Enabling the Possibility of creating a New Smart Resilient City in the Post-Pandemic Period

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Beginning in early 2020, the COVID-19 pandemic sweeps across the globe. Despite the full lockdowns are being released deliberately and gradually in most parts of the world, social distancing is still needed in short-term and medium-term to mitigate the spread of coronavirus. These disruptive changes of life and work landscape bring the needs to reset the way how we use our cities and the opportunities to reshape the way how we manage our cities, which directly impact on the wellbeing during the post-pandemic period. For previous developed smart cities, it remains to be checked whether the historical data and the existing solutions during pre-pandemic still works in the post-pandemic situations. Faced with the post-pandemic situation that we have never seen before, the effectiveness of developed smart city solutions along with the applicability of adopted historical data must be re-evaluated and re-verified timely. This paper aims at providing a start point of enabling a future of resilient cities from the pre-pandemic to post-pandemic. Firstly, behaviour changes will be discussed. Then, the framework of the bidirectional interaction between human and cities will be established in this paper, and the mitigation measures based on digital innovation will be further provided that could guarantee the smart cities from the insufficient post-pandemic data. Future works and challenges will also be discussed. With the pervasive digital transformation of cities, the possibility of creating a more robust and smart resilient city is provided to maximally unleash the value of data, historical or recent, under a people-focused view.

Keywords: Post-pandemic, Smart City, Historical data, Digital innovation

1. Background

Beginning in late 2019, the COVID-19 pandemic swept across the world. On the 11th of March 2020, it was declared by WHO that the COVID-19 was treated as a global pandemic, and as of 23rd of March 2020, the virus has affected 172 out of 195 countries around the world. It not only produces a massive impact on human health, but also brings in the short-term or even permanent changes of civic and commercial activities across the world.

For instance, in the UK, complete lockdowns have been released deliberately and gradually, and 'social distancing (physical distancing)' and 'rule of six' are still strict in the short-term and medium-term to mitigate the spread of coronavirus. In South Korea, since 21st of March

2020, the government strongly recommended to take several actions, such as closing doors to the public for two weeks (including religious facilities, indoor sports facilities, and entertainment venues (Shaw et al. 2020). In China, the responses and their actions can be divided into five phases: 1) very early phase (up to 31st of December 2019), 2) investigation phase (up to 20th of January 2020), 3) early intensification phase (up to 31st of January 2020, 4) criticism, agony and depression phase (up to 14th of February 2020) and 5) positive prevention and curative control phase (up to 29th February 2020). Some effective actions included rules for people arriving from overseas and following '14 days quarantine' (Hua and Shaw, 2020). All these different actions and rules announced by different countries present that the way people work and live has changed and will keep changing, particularly some of these changes will be long term or even permanent, such as 'wearing masks', 'working from home' etc.

With the wide adoption of information and communication technologies (ICTs) and big data techniques in the city scales, the applications of smart cities would benefit the citizens and the underlying environment, including smart economy, smart governance, smart people, smart mobility, smart environment, and smart living (Fernandez-Anez, 2016). At the city level, a tremendous amount of data would be generated from ICT devices, mobile devices, citizen feedbacks, etc. The management, processing, and implementations of this voluminous data are fundamental and essential to the realization and design of smart cities (Gharaibeh et al. 2017). Therefore, a lot of existing methods for achieving smart cities have been developed and the fundaments of data management techniques at the city level are to ensure consistency, interoperability, granularity, and reusability of the data generated (Gharaibeh et al. 2017).

However, currently, the post-pandemic situations need to be considered and citizen behaviours have been changed due to the COVID-19. Hence, the effectiveness of existing smart city solutions and the consistency of the historical data should be re-evaluated and re-verified timely. Moreover, it is the right time to move from a smart city to a new robust and resilient smart city, which can bear unexpected changes in the future. This paper tries to provide answers to the following emerging questions: Is the data collected before the outbreak still applicable during post-pandemic? What is the role robust and resilient smart city plays in making the best use of data adaptively during the transition from the pre-pandemic to the post-pandemic and the future new normal? What is the possible solution to dealing with post-pandemic situations under ever-changing social distancing restrictions?

2. Literature review

2.1 Classification of city systems

Besides buildings (e.g., residential buildings, office buildings, factories etc.), there are other city systems needed to be identified, namely the categorization of civil infrastructure. Shown as the Fig.1, transportation, energy, utility, recreational and water management systems are also part of the whole city. Traditional city operation and maintenance management covered energy, waste, water, telecommunications, policing and emergency response, education and training, transport, health, social services, housing, environmental services and finance and economy, through using technologies and data for providing services to citizens and business. However, this traditional mode was not customer-focused and do not have the abilities to drive cross-system innovation and city-scale changes (Heaton and Parlikad, 2019). The leading international organisation, ISO, developed a series of standards, which provided a direction for the smart city development including but not limited to energy, urban mobility, water, infrastructure, security, and health (ISO 2015; ISO 2016a; ISO 2016b).

