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Brief communication
"An auto-diagnosis tool to highlight interdependencies between urban technical networks"

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Abstract. Natural hazards threaten the urban system and its components that are likely to fail. With their high degree of interdependency, urban networks and services are critical issues for the resilience of a city. And yet, network managers are scarcely aware of their flaws and dependencies and they are reluctant to take them into account. In order to develop an operational tool to improve urban resilience, we propose here an auto-diagnosis method to be completed by network managers. The subsequent confrontation of all diagnoses is the basis of collaborative research for problem identification and solution design. The tool is experimented with the Parisian urban transport society.

1 Introduction

In the race for an operational approach of the resilience concept, some researchers have focused on assessments, indicators and dashboards. But the confusion in the comprehension of this vague concept, its multiple origins and multiple application fields are questioning the effectiveness of this search for implementation (Brand and Jax, 2007). This research focuses on urban resilience to natural hazards. We use here the resilience concept in a previous work: "The ability of a city to absorb a disturbance and recover its functions after the disturbance" (Lhomme et al., 2011). This definition implies that the urban system is able to reduce globally the effects of a perturbation and that its functions (decision-making, economic development, cultural development, life support, etc.) can be maintained or restored rapidly following a disturbance. Now, urban functions depends on urban services (water supply, telecommunications, transportation, energy), so their continuity of service is essential. Also, a resilient city needs reliable services that rely on a resilient network.

Natural hazards are highly susceptible to disturbing urban systems and to threatening human lives, goods and activities (Godschalk, 2003). In addition to the damages on buildings and infrastructures, networks are intensively impacted by natural hazards (see, for instance, the multiple reports written after hurricane Katrina). Their geographical extension and their high complexity expose them to disruption following an event, being directly (pipe disruption) or indirectly (employee absence). And yet, technical networks are needed during the emergency phase and afterwards, to foster a quick recovery and a better reconstruction (Tierney and Bruneau, 2007). Besides, the increase in technology and the internationalization of resources created many interdependencies between networks (Rinaldi et al., 2001). The fact that technical networks are dependent on each other is well-known, but scarcely taken into account in disaster risk reduction. The major parts of research concerning critical infrastructure interdependencies have focused on modeling and multi-agent simulation (Kröger, 2008) in order to understand the interactions between systems. On the contrary, our approach relies on managerial expertise in order to highlight their knowledge of their complex system, build a specific portrait of the

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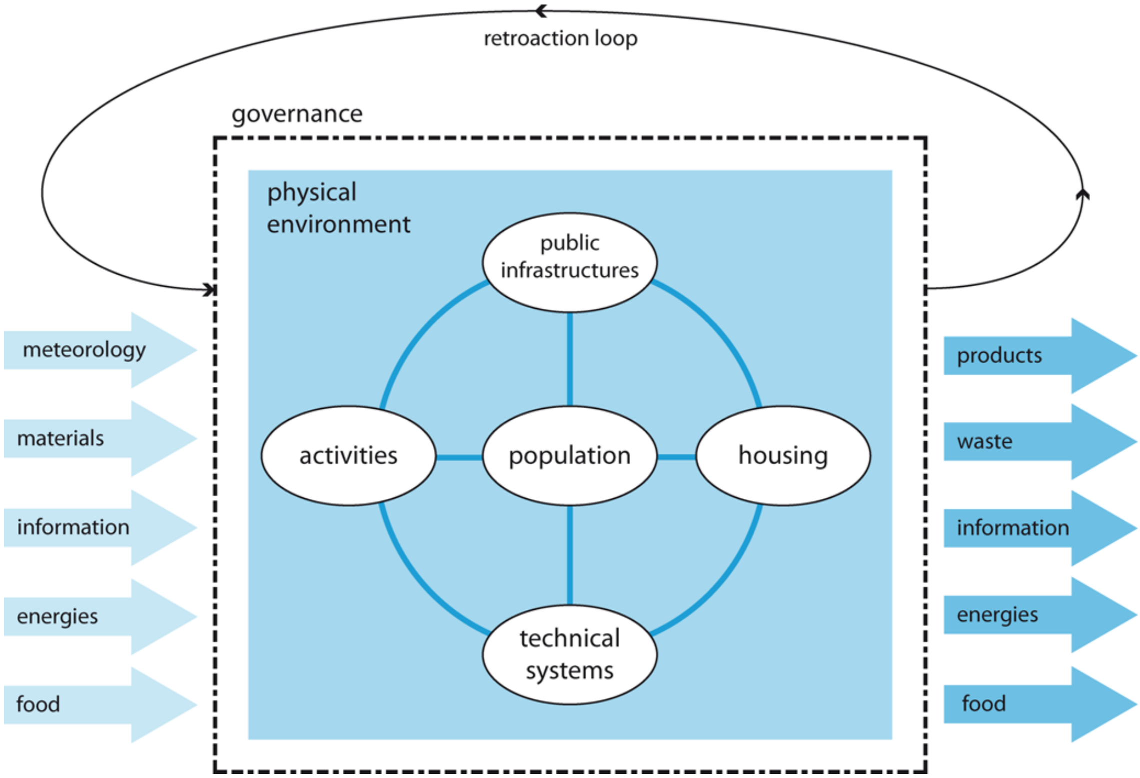

