Adaptive aspects of a resilient city

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Abstract. A city’s disaster preparedness can be measured by two aspects: its vulnerability as the negative aspect of resilience, and its adaptability as the positive one. The efforts to improve cities’ resilience around the world mostly focused on reducing their vulnerability, because this aspect of urban resilience is easier to comprehend and then managed compared to the adaptability aspect. The vulnerability is often perceived as a static aspect and pre-existing condition of an urban characteristic. Thus, reducing vulnerability usually is a one-way process, with clear objectives, goals, and methods of how to achieve it. On the other hand, adaptability is something that dynamic that varies in both spatial and temporal dimension. Analysis of existing methods and practices resulted in a formulation of three types of urban adaptability towards a resilient city, which are its Structural, Behavioural, and a new emerging concept, which is its e-Adaptability.

1. Introduction

As a concentration of people and activities, urban areas face disturbances that usually differ, both spatially and temporally. Those disturbances, or more commonly known as Hazards, can occur in a short-term and then settle (i.e. traffic jams and fire incidents). Another type of hazards, such as floods and hurricanes can occur for days or even weeks before stopping. Hazards can also present for years, or even decades, such as drought, climate change, and extreme cold/warm period. A careful consideration must have taken into account when determining long-term changes as hazards, such as the one that happened during the Industrial Revolution. The growing use of fossil fuels as energy sources, that followed by the increased amount of carbon molecules in the atmosphere, cannot be simply defined as a hazard. Another example is the shift of economy from fossil-fuel based to biotechnology ones, that may require more land to be planted to produce energy, some of those land may even created by opening forests. Reduced size of forests cannot simply be defined as a hazard because there is a growing benefit to the environment from the use of bio-fuel. From the spatial aspects, hazards can vary from local scale, regional scale, national scale and even at a global scale. The impacted communities hence can vary from the neighbourhood, urban residence, a nation, or even the whole human as a species. In the spatial aspect of urban resilience, most of the problems related to hazard management arise because there is miscommunication between authorities in different scale [1].

To cope with those disturbances, we need to apply the concept of resilience to cities. As the centre of human civilization, cities need to be long-lasting to support human activities by protecting them from hazards or at least manage them in an acceptable condition. The government of cities around the world must develop a protocol for them and their citizens about how to respond to crises. And finally, because hazards will always exist, cities need to adapt to existing hazards and possible ones. Therefore, cities
may grow differently, and each of them may require developing unique internal strengths, adequate infrastructures, and a hazard-resistant urban environment [2].

Cities’ resilience is their ability to avoid, minimize, and when finally occur, recover from hazards that happen not only within cities’ boundary but also their surrounding area. Resilience achieved by the intersection of a city’s vulnerability from hazard and its adaptive capacity. Hence, a city’s resilience increases when it has a higher adaptive capacity, and on the other hand, decreases when it is more vulnerable to hazards. Exponential growth in term of population and economic growth cities around the world are put much pressure on cities [3]. There are four most important issues in relevance to achieving resilience for cities, which are [4]:

- The balancing mechanism between a city’s functions, the well-being of its residents, and their quality of life that must fulfill a set of standards.
- The network between government’s offices and the ability of the community to learn and adapt to disturbances in their daily life.
- The dynamics between people, either as the resident of the city, its consumer, and users of city’s infrastructures.
- The built-up environment that defines the physical outline of the city.

A city’s resilience can be measured by two aspects; its vulnerability as the negative aspect of resilience, and its adaptability as the positive one. The vulnerability is the aspect that has been widely discussed, thus this paper focused on the adaptive aspects of a city. The adaptive aspect is a measurement that must be evaluated both by the process and the result of the efforts to achieve it. In general, the adaptability aspects of the city can be achieved if there is an increase of its resilience. However, in some cases, increasing a city’s adaptability can lead to a lower level of resilience, for example [3]:

- Efforts to achieve adaptability may be profitable for a certain group of community, while for other groups, those efforts may give them disadvantages.
- Adaptability measures are not always effective in different scale of implementation, for example, they only effective on a micro scale but not on a macro scale, and vice versa.
- When a city is adaptable to a certain hazard, it can have lower resistance towards other types of hazards.
- The loss of traditional responses, that based on the local wisdom of a community after they are exposed to a hazard for a long period.