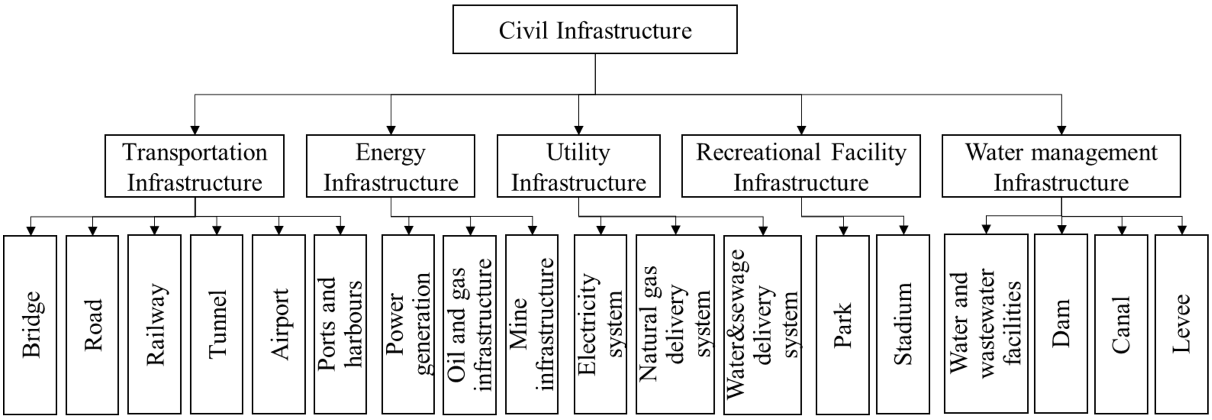

Figure 1 Categorization of civil infrastructure (Cheng et al. 2016; Shou et al. 2015)

2.2 Citizen behaviours and city systems

Citizen behaviours, practices and different cultural backgrounds will have powerful effects for the city systems, such as energy systems, transportation etc. Moreover, the interactions between technologies, practices and individuals would form certain patterns of daily activities, such as living, working, energy use (Verplanken and Roy, 2016). With the increasing attention of the relationships between behaviours and cities, the social contexts of people live, the routines of shaping these contexts, and the drivers of changing their own practices are all key points of analysing citizen behaviours, as well as providing the foremost step for creating a more robust and resilient smart city (Axon et al. 2018).

For instance, in the field of energy consumption and uses, it has been realized that energy conservation actions and energy uses are a complex ecology including motivations and external influences. Multiple contexts (such as home, work, travel and leisure) would be included in analysing the related behaviours (Poruschi and Ambrey, 2016). In details, if we would like to analyse city living, energy saving behaviours and direct residential energy consumption, the following aspects are needed to consider, including: 1). Direct energy (e.g., electricity, natural gas and liquefied petroleum gas), 2). Energy price, 3). Household characteristics, income, and members (e.g., dependent children, people over 65 years of age, renter), 4). Dwelling characteristics, 5). Geography (e.g., capital city, countryside), 6). Seasonality, 7). Climate conditions, and most importantly 8). Sustainable and energy saving encouraging strategies, and 9). Education and training (Poruschi and Ambrey, 2016).

Hence, in the city level, energy-related behaviour needs to be studied from social practice aspects (Moloney et al. 2010). In order to achieve energy efficiency behaviours, concerns, attitudes, knowledge, norms, and empowerment should be included. For instance, habitual behaviour has direct relationships with domestic energy consumption and this behaviour type can be a barrier to behaviour change (Huebner et al. 2013). This habit cannot be easily broken, unless some disruption and dramatic changes happen in their daily lives, such as changing jobs or the COVID-19 spreading recently.

2.3 Smart city and resilient city solutions

Nam and Pardo (2011) defined the "Smart cities" as an "*organic connection among technological, human and institutional components*" and Sta (2017) stated that the "Smart City" is "*a modern city uses smart information infrastructure (contains perfect data) to ensure the sustainability and the competitiveness of the different urban functions by integrating different dimensions of urban development and investments in order to reduce the environmental impact and to improve the quality of citizens' lives*". Technology (software, hardware and platforms), people (education, innovation and creativity) and institutes (government, policy and organisations) are three basic and most recurring components of a smart city (Heaton and Parlikad, 2019). While, the resilient city is considered to be "*the city's ability to absorb, adapt, and transform external pressures and ensure urban safety in the event of any crisis, hazards, or disasters*" (Zhu et al. 2020). For the smart city, research and development usually focus on ICT and modern technologies adoption and evolution, which is an active process. The resilient city focuses on disaster prevention and mitigation, which is a passive process of finding ways to maintain and recover from external influencing factors (Zhang and Li, 2018).

