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SMART CITY RESILIENCE: A SYSTEM-OF-SYSTEMS APPROACH

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Abstract:
The concept of „smart city" represents the new buzz word when discussing the contemporary urban planning practices. With the help of ICT infrastructures, settlements are nowadays more interconnected than ever, mediated at the distance and operated through control centres. At the same time, the proliferation of threats and risks to the ICT networks affect the well functioning of such intelligent tools of urban governance. Thus, the resilience of such a connected and prone to malitious actions system becomes the desiderate to decissions makers. The current research attempts to disentangle these concepts by providing an up-to-date state of art and concequently discussing gaps in the current literature on this matter. Moreover, the paper suugests some further directions of study and limits of current scholarship in this realm of research. The paper concludes that a system-of-systems approach to smart cities' resilience is missing in the literature.

Key words: smart city; resilience; system-of-systems; complexity

1. Introduction

The concept of „smart city" represents the new buzz word when discussing the contemporary urban planning and governance practices. With the help of ICTs and infrastructures, settlements are nowadays more interconnected and interdependent than ever, mediated at the distance and operated through control centres. At the same time, the proliferation of threats and risks to the ICT networks affect the well-functioning of such intelligent tools of urban governance. Thus, the resilience of such a connected and prone to malitious actions system becomes a desiderate to decisions makers.

This paper attempts to address the global trends situated at the intersection of smart city, critical infrastructures, outer space politics and resilience as a novel form of ensuring the protection of assets and citizens. It therefore reviews the implications of transitioning from analog to digital, from protection to resilience, as well as from networked to smart infrastructures, in order to shed light on the current complexities. The paper concludes that a system-of-systems approach to smart resilient cities is of benefit to decision makers.

2. From analog to digital

The collapse of the Iron Curtain in late 1980s and early 1990s produced profound changes in the global security and defense landscape. Among the most important paradigm shifts is the use of information and communication technologies (ICTs) in what is known today as digital or cyber revolution. With more than half of world's population having access to internet [1] the digital realm marked a profound paradigmatic shift of how we understand reality. While in Thucydides' time, battles were fought only on two domains, i.e. on land and at sea, the

international community agreed that current wars could be fought also in air, in outer, and in the cyber space. Indeed, in 2010 the U.S. declared cyberspace as a new military "domain" [2], while in December 2019 NATO formally declared space as the fifth operational realm [3].

However, as the allied forces struggled to keep up the pace with these global initiatives, the understanding of both space and cyber risks and threats also proliferated. The new understanding clustered around their dual use character, namely around a general fear of malign forces having "the ability to cause effects remotely not only over regional but also global distances" [4]. Similarly, critical areas as communications, navigation and intelligence which are enabled by the satellite-based technologies started to be seen as more vulnerable to new risks, as well as to potential threats of interference from non-allied nation-states [5].

While the cyberspace changed the nature of communication, from the mass media's "one-to-many" [6] into "many-to-many" [7], so it changed the understanding of space technologies' involvement into our daily routine. From weather monitoring, environment and agriculture, to transport, science, communications and banking, to name only a few, the information gathered and delivered through satellites is critical for military activities, operations and missions, including collective defence, crisis response and counter-terrorism [5].

In the international relations, this new vision of how reality unfolds maked the transformation of real politics into more fluid forms of "cyber" or "outer space" politics, constructed by various actors in different layers and at different levels. Thus, the rapid technological advancements over the past three decades determined permanent changes in national and international political and strategic agendas of countries and organizations, as well as in structures, resources allocated, research and innovation patterns, leading up to an intense technological competition on all realms of life.

3. From protection to resilience

At the same time, while risks and threats to critical assets proliferate, the concept of protection became obsolete. With ever increasing numbers of "black swan" events, the overall thinking of protection shifted towards ensuring the continuity of essential services. The interdependency of infrastructures means that a domino effect is likely to paralyse several critical sectors at once, with severe implications for society in general. While infrastructures are large, dynamically unsynchronized, and complex [8], vulnerabilities are many and the speed of proliferation is sometimes too high to keep up the pace with it. In other words, the idea of protection blurrs facing the technological expansion that permits threats to circulate through the same channels of everyday life.