Adaptability is the capacity of the actors in a system to manage resilience. Cities can also be considered as a system, where actors are connected to manage them. An adaptive system can be characterized by the presence of self-organizing control for a certain issue assigned to. An adaptive system also needs to be able to make decisions, at some levels, without the human control. For example, an electric circuit breaker needs to cut the current immediately when needed, without authorization from a human decision-maker. On the other hand, humans have the capability of a foresight and make a deliberate action when needed. Therefore, management of a city’s adaptability is a combination of the two issues; the capability of the city to make an automated decision, and human’s capability to see unexpected disturbances and hazards. However, in the current scheme of city’s governance around the world, human decision-makers still dominate the hazard management system, thus the adaptability of cities still relies on the capability of individuals and groups belong to branches of governments’ offices. Their decisions will influence adaptability of cities, either by the intention to do so or as a side effect that unpredicted before. [5].

To make the development of the cities can move towards the improvement of their social, economic, and environmental aspects, their government must be able to build an adaptable protection system that can deal with the hazards that they are facing. With an adaptable safety measure, both the government and the residents of the city will be able to create a resilient urban system. The term resilience itself emerged as a notion in urban planning practices that surfaced in the 1990s, as the response to the threats to the environmental balance due to the growing realization of the extent of climate change and global warming problems. Urban planners and decision makers worldwide got a common understanding that solely relies on mitigation measures to deal with global warming will be ineffective, thus prefer adaptive
and flexible measures to achieve a resilient city towards the threat of climate change [6]. When a city is ready to face the occurrence of previously predicted hazard, and quickly return to its prior condition before the hazard, can be defined as a resilient city [7].

Urban resilience measures can be applied in urban planning practices in different ways, depends on the planning culture held by the municipality. For example, in the United States of America and the United Kingdom, the main focus of the resilient city is toward the threat of terrorist attacks, whereas in the countries on the European mainland, the focus is towards the threat of global warming and climate change [8]. To answer the challenge of achieving cities that are sustainable, resilient, and inclusive, massive financial resources have been and still can be expected to be provided by municipalities around the world. This financial resources will be allocated as investments in various sectors of urban governance, either the infrastructure, housing, social welfare, and energy, in-line with the statement of a “new urban agenda” issued by the United Nations Conference on Housing and Sustainable Urban Development [9]. The efforts to improve cities’ resilience around the world mostly focused to reduce their vulnerability, because this aspect of urban resilience is easier to comprehend and then managed compared to the adaptability aspect. The vulnerability is often perceived as a static aspect and pre-existing condition of an urban characteristic. Thus, reducing vulnerability usually is a one-way process, with clear objectives, goals, and methods of how to achieve it. On the other hand, adaptability is something that dynamic that varies in both spatial and temporal dimension. To give urban planners and decision-makers a better understanding about how adaptability measures toward a resilient city are being implemented, this paper tries to make an overview about those efforts and categorize them into different types of adaptability measures.

2. Method
This paper implements a Meta-Synthesis approach, which analyses and synthesise the key elements in researches related to the concept of a resilient city and the implementations of measures to achieve it. The aim of the meta-synthesis in this paper is to transform findings in each of the research and implementation to construct a new concept and generalization [10], [11]. In this paper, available methods and practices to improve or achieve the adaptive aspects of a resilient city were examined to make a categorization of those methods and practices. While previous works related to implementations of hazard mitigation measures in urban areas are abundant, a specific research that summarizes those measures and categorizes them based on their characteristic is not available.

To establish an overview of methods and techniques related to adaptability measures in urban areas, this paper first formulates the underlying characteristic of those measures. This step will produce general categories of adaptability measures. The main hypothesis of this paper is that by comparing the main characteristics of adaptability measures toward a resilient city, a pattern will emerge, that will make a categorical grouping of those measures possible. After the general categories of adaptability measures are established, the next step is to perform an in-depth analysis of each category, to explore the similarity and variance of adaptability measures that fall within the same category. The result of this phase will give a detailed explanation about types of adaptability measures, how they are implemented, and examples of their implementations.

