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A RISING ISSUE

Over the last decade, every part of the world has been severely affected by disasters.

If earthquakes are among the deadliest (Sichuan/China/2008, Haiti/Caribbean/2010, Japan/Asia/2011), storms (Katrina/USA/2005, Nargis/South Asia/2008) and tsunamis (Indian Ocean/2004) were responsible for many losses and damages.

Droughts and floods are usually less impressive but they affect hundreds of thousands people every year with dramatic consequences on the long term.

In such circumstances, human lives depend on a robust construction of building and urban spaces, but also on authorities capacity to react and manage the crisis from emergency to reconstruction.

To do so, they have to rely on infrastructures usually severely damaged. Resisting capacity, crisis management and recovery are then hampered by these invisible but fundamental services.
Technical urban services, supported by network infrastructures, are vulnerable to disasters.

- According to Haiti Post Disaster Needs Assessment 2010, damages following January earthquake requires that 15% of financial needs are dedicated to infrastructures (including housing).

<table>
<thead>
<tr>
<th>Technical system</th>
<th>Damages (direct cost in million USD)</th>
<th>Losses (indirect cost in million USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water and sanitation</td>
<td>34</td>
<td>201.4</td>
</tr>
<tr>
<td>Transport</td>
<td>307.1</td>
<td>289.1</td>
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<tr>
<td>Telecommunication</td>
<td>94</td>
<td>46</td>
</tr>
<tr>
<td>Energy</td>
<td>20.8</td>
<td>37.23</td>
</tr>
</tbody>
</table>

- After hurricane Sandy, 7 tunnels crossing under East River and 8 metro stations were drowned in New York, along with North’s Harmon yard station and 6 bus depots. If 80% of MTA service is recovered in 5 days, transportation service is degraded for several weeks. As a consequence, New Yorker people suffered from discontinuous and less efficient transportation service during several months because of damaged regulation infrastructure among others.
A RISING ISSUE

What is new?

Urbanists and engineers have a long history in designing cities and infrastructures for decades, even for centuries.

We balance cost and performance, always aiming at safe operations. However, disasters do happen and we have to face situations.

As a consequence, we need to assess and secure how the malfunction of an infrastructure can impact a wider territory.

Technical urban networks: power supply, drinking water supply, sewage system, telecommunication networks, roads and transportation systems are supporting each city’s function.

They are particularly vulnerable to disasters but also necessary for disaster management and recovery activities. However, they are strongly interdependent but usually managed autonomously, which questions their reliability in case of disturbances.

We assume they are a powerful leverage for local authority to improve their city’s resilience.
Resilience: literally to jump backwards

First definitions of resilience refer to bouncing and being able to quickly return to a previous state.

In mechanics, Charpy’s resilience test is a torture test by traction, compression, flexion, cutting, twisting or fatigue. It characterizes a material’s resistance to a shock.

Psychology
- One’s ability to recover from a trauma

Ecology
- An ecosystem’s ability to maintain its functions under stress

Economy
- Ability to maintain production close to its capability inspite of a shock

Computer science
- Ability of a system or network to maintain operation during a failure

Questions:
- Is it a property or a process?
- Is it inherited or learned?
- Does it imply a return to a previous state or a new state?

How to translate it for cities?
What system perimeter should be considered?
Which characteristics should be assessed?
The resilience concept is becoming a cutting edge in urban management and design.

Indeed, it is a powerful tool to take uncertainty and complexity into account, from short to long term. Changing constraints, such as climate change, socio-economic conditions, regulations or natural disasters, disturb the urban system. It is then diverted from its ideal trajectory which is optimal satisfaction of all inhabitants needs.

Resilience is then dedicated to answering uncertainty, focusing on activity continuity and flexibility, rather than technical solutions and structural measures. The objective is to develop territory by maintaining attractiveness.

**Definition:**
Resilience is a continuous improvement approach aiming at building a city’s capacity to recover durably from disturbances.
Urban resilience relies on the articulation of 3 dimensions in an integrated approach.

A resilient city is then able to adapt to unexpected and intense disturbances relying on its internal and external abilities: flexibility, adaptability, autonomy, redundancy, connectivity, etc.