Fig. 1. City system as an input-output model (source: Lhomme S.).

system and ensure the managers' acceptance and awareness of infrastructure interdependencies.

Thus, the issue is to have network managers collaborate in order to tackle these interdependencies and implement common solutions improving urban resilience (Toubin et al., 2011). Indeed, resilience needs an integrated approach able to overcome the usual segmentation that hampers knowledge and resource sharing or collaborative implementation of mitigation measures (Boin et al., 2010). Prior to the event, network managers need to know on which networks they rely on and to what extent they are dependent on them to operate their service. This knowledge should then be used during the crisis management to prioritize repair interventions or to plan additional resources allocations. It is also valuable information to design more resilient systems or to adapt technical networks so that they can withstand disturbances. In this paper, we use equally the term technical network or system, because we chose a systemic approach to assess urban resilience, so that technical networks are sub-systems of the urban system.

The following part describes the tool developed to highlight those interdependencies and explains how it is used to raise awareness of urban resilience to natural hazards in general. The third part gives an example of application with the Paris transport service (RATP) and its issues facing flood hazards. Then, the method is discussed in part four.

We present here the first results of a research began in late 2010, so some notions are still in construction and the method will be improved with several case studies.

2 Methodology and tool

The methodology developed here is designed to challenge hurdles identified in the existing tools to improve urban resilience. The essential issue is interdependencies identification and management. Then, the tool should enable network managers to identify the networks they are dependent on: it is a diagnosis. Each manager describes his/her system with a chart, indicating which resources (s)he needs and which resources (s)he provides (Fig. 1). We are addressing here "input" interdependencies between systems (Eusgeld et al., 2011). For the water supply, for instance, water is needed from a source (river, water table), electricity is needed to run pumps and telecommunications are needed to remotely manage pumps and gates. The resource provided by the system is drinkable water.

Resources are separated into two categories: internal or external. Internal resources are the ones coming from the system that are available inside the boundary of the system and on which the manager should have more control. For instance, employees and financial resources are considered intrinsic to the system, whereas electricity or other materials