3. Results

3.1. Structural Adaptability
The most common approach to implement the adaptability aspect in urban areas is the structural adaptability. Structural Adaptability is achieved by modifying man-made structures to cope with existing and future hazards. This approach can be both static, i.e. when buildings are constructed to make them adaptable towards hazards, and also can be dynamic, i.e. with an adjustable structure. An example of a static structural adaptability is when a city was designed to be adaptable to hazard, by arranging infrastructures, building blocks, etc. Another example of implementation of structural adaptability on urban areas are the climate-change related ones. In this effort, measures to mitigate urban heat islands were implemented through the construction of systemic and interconnected microclimates that can protect and support urban activities. Furthermore, this effort seeks to reduce energy
consumption and produce a cleaner air quality. Performance standards were formulated and measured for objects related to the improvement of structural adaptability of cities, such as ventilation systems within buildings, green and eco-friendly infrastructures, and alternative energies. The impacts of the operation of those objects also measured, such as urban reflectivity, sky visibility, greenhouse gases emissions, and surface temperature [12]. Another area where implementations of static structural adaptability are in urban flood management, where the utilization of structural defence to minimize the impact of flood hazards. These static structural adaptability measures were implemented by urban authorities worldwide by the construction of flood protection systems. [13].

![Figure 1. Static Adaptability Approaches to Flood Adaptation.](source:14)

Figure 1 shows an example of static structural adaptability measures, where buildings can be constructed with three alternatives when considering a nearby flood hazard. Buildings can be constructed as far as possible from hazards, constructed with a protection from hazards, or even design to accommodate the existing hazards. The static structural adaptability measures can also be implemented for the whole city, where the general outline and design of the city is already incorporated the existing hazard. Figure 2 below shows how this approach is done, by using streets to allow a relatively unblocked path for strong wind and storm surge. With this measure, hazards will be dissipated faster rather than their path are blocked by buildings.

![Figure 2. An Urban-Scale Static Structural Adaptability](source:12)
These static structural adaptability methods mentioned above usually designed to be long-lasting, by considering existing hazards. Despite proven to be useful when faced with hazards that already have been predicted, static structural adaptability may not perform well when faced with unexpected hazards. Another approach to structural adaptability, which is the dynamic ones, may perform better when implemented to manage hazards that are not predicted before.

Because static structural adaptability measures are a common feature in urban environments, a dynamic adaptability measures usually complement the existing infrastructure by adding new features to the static measures ones. For example, dynamic adaptability measures in cities usually achieved by adding hydraulic structures that can be utilized to either managing, diverting, reducing, or even completely stop the water flow into the city. Therefore, dynamic structural adaptability measures will encompass a common key component, which is an adjustable regulatory feature, such as in an urban flood management system [15].

An example of a dynamic structural adaptability can be seen in the implementation of a Barrier Transfer Machine, or a road “Zipper” that can modify the width of a road by moving its separator. This method makes road segments can have different capacities, that adjusted based on requirements. For example, road segments towards city centres are widened during morning rush hours, thus made road segments towards sub-urban smaller, and vice versa. The implementation of a Barrier Transfer Machine can be seen in the figure below.

![Figure 3. Barrier Transfer Machine](http://cloverleafcorp.com)

3.2. Behavioural Adaptability

The Second aspect of adaptability is the Behavioural Adaptability, which focused on improving individual and community in responding to disturbances in urban areas. Behavioural adaptability can fill the gap left by structural adaptability, which requires a relatively higher amount of resources and efforts to be implemented. In developing countries that cannot afford to implement structural adaptability, urban resilience can be achieved by modifying the behaviours of its residences when facing a disaster. Behavioural adaptability, despite its simplicity, can help communities in urban areas to avoid casualties and limiting the disruption and damage caused by hazards. This realization promotes a worldwide movement that shifts the risk management approaches from structural adaptabilities to non-structural approaches in hazard and risk management [16].

The essential element that must be taken into account when formulating behavioural adaptability measures to achieve a resilient city is a combination between discipline, which includes structural, policy, and process, and agility, which is the ability to be creative and improvise if measures don’t work [17]. Behavioural adaptability measures mainly concern on non-engineering actions such as restricting urban development, regulating physical activities within the city, and providing training and drills to cope with disaster [15]. In this approach, resilience is achieved by altering the behaviour of its residents, the spatial and physical characteristics of a city, and its surrounding areas. Behavioural adaptability can
also be achieved by providing an Early Warning System (EWS) to avoid or reduce damage during a disaster. The presence of EWS as one part of adaptability measures is very important because of residents of the city aware of possible disasters and their coping strategies, they will be better prepared when disasters occur. Community-based adaptation (CBA), is a newly emerging approach to improve the behavioural adaptability of the residents in a city, thus increasing the capacity of local people to adapt [18]. The main premise of CBA is that when a city’s residents have the required skills, experience, local knowledge, and networks, they themselves will be able to take necessary measures when faced with disaster, increase their resilience, and reduce their vulnerability to various type of hazards, even climate change [19].