In order to do so, all system scales must be articulated together: from user to larger territory and from infrastructure to neighborhood, with the common objective to improve the global system continuity.

Systemic analysis can highlight interactions between project components, between the project and its environment (from small to large scale) and between the project and its socio-economic context (short and long term needs, new data or regulations).

This approach enables to identify project risks and opportunities and to propose control, compensation or mitigation solutions to reduce negative impacts in order to improve the project sustainability.
RESILIENCE CONCEPT

To design a resilient project, functioning levels must be thought from the beginning, according to disturbances and acceptability levels.

The objective is to go beyond former approaches focused on reliability, which cannot bring effective solutions when disturbances overcome regulatory levels. The objective is not to abandon norms and regulations, but rather to establish strategies able to provide adapted answers whatever the situation.

Then, to do so, it is not necessary to implement cumbersome and costly technical systems. Indeed, a well-scheduled and flexible organizational response can be as effective in maintaining an acceptable level of functioning. Communication and coordination are the best tools.

Guarantee an acceptable level of functioning also requires a long term vision concerning needs and context (climate change, socio-economic evolutions or technological advances). A better adequacy between the project, its environment and its objectives can be ensured by maintaining margins of maneuver. Adaptation or redeployment margins can reduce to minimum irreversible choices, without compromising neither (technical and economic) sustainability nor immediate functions.

Thanks to information and anticipation, people expectations can be reduced to an acceptable degraded level of service. On the other side, degraded quality or quantity can be guarantee thanks to flexibility and service adaptation.
Resilience improvement first relies on objectives and means definition.

Indeed, resilience cannot be absolute, it depends on arbitrations. Our expertise can help you define margins of improvement in order to meet ambitious but realistic goals, their short and long term consequences, at different spatial scales. To do so, a diagnosis of your territory’s resilience can be carried out and translated into actions.

A complete evaluation of a system’s resilience (region, infrastructure, building, new development ...) can be carried out with a method based on frequent interactions with stakeholders. First, a diagnosis method collects information on strong and weak points in the system. Then, a systemic approach is necessary to take all failures and domino effects into account, whatever the initial disturbance.

The diagnostic step highlights critical problems and helps prioritizing actions. The objective is to limit negative impact propagation and to identify solutions to implement based on a cost-benefit analysis. Then, we can accompany you in the definition of an action plan according to your system level of functioning, facing different scenarios.

Monitoring tools, such as dashboards, are used to follow the implementation and results in order to initiate a second loop of this iterative method.
OUR INSIGHT

**ROSau is a GIS tool dedicated to city resilience management.**

The tool supports the identification and assessment of urban service interdependencies in order to characterize domino effects between electrical network, water supply, telecommunications, public transportation, etc.

The assessment and solution identification is to be carried out collaboratively with urban stakeholders in order to foster an integrated management of disasters.

This solution can be mobilized at different steps of a resilient strategy and with different objectives:

- City resilience diagnosis
- Resilient urban design
- Identification of a resilient location
- Resilience assessment of a location within the city

This solution is based on a GIS tool enabling the identification and organization of existing but scattered information. The objective is to create a common knowledge of urban services resilience in order to support the identification of technical and organizational solutions that increase the city's resilience as a whole.

Benefits can be identified both during normal operation and in case of disaster. Indeed, taking interdependencies into account in normal conditions improves reliability and efficiency of urban services. Moreover, this preparatory analysis increases knowledge of weak points and fosters communication between managers. Then, in case of disasters, priority actions will already be known, and if available, the tool could support the anticipation of domino effects.
The first step is to collect information about infrastructure functioning and interdependencies of the system considered.

The objective is to identify and characterize each component dependencies to external services (for instance power needs, water consumption, dependence to telecommunications or transportation). A simple architecture in data is adapted to any level of information available on the territory: from major components to very detailed network structures.

Then the tool enables the assessment of disturbance scenarios and domino effects identification within the system. The qualitative data concerning dependencies and the temporal information concerning impacts on the service support the identification of critical components both spatially and temporally.
Within a city, the objective is to consider both technical urban services and city stakes.