In the post-pandemic period, the smart city and resilient city are recommended to be integrated and provide a more flexible solution for dealing with the COVID-19. The ICT systems, hardware and software of the smart city system can provide supports and collect information for improving urban resilience, such as the positive cases tracking system. A large amount of information and data collected based on internet of things (IoT) devices and intelligent functions embedded can be the solid foundation for integrating "smart" in daily operations and further achieving "resilience" in emergency scenarios (Zhu et al. 2020).

3. The bidirectional interaction between human and cities

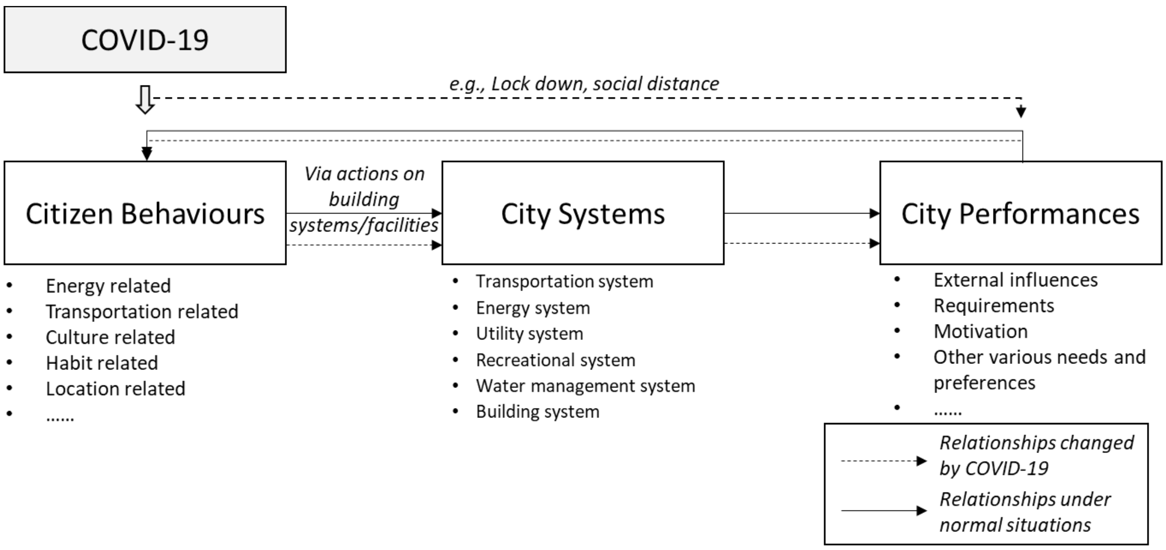

Figure 1 The bidirectional interaction between human and cities

The bidirectional interactive relationships between the human behaviours and city performances are the most important linkages between human and the city. During the COVID-19 pandemic, most people changed their working patterns and had to work from home. Some specific guidance towards the COVID-19 has been announced around the world. For instance, in the UK, the tier 4 guidance (Stay at home) is: 1). Citizens must not leave or be outside of their home or garden except where they have a 'reasonable excuse'; 2). If citizens live in a Tier 4 area, they must not leave their home unless you have a reasonable excuse (for example, for work or education purposes) (Tier 4, 2020). Governments showed a very strong government control when the COVID-19 cases are spreading with a high rate and the recovery rate is differential around different countries.

In order to protect our human and rapidly control the COVID-19, human behaviours have been changed in the short term or in the long term. Currently, residential buildings acted as both living and working spaces, private transportation was used more than public transportation, and public areas were closed or had limited open periods. Essential internal and external social, working and living behavioural patterns have been changed and directly affected the performances of the whole cities (shown as Fig.1). These changes bring great challenges to the established smart city applications. The existed solutions highly rely on the data, information, and knowledge extracted from historical data. However, the data collected is different before the outbreak, during the COVID-19 period and during post-pandemic. What kinds of the mitigation measures based on digital innovation will be needed for guaranteeing the smart resilient cities from the insufficient post-pandemic data? It is an urgent demand that creating a more robust and smart resilient city is to maximally unleash the value of data, historical or recent, under a people-focused view.