Thus, while on a political level the emphasis on such approaches was growing, at the technical level, efforts were clustered around finding ways to withstand the ever growing number of potential threats. Accordingly, the capacity of bounce-back-ability of critical systems to recover their function became key in attempting to manage all the panoply of potential disasters. Resilience as a concept became the new trend, being understood more like an elastic property of critical assets to recover than to resist the myriad of potential attacks.

As governments, industry and researchers are currently pursuing next-generation capabilities, resilience emerged as an optimal solution. A recent U.S. governmental report on the politics of space operations claims that "protection is probably unlikely to be as cheap as resilience" [9]. This approach underlines the fact that constructing assets with a built-in resilient character is more efficient and arguably cheaper than to invest into the post-disaster industry.

At the European level, different research activities such as the development of methods and tools for international cyber security exercises, the assessment of the vulnerability of networked infrastructures in case of extreme space weather events, and the evaluation of the resistance of buildings and transport systems against explosions [10] also shifted from protection to resilience. Thus, emerging threats, as well as unconventional attacks to critical infrastructures have exposed the limits of traditional risk assessment and risk mitigation efforts. Some threats cannot be foreseen, while reducing all possible risks at the minimum possible level is not always cost effective. Resilience offers the perspective of reassuring service continuity in the aftermath of destructive events especially in cases when these cannot be predicted. The performance of technological systems needs to take into account their interdependencies across sectors and across borders and quantify the economic impact of disruption of critical infrastructures on society [10].

4. From the 'networked' to the 'smart' infrastructures

The 'smart city' as an evolving paradigm, situates at the convergence of technology and the city. In fact, a smart city's development is connected to the ICTs in such a way that its 'smartness' translates into high technological integration. At the same time, the outer space infrastructure opened up critical information to numerous mass market applications, fostering not only urban innovation, but access to fundamental services such as transportation, provision of energy, water and food, and healthcare, among others. Smart cities use information and communication technologies to increase operational efficiency, share information with the public and improve citizens' welfare and the quality of key services. Advances in satellite-based technologies are giving rise to more competitive services, while minimizing environmental and social impacts. Certainly, these intimate integration aspects between space technologies and cities are also valid in the cases of malevolent interventions, disruptive technologies or in any other case in which space technologies are interrupted by intent, this feature trickling down inevitably to the well-functioning of smart cities. In fact, in the moments of failure it is the most visible the profound interconnections between technologies, services and societal well-being.

Historically, urban planning has considerably changed over the last century. When, as a consequence of industrialization and massive rural-urban development in the 19th and 20th century, cities expanded beyond their middle-age walls, engineers planned the urban expansion by designing urban street networks, building electricity grids, water supply and sewage networks. In the beginning of the 21st century, a new era of infrastructure development emerged and information and communication entered the stage of urban development. Currently, the smart city adds up another dimension of urban development, one in which urbanization expansion is happening in a networked manner, giving rise to a different reality.

The contemporary urban settlements are not only networked, in the sense of being connected and interconnected through large engineering systems of pipes and wires, but they are also intelligent due to their expansion into outher spaces, namely the cyber and outer space. What would a city be without access to internet, or without telecommunications? The novel form of habitable settlement is automatically intimately connected to both technologies supporting modern lifestyle, as well as threats lurking in the shadows of such technologies, both using the same pathways to circulate and to operate. It falls from here that resilience, as a built-in capacity to absorb shocks of all kinds, is currently the only way in which the humanity could attempt to survive potential disasters.

