructure carrying capacity	Demand	Number of citizens per sqm
			Number of industries
		Supply	Per capita construction land area
			Per capita public spaces
	Environmental carrying capacity	Demand	Comprehensive energy consumption
			Per capita daily water consumption
		Supply	Green coverage ratio of construction land area
			Processing capacity of municipal sewage plant per day
	Economic carrying capacity	Demand	Unemployment rate
			Taxes on key industries
		Supply	Tourist population ratio per year
			Growth rate of gross value of production
	Society carrying capacity	Demand	Number of homeless in relation to total population
			Number of citizens without access to education
		Supply	Percentage of social housing
			Percentage of population with access to health care
	Traffic carrying capacity	Demand	Number of registered cars
			Percentage of population committing by public transportation
		Supply	Per capita road area
			Public transport network length

Methodology (5/7)

STEP 5: Calculation of Urban Smartness (US) weight

- The Urban Smartness weight is calculated based on specific key performance indicators monitoring the implementation of smart and innovative solutions across 5 dimensions
- Urban Smartness weight of each city/area/zone **k** is obtained with scores ranging from 0 to 100, standardized by the sample city/area/zone highest score:

$$US'_k = \frac{US_k}{US_{max}}$$

Table 2: Proposed Dimensions & Indicators for calculating US

Dimension	Indicator	Unit
Environment & Construction	Urban grid management coverage	%
	Intelligent transportation citizen use ratio	%
Governance & public service	Online openness of non-confidential governmental documents	%
	Online public participation ratio	%
	Level of citizen using e-health recording	%
	Emergency reacting performance	%
Economy & industries	R&D expense/GDP	%
	Urban intelligent industry ratio	%
Informatization	Free WiFi coverage in public space	%
	Average mobile network access	%
	Building automatic system popularization	%
Innovative human resource	Urban netizen ratio	%
	IT professionals ratio	%
	Population ratio with college education	%
	Popularity of e-purchase	%

Methodology (6/7)

STEP 6: Urban areas Attractiveness Assessment

- The value of Attractiveness $\mathbf{T_k}$ is obtained by multiplying the UCCC value, $\mathbf{A_k}$, with the US factor, for each study area **k.**
- $\mathbf{T_k = A_k * US'(k)}$
- Based on the above steps the city/area/zone with the best ranking is proposed.
- The factors with the **highest impact** are identified (i.e. environmental factor)
- The indicators with the highest impact in these factors are identified.(i.e. per capita water consumption).

Methodology (7/7)

STEP 7: Process Control Loop

- The **processes** which affect the high impact indicators are identified.
- For example, we assume that the **environmental factor** is the one with the highest impact on UCCA and
- the indicator **“per capita daily consumption”** is the one with the highest impact on this factor.
- Water Consumption is the main process identified
- The control loop is developed for the process as shown in Fig(2)

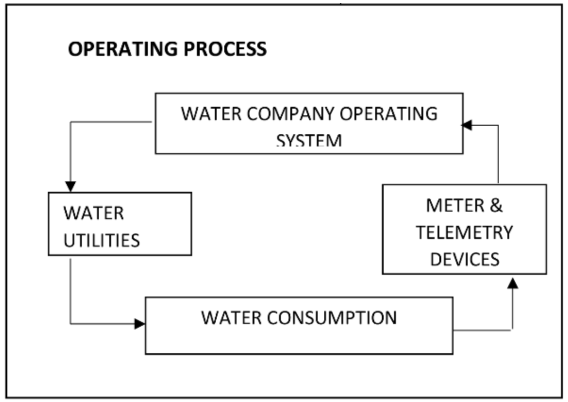

Figure 2: Process Control Loop

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URBAN DEVELOPMENT SCENARIOS

Urban Development Scenarios (1/2)

A Neural Network is developed an trained based on historical data.

- The outcome is the value of the controlled process related indicator (i.e. water consumption)
- The inputs contains :

1. the parameters of the controlled process loop (i.e technologies and water efficiencies, metering programme, innovative water tariffs)
2. the values of the interconnected processes related indicators (number of habitants per house, short term migrant population, tourism)
3. Other external parameters (climate change)

- Alternative urban development scenarios can be extracted

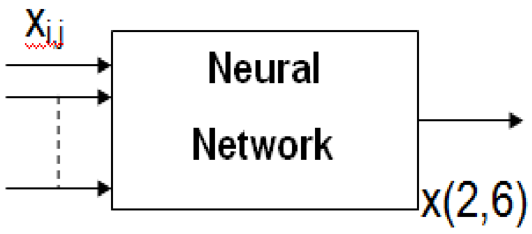

Figure 3: ANN for scenarios development

Urban Development Scenarios (2/2)

Table 3: Scenarios Probability / Impact Index

Scenario	Probability	Impact on Outcome (Deviation form mean value)
1	**High**	**Low**
2	**High**	**High**
3	**Medium**	**Medium**
4	**Low**	**Low**

- Scenarios with high severity are further analyzed by using STPA method for proactive risk control.