Electrical transformers, water tanks, telecommunication nodes must be identified and located. Then hospitals, decision-making centers, major firms, densely populated areas, or any other stake are also added to the database.

Then for each component, dependencies to other services (for instance power needs, water consumption, dependence to telecommunications or transportation) are characterized. Best approach is to get information from local services operators and urban services managers.

Then the tool enables the assessment of disturbance scenarios between networks and domino effects within the system. The objective is to assess impacts on urban stakes: is the hospital able to operate? How many people are deprived of power? Etc.

These results must not be considered as simulation of real events but as a basis for collaborative thinking on city’s capacity to react to service degradation. Involving all urban stakeholders, it is then possible to test solutions (displace a transformer, strengthen a pipe, reorganize staff, provide emergency tools, etc.). These solutions contribute to general interest and not only to one service or one district resilience, which is often the case if urban services are managed separately or if decision are not made at a proper level.
IDENTIFY A RESILIENT LOCATION

When looking for an infrastructure location, identify reliability of urban services secures investments.

Depending on activity requirements, the most suitable location between land opportunities can be identified. Several criteria can be analysed with the tool in order to assess the feasibility and resilience of proposed location.

What is the activity level of operation requirement: All year long? Seasonal? 24/7? Can operation be interrupted during few hours, few days, never?

Which services are necessary for operation? Are they directly essential? Are they needed for operation optimization or organization?

Which constraints or benefits are predominant: Location near transport infrastructure for logistics activities? Location near customers for commercial activities? Location near resources (river, power plant, quarries)?

A multi-criteria analysis, weighed according to manager expectations, can help identifying the best location for its implantation. In doing so, preparing the site and operation continuity can rely on this first diagnosis, which can be refined in a second step with a specific assessment of supply resilience.
Guarantee safety and continuity for a system relies on identifying possible disturbances generated by network supplies.

Thanks to information collected regarding city resilience, it is possible to refine a specific location resilience assessment. This assessment first relies on a diagnosis to be conducted with the operator in order to identify and assess dependencies to external services.

Then it is possible to assess the availability of these services during situations (floods, power shortage, industrial accident, etc.) relevant for activity operation continuity.

The tool maps these dependencies and their exposure to identified risks. It also enables the identification of alternative solutions such as backup from another infrastructure, redundant connections, need for infrastructure strengthening.

This model can help managers to identify weak points and possible solutions but precise diagnosis of infrastructure reliability should be carried out with every network operator in order to assess real capacity to supply the site. Equally, feasibility of solutions (strengthening, redundance) should be assessed in coordination with network operators. However, at the activity scale, several organizational solutions can also be implemented without delays in order to limit negative impacts of supply failures.
RESILIENT URBAN DESIGN

During design stage, resilient network structure can be identified and land use optimized according to risks.

Thanks to risk analysis and understanding of city’s networks functioning, it is possible to design a more resilient project, taking into account both risk exposure and services reliability.

Functions identified in urban programmation can be distributed in the project area according to their sensitiveness to risks in order to optimize overall continuity. Besides, this plot allocation can give more value to non-exposed areas where value-added activities can be located. In most exposed areas, activities are not prohibited but they should be adapted to risk exposure. In particular, no housing or flood-sensitive activities should take place at ground floor level. Ground floor level should improve hydraulic neutrality with parking, sports ground or green spaces for instance.

Connections with existing networks can also improve project resilience if flood-proofing or redundancy is possible. Inside project, networks should also be adapted to expected disturbances: looped power supply, water-proof distribution, autonomous equipments, etc.

Road scheme is a major component of resilience as far as it is necessary for both population evacuation and emergency services access. Main roads should be kept out of risk level at all time and every point should be distributed by at least two roads. Evacuation routes must be signaled and people trained in living in these exposed areas.

Indeed, people risk awareness is essential when creating resilient neighborhood.
CONCLUSION

ROSAU is a powerful and simple tool dedicated to local authorities willing to anticipate the effects of urban services disruption on their city.

It is not made to assess the vulnerability of technical infrastructures but to identify domino effects following a disruption. As a consequence, it can be combined with other studies focused on climate change effects and damage assessment on infrastructures.