5. A system-of-systems approach to resilient smart cities

Complexity is now an ubiquitous part of our lives. The "complex" view of reality is perceived as increasingly fundamental to understanding strategies at all levels, from the international consensus to domestic realm, and from governmental to private entities everywhere. Therefore, the inclusion of complexity into the management discourse is a natural consequence, and many researchers, strategists, or managers have attempted to find the right approach to managing complexity. However, it is not the place here to theoretise the models of complexity management, but to introduce the concept of complexity into the discussions about critical infrastructures and resilient smart cities.

The attacks on the everyday channels of mobility have accentuated changes in the everyday geographies of urban space driven by both imagined vulnerability and research and innovation pushes from the security industries. In fact, national security merged with politics of critical infrastructures, transport security and urban safety. The city perceived as a fragile and vulnerable space, one that contains both 'the good' and 'the bad', became the operational field of strategies that attempted to harden it and to increase its resilience or 'bouncing back-ability' to recover as quickly as possible from any incident, from terrorist attacks to natural disasters or accidents, by building "resilience". Furthermore, with that came other concepts such as 'societal security'- "the ability of a society to persist in its essential character under changing conditions and possible or actual threats" [11] that got to put even more emphasis on the places with high density of people. Additionally, more and more attacks from non-state actors have been consolidating this ambivalent nature of urban infrastructures as both indispensable and vulnerable.

Detecting and isolating the 'unseen threat' from the flow while maintaining circulations running requires innovative security solutions as well as high integration of previously-independent systems. As security relies heavily on real-time digital technologies of monitoring, visualization and simulation for sorting the malign components, civilian urban spaces turn into assemblages of material and non-material elements, tangled together by hopes for the absolute control of the 'enemy within'.

The systems that have been created to help and support our needs, many of which being critical, such as energy, transportation and communications, food production, water management, and heath care, among others, are being now transformed by newer technologies and are becoming increasingly connected to each other [12]. In other words, the interactions within these large-scale complex socio-technical systems as well as their interaction beyond the system boundaries raise even more challenges.

Having said that, the challenge we face nowadays is how to address the problems associated with integration of multiple complex systems [13]. Furthermore, the need to solve system of systems problems is urgent not only because of the growing complexity of today's challenges, but also because such problems require large monetary and resource investments with multi-generational consequences.

Organizational systems as well as the usual life routines are becoming increasingly complex due to involvement of more sophisticated information and communication technologies [14]. As Weck et all (2011) discusses, "systems that had once been clearly separate began to interact more than anyone could have imagined" [12]. One reason is because "scale and

complexity increased inexorably and we ended up with system on systems. These, in turn, touched more and more lives and affected how we do things".

An integration of the smart practice into the resilient city is, therefore, promising to overcome the urban complexities to support social-ecological-engineering resilience. In particular, a resilient smart city is expected to use big data, Internet of Things (IoT) and other smart information technology to manage cities to enhance capability of resisting, absorbing and adapting to external changes, thereby achieving urban resilience. Beyond this, building and understanding a resilient smart city by the use of system-of-systems enhanced approach, could reduce vulnerabilities.

6. Conclusion

This paper attempted to review some of the current trends related to security and resilience of smart cities at the same time introducing the idea of system-of-systems into current academic thinking.

It is the time to expand our thinking both in interdisciplinary as well as in trans-disciplinary ways. While, historically, outer space has been considered the realm of astrophysicists, current threats and the interconnected nature of modern society with its fusion between ground-based critical infrastructures with space-based ones to supply key services make space a realm for security experts. As these sectors are interrelated and interdependent, it is important to familiarize ourselves with a more holistic manner of thinking that is not reduced to single academic disciplines or sectors of life. It should not be solely under the jurisdiction of outer-space specialists concerning the identification, designation and management of such important systems.

Furthermore, with respect to the scholarship in governance studies, where are the limits of global politics end and the limits of urban governance start? The conclusions highlight that there is a lack of studies on the integration of smart city into resilient city and the opportunities and challenges of building smart resilient city have not been revealed.

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