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Urban Development Scenarios Risk Analysis

STPA Application (1/3)

Risk analysis, based on STPA, is conducted in order to assess risk impact of the proposed urban development scenarios.

Step 1. Define the **purpose of the analysis** is the first step with any analysis method. This includes:

- the kinds of loss the analysis aims to prevent

Step 2. Build **hierarchical control structure**.

- It captures **functional relationships** and **interactions** by modeling the system as a set of feedback control loops.
- It usually begins at a **very abstract level** and is iteratively refined to **capture more detail** about the system.

STPA Application (2/3)

Hierarchical control structure - Example

- Hierarchical control structure is created for the **water consumption controlled process** (figure).
- This bottom up approach begins with **the upper legislation** and policy layers extended to **the lower operation process layer**.
- The coordination and interrelationship with other factors/decisions systems is described.

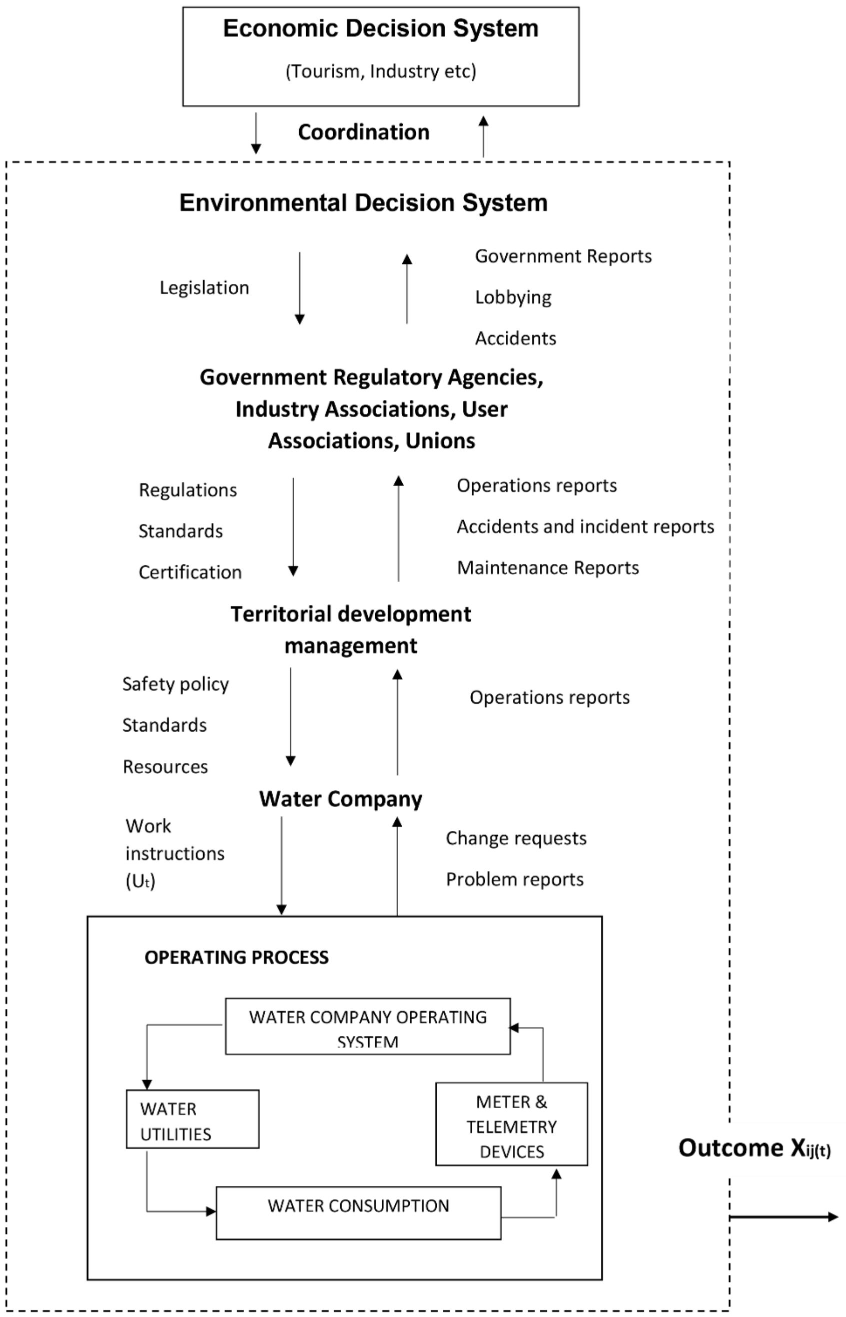

Figure 4: Hierarchical control structure for water consumption

STPA Application (3/3)

Step 3. Analyze **control actions** in the control structure to examine how they could lead to the losses defined in the first step. These unsafe control actions are used to create **functional requirements** and **constraints** for the system.

Step 4.The fourth step identifies the **reasons why** unsafe control might occur in the system. Scenarios are created to explain:

- How incorrect feedback, inadequate requirements, design errors, component failures, and other factors could cause unsafe control actions and ultimately lead to losses.
- How safe control actions might be provided but not followed or executed properly, leading to a loss.