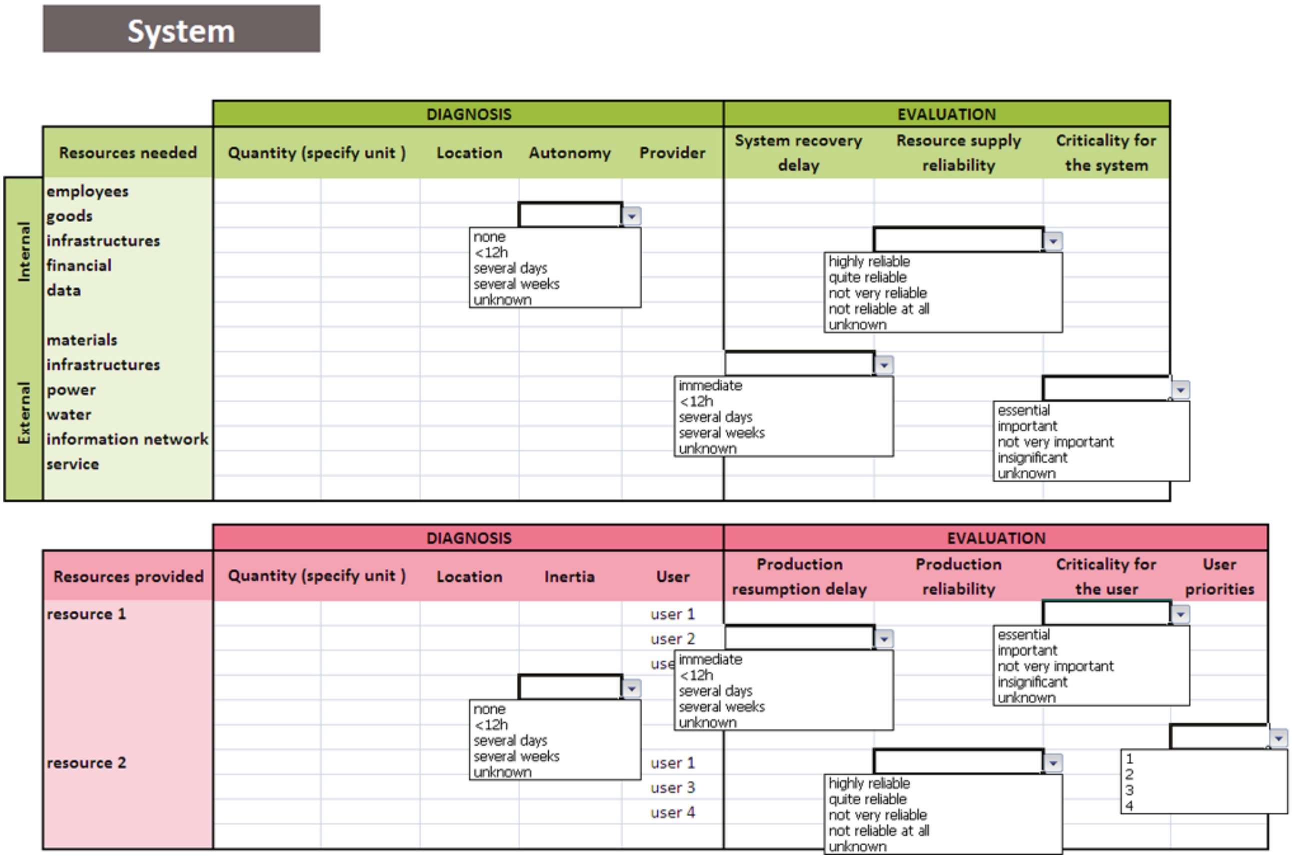

Fig. 2. Auto-diagnosis to be completed by the network manager.

are external. Additional information can be added, such as quantification and location of the needs, but it is not necessary to the first approach. Indeed, managers are often reluctant to share information about their network. The precise needs, the location and the subsequent infrastructure are critical information for safety and strategic reasons (Robert et al., 2009), but also for the competition between operators or their notoriety, or simply because the exact location is not known. Those issues imply that the diagnosis should not be too accurate, and that the managers fill it in themselves: it is an auto-diagnosis.

In order to have relevant information concerning interdependencies, managers are asked to assess the criticality of their needs for the functioning of their system. With the consequent hierarchy between the entering resources, they should better understand why they have to take them into account, collaborate with the provider and find solutions to ensure their reliability (Fig. 2).

Several pieces of information are required, prior to the criticality evaluation, in order to help the manager. For instance, whether the system has an alternative source to compensate a resource, providing it with additional autonomy (e.g. an electric generator in order to compensate a power cut). Other information concerning the impact of a possible shortage on the system also helps the manager in characterizing his/her dependency towards a resource. Thus, it is asked how long the system would keep on functioning in case of a shortage of a resource; then, when the entering resource is available again, how long it would take for the system to recover its functions. It is a rough evaluation: from a few hours to several weeks, but this temporal information is relevant to assess the margins of the maneuver of the system. It enables the assessment of cascading failures between systems (Fig. 3) and when the systems are recovering, the lag between systems that can delay the final supply of a service.