4. Discussion

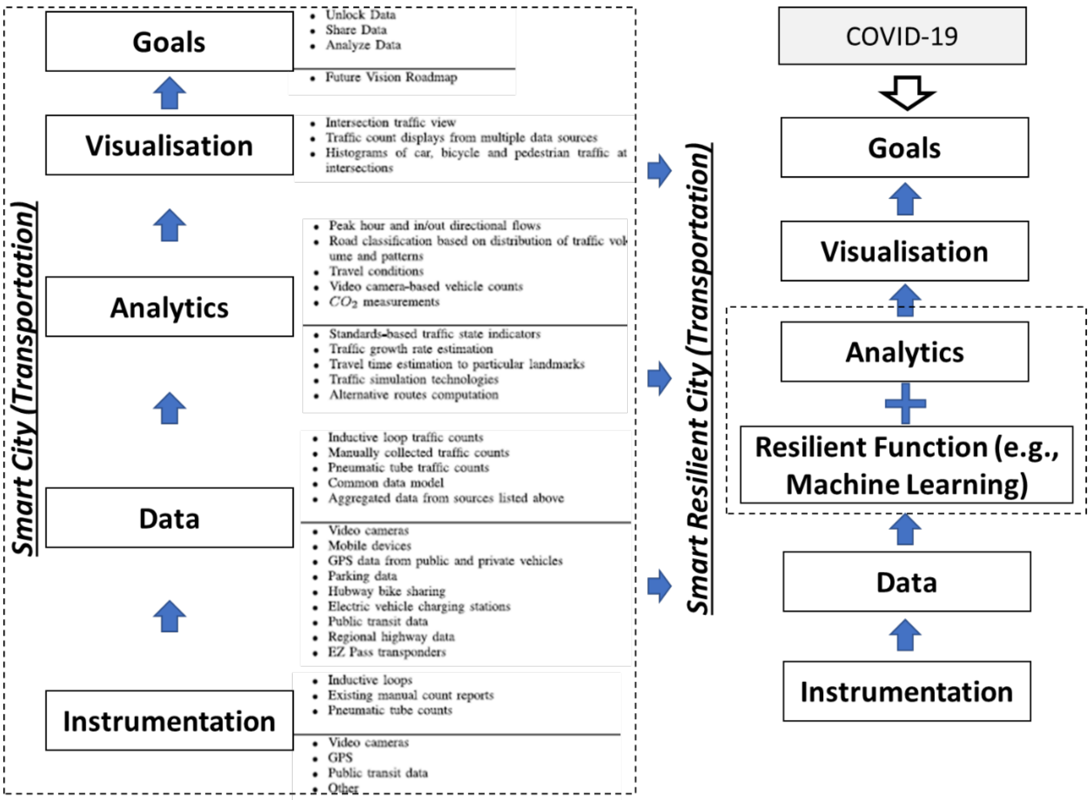

Figure 2 The roadmap towards smart resilient cities using transportation as an example (Gharaibeh et al. 2017; IBMs Smarter Cities Challenge, 2012)

Data management is the fundamental element in realising the smart cities, which consists of data acquisition, processing and dissemination. Data acquisition includes data standards, quality and use (Gharaibeh et al. 2017). In order to achieve the smart city, it is important to integrate a wide range of assets, city systems and technologies. Through establishing the heterogeneous system of a smart city (shown as Fig.2), it enables the whole city to be possible for different users (e.g., citizens) to take advantage of the system (e.g., smart transportation management, smart street lighting). Furthermore, in order to achieve the smart resilient city, it is suggested to integrate the smart and resilient city concepts and provide a new possibility, namely the smart resilient city. Shown as the Fig.2, more functions enabling the resilience and rapid recovery from the COVID-19 should be included, such as the digital solutions, machine learning and artificial intelligence (AI). These resilient functions would be able to assist in recovering from the COVID-19 and enable the data collected before the outbreak still applicable during post-pandemic.

5. Conclusion

This paper will provide the start point of enabling the possibility of creating a new smart resilient city in the post-pandemic period. Firstly, behaviour changes were discussed. Then, the framework of the bidirectional interaction between human and cities was established in this paper, and the mitigation measures based on digital innovation were further provided that could guarantee the smart resilient cities from the insufficient post-pandemic data. With the pervasive digital transformation of cities, the possibility of creating a smart resilient city was provided to maximally unleash the value of data, historical or recent, under a people-focused view. Future works will be focused on provide a system architecture and a real case study of the proposed smart resilient city for providing a better solution in the post-pandemic period.

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