There is probably no behavioural adaptability improvement effort that is more famous than the one regularly conducted in Japan, where children from early ages are involved in a disaster prevention drill, mostly earthquake. This effort has proven to be efficient to reduce the number of injured school pupils during an earthquake. Research about how behavioural adaptability is related to education is still limited, but there is one result that highlights an observed paradox; the highly educated are the ones with the high sensitivity and lack of adaptability in disaster situations [20].

![Figure 4. Typical Earthquake Response Drill in Japan](http://telegraph.co.uk)

### 3.3. e-Adaptability

Development of computer technologies opens new opportunities for city planners and engineers to explore new methods to improve cities’ resilience worldwide. One of that software is a traffic management software that linked to the on-the-field traffic signals. With this kind of software, city managers can observe traffic conditions in real-time and then adjusted the timing of signals to adapt to disturbances, as shown in Figure 5.

![Figure 5. Traffic Control Room](http://www.smartsunguide.com)
There is already available software, in which where planners and decision makers can develop scenarios so predict how to implement adaptability measures when a disturbance occurs. Indeed, real-world scenario testing may produce more accurate results. However, with fewer resources required, using software such as shown in Figure 6, different scenarios can be utilized to decide which scenario is more efficient in infrastructure planning.

![Figure 6. Example of an Infrastructure Planning Application](image)

Recently emerging global use of handled devices provides an individual approach to adaptability. With this approach, mobile applications can give suggestions to users to avoid disturbances, such as traffic jam, flood, etc. It is up to the user whether to use this suggestion or not. The most rapidly emerging applications for this purpose is route suggestion ones, in which applications shows available alternatives, existing disturbances, and then shows the best route, as shown in the Figure 7.

![Figure 7. Example of an Online e-Adaptability Application](image)

Web-services, as shown in the figure above, are focused to help users to evaluate which route is the most convenient to them. In an urban resilience theme, those web-services can also be utilized in the event of a disturbance or a disaster, by providing suggestions or instructions to users about how to access the nearest safety point.
3.4. Composite Adaptability
Above discussions consider adaptability measures as separate approaches that can be implemented independently. However, in achieving a resilient city, two or more approaches can be implemented simultaneously. One of the urban planning concepts that can be utilized to achieve urban resilience is the compact city concept [21]. While this concept has been considered as a useful solution to the urban problems such as sprawl, congestion, and hazard, its implementations to promote a disaster-resilient city is not observed yet. Most of the implementations of the compact city concept are to improve traffic conditions in cities.

Based on the fact that urban areas that prone to hazard, especially in developing country, mostly have a high density but little degree of compactness, their residents usually have difficulty to access the facilities in the event of a disaster. A compact city, which provides an easy access to the public services, emergency services, and health services [22], will increase its resilience towards disaster

4. Conclusions
Adaptive aspects were seldom given priority in promoting a resilience city, due to those aspects' complexity compared to the vulnerability aspects. Because a city's resilience is measured in both adaptive and vulnerability values, the lack of adaptive efforts was not emerged as a concern, as long as the vulnerability-reducing efforts were adequate. By focusing not only on vulnerability but also towards adaptive aspects, the quest to make a city resilient will be improved. Recently emerging technologies provide an opportunity to further increase and promote the adaptive measures in facing disturbances and disasters. With these technologies, various applications, either desktop or mobile, can give suggestions to users to avoid disturbances, such as traffic jam, flood, etc. It is up to the user whether to use these suggestions or not.

The main challenges of utilization of those technologies are the security aspect of the technologies itself because the implementation of applications to increase a city’s adaptability will also increase in its vulnerability, because technologies, especially in form of computer systems, are prone to malicious attacks, i.e. from hackers and computer viruses. Therefore, implementation of new technologies in promoting a resilient city must be taken very cautiously.

