Urban Quality Management Framework for Assessing Social and Economic Resilience

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Abstract. Continuous resilience assessment is important to improve quality of urban systems. Resilience of a city is affected by the dynamic nature of social and economic situations, especially during crises such as pandemic and natural disaster. In this research, a framework called Urban Quality Management has been proposed to perform resilience assessment using modeling and simulation methods. A group of cities are modeled as multi-agent system composed of many agents that represent individuals in the population, each with its own profile and properties. The assessment is implemented as data management process and executed in a case study to detect resilience threats in the cities. The resilience requirements are identified in order to define rules and to design algorithms for assessing the properties. The detection results can be analysed using advanced data analytics approach aiming to reduce the threats and to improve resilience in the cities.

Keywords: urban quality · city resilience · smartness · sustainability

1 Introduction

Resilience is one of the measurable urban quality properties, besides smartness and sustainability. Resilience for a city is "the ability of a city to absorb, adapt and transform external and internal pressure and guarantee urban safety during any crisis, disasters, hazards and pandemics" [1]. Resilience has been assessed by many researchers, cities authorities and independent analysts to prioritize cities strategies [2]. Many indicators and methods have been used to assess and rank cities resilience [3]. Indicators for resilient cities are very critical to be considered in every action plans and decision making stages made by city authorities. Due to the dynamic of cities social and economic situations combined with external factors such as pandemics and natural disasters, threats to cities resilience could occur. Besides knowing the resilience status and rank, detecting resilience threats is equally important so that cities authorities can identify the symptoms, as well as the root causes that affect cities resilience.

This study focuses on assessing the economic and social resilience of smart cities. Basically, economic resilience is the ability for individuals to maintain or improve their take home income during crisis such as pandemic and natural disasters. It is also directly associated to their ability to minimize the potential losses and damage severity while

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maximizing the recovery capacity and employment recovery. Social resilience is the ability of individuals to survive and to maintain their social capital within the community. The individuals with social resilience are able to respond and recover during crisis [4].

Projects have been initiated to evaluate and diagnose cities resilience for the cities authority to make urgent and informed decisions during and after crisis such as pandemic [2][5]. To assess city resilience, efforts to continuously detect resilience threats are however still need to be explored. This paper proposed a framework called Urban Quality Management (UQM) to assess cities resilience continuously and repeatedly. The framework allows the authorities to understand how threats that occur in the cities are affecting city resilience. By implementing the framework, the assessment of cities resilience could be made during the execution of cities simulation models. The resilience threats detected can be analyzed to reduce the threats and to improve city resilience status from time to time.

The rest of the paper is structured as follows. Section 2 reviews the background and related works while Sect. 3 describes the proposed UQM framework. Next, Sect. 4 explains the experiment procedure and Sect. 5 presents the results and discussion. Finally, Sect. 6 concludes the paper and suggests future works.

2 Background and Related Work

This section reviews existing works on resilience assessment in smart cities. Next, it is followed by the explanation of social simulation and modeling approach in social sciences. Finally, data quality management that is adapted to develop the proposed framework in this study is presented.

2.1 Resilience Assessment in Smart Cities

The process of assessing resilience for smart cities around the world has been performed and reported in many literature [2][3][4]. There are also critical reviews on resilience assessment challenges, needs, framework, techniques and tools [6]. Some of the previous works are proposing comprehensive framework while the others are focusing on selected resilience indicators such as economic, social or community, infrastructural, institutional and environmental resilience [3].

The related works stated above shows that significant amount of efforts have been contributed to implement resilience assessment for smart cities. However, from the review, there are still gaps that can be further explored. First, the existing assessment approaches mainly rely on literature review, stakeholders' input, experts' opinions and field testing [6]. Thus, assessment that is performed using modeling and simulation still needs to be explored. Second, the resilience assessment processes are performed by checking the evidence as described by the resilience indicators and by identifying the effects of each indicator and sub-indicators towards resilience. Most of the assessments are towards the indicators that give positive effects towards resilience and not many are considering indicators that give negative effects or threats to resilience. Thus, efforts to detect resilience threats are however still need to be explored. Finally, there is still a need for a framework that is flexible and adaptable to different resilience requirements

and threats. By continuously detecting those threats that could occur during critical situations, it is hoped that cities authority could eliminate the risks or reduce the threats by taking proactive actions for the benefit of the community. This research acknowledges those gaps and complements the existing works by proposing an approach to detect resilience threats that occur in the cities.

2.2 Social Simulations and Smart Cities Modeling

This study explores the use of computer modeling to perform social simulation. Previously, social simulation approach has been used to study issues in social sciences area such as law, psychology, organizational behaviour, political sciences, geography and linguistics [7]. Social science studies are normally descriptive and use direct measurement of the real world as the input. Social simulation, however, use technology to allow social science studies to be focusing on behaviour that can be processed by technology to build modeled reality. The model can be executed as simulation to receive relevant data and to use specified rules to generate more data that can be analysed to support human reasoning.

Agent-based modeling of economic and social behavior has been practiced and reviewed [8]. This study uses Anylogic [9] as the social simulation and smart cities modeling tool. Anylogic has been used to create smart city model that simulates smart city to assess the effect of action plans, decisions and policy making by city authorities towards the happiness of the people in the cities. There are several advantages of using Anylogic. It is an agent-based social simulation tool that offers the monitoring of interactions between simulated agents that represents the population in a city. The properties, behavior and process flow of the agents can be used to predict urbanization future or to study the effectiveness of policies.