Concerning the resource provided by the system to other systems, the managers are also asked which users they have identified and how critical they think their resource is for the user. This second evaluation is added in order to compare the perception of the provider and the user towards the same resource and to highlight offsets.

Once those diagnoses are realized for each system, the interest is to gather the managers and to have them discuss on the basis of the diagnoses. A common representation of interdependencies can be displayed to summarize the results and identify critical links (Fig. 4). Differences in perception are emphasized by the difference in arrow width, so that the

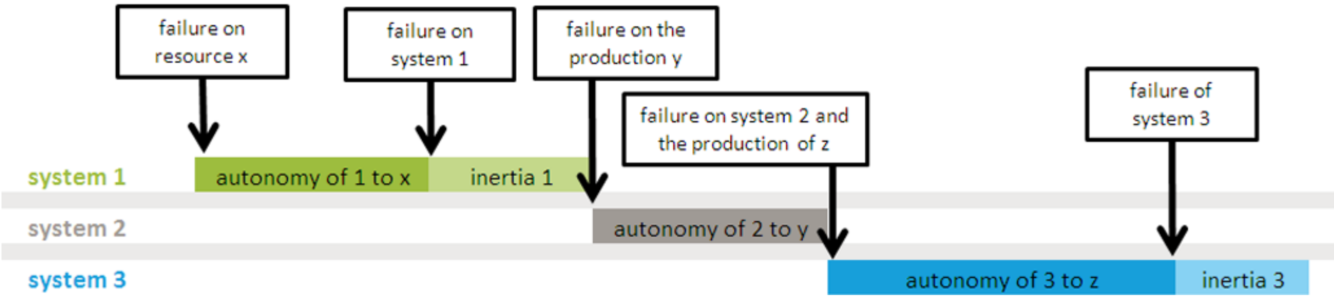

Fig. 3. Cascading failures between 3 systems.

following managers can discuss the criticality, and agree on the importance of the dependency.

3 Case study

The method was first applied to the Parisian transportation society (RATP), which manages the metros, buses and suburban transports (RER). Several metro lines were already in service in 1910 when the Seine flooded many districts of Paris and neighboring cities. These floods now serve as the reference for flood risk management in Paris. The RATP already experienced the event: in 1910, 50 % of the metro network was flooded, but the system recovered in 4 months. The RATP planned for the crisis and now benefits from information on how the network behaved during the floods. This reference will be used in this case study for reducing the vulnerability of the present network. The transportation network (especially the metros) is very old and highly vulnerable in case of floods. In order to preserve the infrastructure and the trains, which would be irreplaceable, the RATP plans to protect the network. For each level of the river, they know which points are likely to be flooded. As a protective measure, they have planned to build walls around the station entrances (among others) in order to prevent the water from entering the underground.

According to the RATP manager we met, they will focus here on the metro system in the situation of moderated floods, i.e. where the network is not entirely flooded. In fact, 30 % of the service should not be ensured because of the closed stations, mainly in the center part of Paris, near the Seine. Because of confidentiality matters, the auto-diagnosis is limited to the external resources and no information on quantities or location were given. The information collected allows identifying external dependencies, which is the main challenge of our research.

For each resource, the manager identifies why it is needed, what autonomy the system has, the alternatives solutions that can be set up and then the criticality of the resource. For instance, they spontaneously added the resources needed for train maintenance. They come from several suppliers and the RATP has a stock of spare parts (enabling a few weeks of autonomy), but it is necessary for the functioning of the system. The manager also identified several resources that are necessary for the employees to be able to work: transportation and roads to come to work, food and water supply, and sewage disposal. Degraded conditions of these resources could probably be accepted for a few days in case of crisis, but the impacts of a longer disruption should be assessed.

All in all, the portrait of the RATP system, as constructed with the manager, is given in Fig. 5.