Once scenarios are identified, policy makers can use them to create **additional requirements**, identify **mitigations**, drive **the architecture**, make **design recommendations** and **new system design decisions**, **evaluate/revisit** existing design decisions, define **test cases** and create test plans and develop **leading indicators** of risk.

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CONCLUSIONS

Conclusions

- An **assessment framework** with reference to the UCCC concepts and **smartness is developed to** provide strategic solutions for urban development.
- The proposed framework can facilitate urban planners and managers to evaluate potential urban development plans , determine challenges and limitations, and **identify cross-sector interrelations** .
- The need for specialized **urban knowledge for risk reduction** goes hand in hand with the need for a more interdisciplinary and multi-sectoral approach.
- In this context, **STPA, inter-disciplinary** research and **trans-disciplinary** collaboration are crucial in order to narrow the gap between local-level realities, science and policy.
- The proposed framework can be applied in various ways in **different areas scale**.

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Thank you

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Additional Slide

- The controlled process can be considered a **coordinated process**
- There are three dimensions related to coordination interactions, including:
- 1) vertical or lateral coordination,
- 2) within or between decision system coordination and
- 3) coordination to control a single or multiple independent processes (Johnson, MIT, 2017).

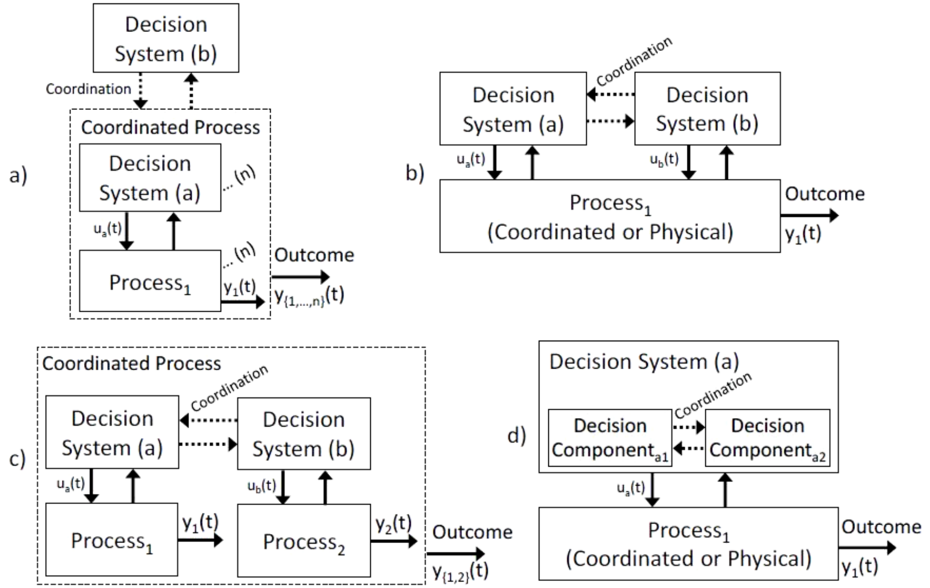

Figure 2: Fundamental Coordination Relationships in Sociotechnical Systems