5. References
[1] B. Müller, German Annual of Spatial Research and Policy 2010: Urban Regional Resilience: How Do Cities and Regions Deal with Change? Springer Berlin Heidelberg, 2010.
[2] P. Newman, T. Beatley, and H. Boyer, Resilient Cities: Responding to Peak Oil and Climate Change. Island Press, 2009.
[3] R. Barkham, K. Brown, C. Parpa, C. Breen, S. Carver, and C. Hooton, Resilient Cities: A Grosvenor Research Report. Grosvernor, 2014.
[4] R. Alliance, Research Prospectus. A Resilience Alliance Initiative for Transitioning Urban Systems towards Sustainable Futures. 2007.
[5] B. Walker, L. Gunderson, A. Kinzig, C. Folke, S. Carpenter, and L. Schultz, “A Handful of Heuristics and Some Propositions for Understanding Resilience in Social-Ecological Systems,” Ecol. Soc., vol. 11, no. 1, 2006.
[6] M. Spaans and B. Waterhout, “Building up resilience in cities worldwide – Rotterdam as participant in the 100 Resilient Cities Programme,” Cities, vol. 61, pp. 109–116, Jan. 2017.
[7] A. Renald, P. Tjiptoherijanto, E. Suganda, and R. D. Djakapermana, “Toward Resilient and Sustainable City Adaptation Model for Flood Disaster Prone City: Case Study of Jakarta Capital Region,” Proceedia - Soc. Behav. Sci., vol. 227, pp. 334–340, Jul. 2016.
[8] J. Coaffee, “Towards next-generation urban resilience in planning practice: from securitization to integrated place making,” Plan. Pract. Res., vol. Volume 28, no. Number 3, pp. 323–339, Aug. 2013.
[9] A. Zoomers, F. van Noorloos, K. Otsuki, G. Steel, and G. van Westen, “The Rush for Land in an Urbanizing World: From Land Grabbing Toward Developing Safe, Resilient, and Sustainable Cities and Landscapes,” World Dev., vol. 92, pp. 242–252, Apr. 2017.
[10] D. Polit-O’Hara and C. T. Beck, Essentials of Nursing Research: Methods, Appraisal, and
[11] D. Walsh and S. Downe, “Meta-synthesis method for qualitative research: a literature review,” J. Adv. Nurs., vol. 50, no. 2, pp. 204–211, Apr. 2005.
[12] J. Raven, “Cooling the Public Realm: Climate-Resilient Urban Design,” in Resilient Cities: Cities and Adaptation to Climate Change - Proceedings of the Global Forum 2010, K. Otto-Zimmermann, Ed. Dordrecht: Springer Netherlands, 2011, pp. 451–463.
[13] E. J. Plate, “Flood risk and flood management,” J. Hydrol., vol. 267, no. 1–2, pp. 2–11, 2002.
[14] U. Eichhorst, Adapting Urban Transport to Climate Change. Deutsche Gesellschaft für Internationale Zusammenarbeit (GTZ), 2009.
[15] K. Hansson, M. Danielson, and L. Ekenberg, “A framework for evaluation of flood management strategies,” J. Environ. Manage., vol. 86, no. 3, pp. 465–480, 2008.
[16] G. Pender and S. Neelz, “Use of computer models of flood inundation to facilitate communication in flood risk management,” Environ. Hazards, vol. 7, no. 2, pp. 106–114, 2007.
[17] J. R. Harrald, “Agility and Discipline: Critical Success Factors for Disaster Response,” Ann. Am. Acad. Polit. Soc. Sci., vol. 604, no. 1, pp. 256–272, Mar. 2006.
[18] D. Satterthwaite, “The implications of population growth and urbanization for climate change,” Environ. Urban., vol. 21, no. 2, pp. 545–567, Sep. 2009.
[19] J. Ayers and T. Forsyth, “Community based adaptation to climate change,” Environ. Sci. Policy Sustain. Dev., vol. 51, no. 4, 2009.
[20] K. Markandey and B. Srinagesh, “Housing in Hyderabad: Perception of Inclusivity,” in Urban Development Challenges, Risks and Resilience in Asian Mega Cities, R. B. Singh, Ed. Tokyo: Springer Japan, 2015, pp. 195–203.
[21] M. Z. Mahriyar and J. H. Rho, “The Compact City Concept in Creating Resilient City and Transportation System in Surabaya,” Procedia - Soc. Behav. Sci., vol. 135, pp. 41–49, Aug. 2014.
[22] M. Sanroychansyah, A. Farmawati, D. S. Anindyah, and L. Atianta, “Urban Compactness Effects on the Distributions of Healthy Houses in Yogyakarta City,” Procedia - Soc. Behav. Sci., vol. 227, pp. 168–173, Jul. 2016.