This graphical representation highlights the strong dependency on electricity and the high vulnerability of the system to a possible disruption. As the manager notified, the RATP already knows this critical dependency and it has set up a complete strategy to reduce its specific vulnerability. It relies on an expected vicious circle, where electricity powers pumps that evacuate waters from the underground in order to protect the electrical infrastructures that supply pumps! We identified another interesting result of this analysis: an interdependency created by the system and symbolized by the dotted loop. Indeed, in order to protect its own infrastructure, the RATP plans to pump water and eject it in the streets or in the stormwater network. The amount of water ejected in the stormwater network is likely to be very small compared to the volume of an intense storm, but it is possible that in doing so, they bring water in areas that are not directly submerged (the location of which is known). The exact impact is studied by the RATP; it will not question the accessibility of these areas. Nevertheless, the possible retroaction loop was worth mentioning.

4 Results and discussion

This first experimentation with a network manager stresses the importance of interdependencies for the functioning of a system. Though the system we chose was one of good practice and already knew its dependencies, this analysis is useful for the comprehension of the interactions between systems. This quite simple tool can be used with other managers that are not as well prepared as the RATP in order to help them identify those dependencies. The tool is useful for the manager to prioritize the safety work for supplies, plan

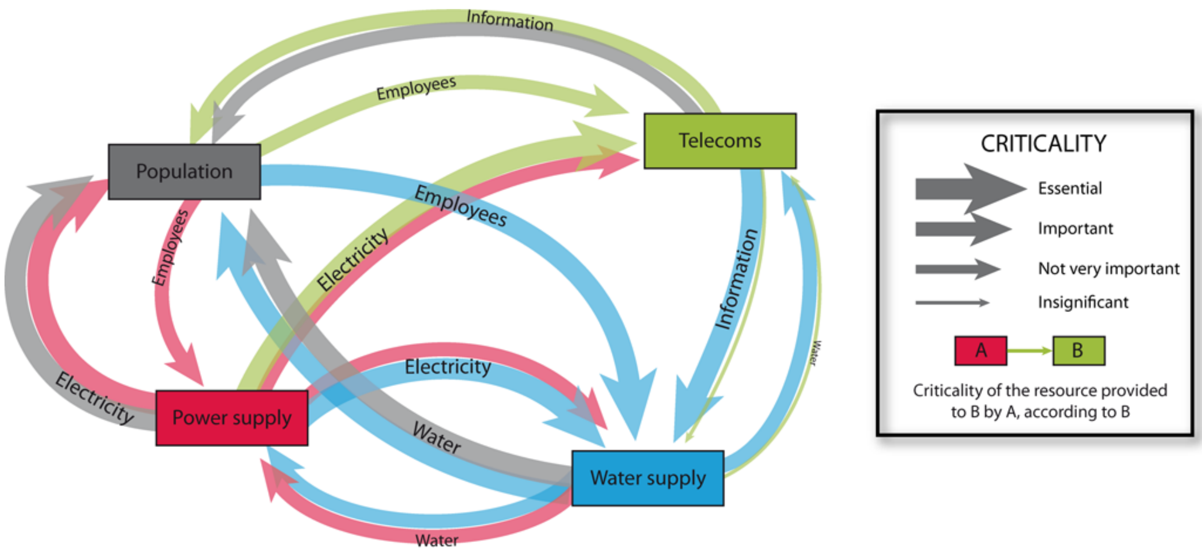

Fig. 4. Four interdependent systems.

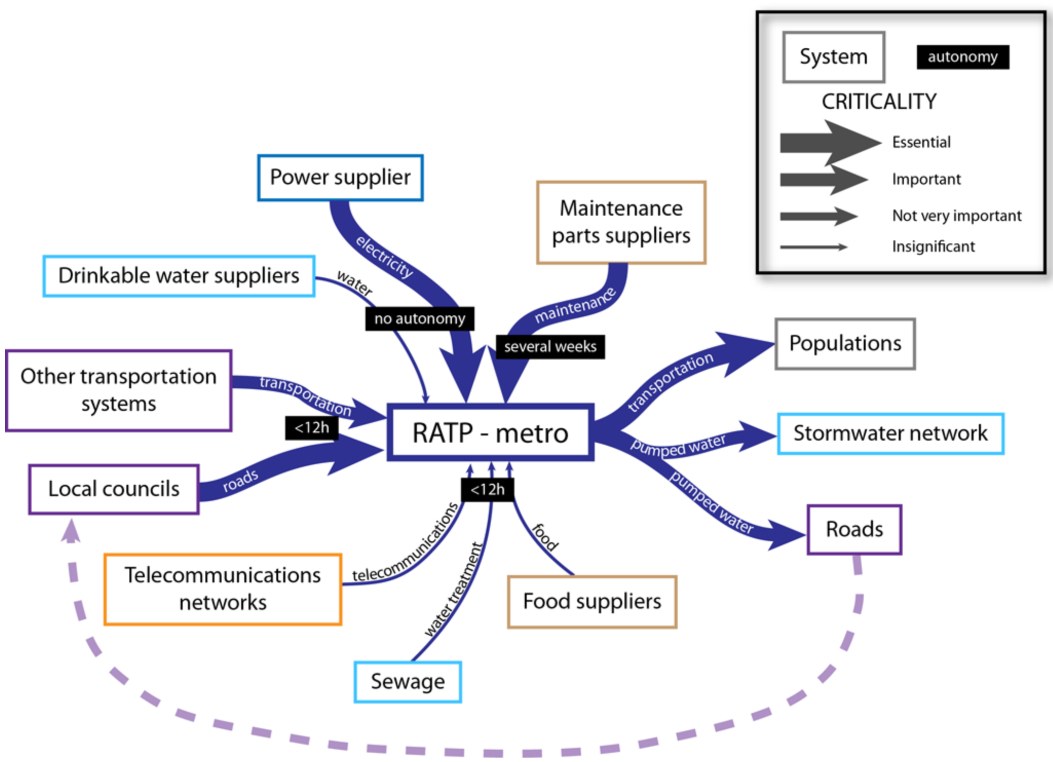

Fig. 5. Metro portrait.

for alternative sources or optimize recovery. Of course, the graphical representation is just a tool for better communication; the most important information comes from the discussion with the manager. Here, we highlighted that the critical dependency of the RATP network on electricity supply is well taken into account, but also highly uncertain. The exploitation of temporal information is limited here to autonomy (black boxes in Fig. 5), because the inertia or the recovery delays have no relevance here. Indeed, the RATP managers decide to avoid damage by interrupting partially the service, so that the infrastructure is not endangered. Then, the return to normal conditions depends on the duration of floods and if everything goes right, the metro should be able to operate almost immediately.

With only one system, we begin to imagine the mutual effects that systems can have on one another, justifying the systemic approach we chose for the city. It is also clear that collaborative work around those interdependencies is needed and that more detailed data will also become necessary. Indeed, beyond this first approach, if managers want to enforce common solutions to tackle these interdependencies, they need to know where and how they take place so that technical and organizational measures are efficient.

This research will keep on with the diagnosis of all network managers in Paris: drinkable water, sewage, electricity supply, telecommunications, but also city services or private firms identified by the previous systems as essential for their functioning: road network, food suppliers, goods and services. Then with all the diagnoses, a collaborative session will be gathering all the managers in order to share the information highlighted.

5 Conclusions

In this way of implementing resilience, we hope that our method raises awareness to urban services managers, at least. We aimed at realizing a method that can be accepted and understood by managers in order to help them identify their flaws, and assets as well. The case study has shown that this is a practical analysis tool and that relevant conclusions can be reached for the network manager. In our future work, we will improve the method with more case studies. The collaborative part will be quite challenging, but a robust work on collaborative methods used in water management (Ridder et al., 2005) or land use should ensure the effectiveness of the workshops. We have focused here on general methods to meet the reluctance or lack of information from managers; we remain convinced that a geographical tool to locate and quantify interdependencies is needed. A common GIS platform gathering all networks, city infrastructures, populations and issues could be of high value in planning for a more resilient city.

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