3 Proposed Solution: Urban Quality Management Framework

The UQM framework is proposed by adapting TDQM model [10]. TDQM principle is adapted to manage urban resilience within cities. Multiple processes are organized into four elements of UQM framework that are Definition and Specification, Modeling and Simulation, Detection and Assessment, and Analysis and Improvement. This framework is general enough and can be used to manage other urban quality such as smartness and sustainability. Figure 1 shows the UQM framework adapted from TDQM cycle.

3.1 Definition and Specification

In this research, the focus is towards the resilience requirements of smart cities. The high-quality cities are the cities that manage to reduce constraints to improve city resilience during crisis. UQM framework is proposed in this study as a solution for assessing resilience in smart cities. This section elaborates on the UQM framework and the incorporation of the framework components within cities model and simulation.

Depending on the type of cities and its features, to perform tasks and to achieve goals in smart cities, cities have their own action plans. During pandemic, the action plans are

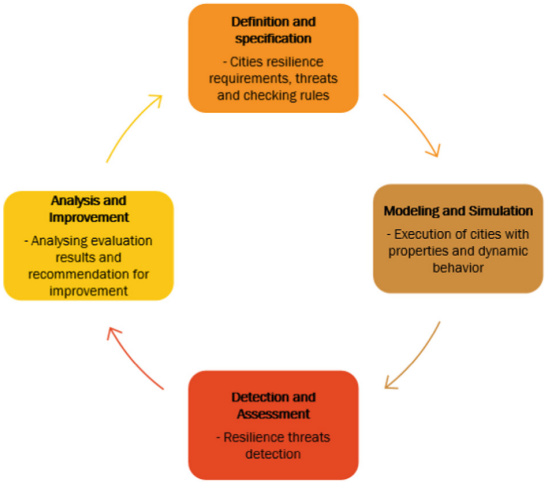

Fig. 1. Four elements of UQM framework

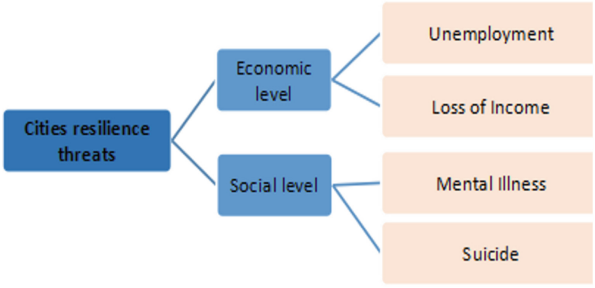

Fig. 2. Factors that contribute to resilience threats

to control and to protect the residents from infectious diseases. However, those action plans are susceptible to economic and social resilience threats such as unemployment and mental health issues.

As resilience is one of the urban qualities in smart cities, it is very important for the authorities to ensure the resilience of the community is protected and maintained. The resilience requirements are to fulfil the needs to determine cities resilience status during pandemic.

Factors that contribute to resilience threats, the definition of cities resilience requirements and the possible threats for resilience criteria, the extracted indicators with attributes and the constructed checking rules for each of the resilience indicators are specified. Figure 2 summarizes the identified contributing factors or conditions that are considered as threats to cities resilience.

Next, here are the steps to define the checking rules,

Table 1. Economic and Social Resilience Requirements and Threats

Resilience	Requirements	Threats
Economic	Individuals in the city population are employed and are maintaining their take home income.	When the number of unemployment and loss of income are increasing within the population.
Social	Individuals in the community can cope with stress, be productive and contribute to their community	When the number of mental health and suicide cases are increasing in the community.

Table 2. Economic and Social Resilience Indicators

Resilience	Indicators	Individual Attributes
Economic	Employment	Employment status Income status
Social	Social capital	Mental health status Suicidal status

1. Resilience goals for the city are defined; the resilience goals during crisis are to ensure that cities economic and social resilience requirements are fulfilled.
2. Resilience requirements are defined; to define the resilience requirements, the selected criteria should represent the quality of cities in various conditions and action plans during pandemic. Table 1 presents the resilience requirements.
3. Resilience indicators are defined; the abstraction of resilience requirements and threats defined is transformed into resilience indicator. The cities parameters and critical states are defined to be included in the resilience indicators definition. A resilience indicator is a measure of resilience properties. Table 2 shows the resilience indicators.
4. Resilience checking rules are defined; For each indicator, the rules require the execution of threats detection during simulation of the cities model. The checking rules are presented in Table 3.

3.2 Modeling and Simulation

In this phase, cities are modeled starting from the creation of the population and followed by execution of the flow of the individuals in the population. To continuously perform threats detection and assessment during execution of the simulation, the resilience checking rules defined in previous phase are used to assess resilience. The cities to be assessed are modeled using Anylogic system [9]. Population for a city is created and their economic and social flow are modeled using state charts.

Table 3. Economic and Social Resilience Checking Rules

Resilience	Conditions and Statuses
Economic (Threats Detection)	For all individuals (x) in the population, if x is unemployed, then an economic resilience threat has occurred at time t.
	For all individuals (x) in the population, if x is losing income, then an economic resilience threat has occurred at time t.
Economic (Status Assessment)	For all cities (i), if number of detected economic resilience threats is low, then City Economic Resilience Status is high.
	For all cities (i), if number of detected economic resilience threats is high, then City Economic Resilience Status is low.
Social (Threats Detection)	For all individuals (x) in the population, if x has mental health issue, then a social resilience threat has occurred.
	For all individuals (x) in the population, if x is one of the suicide victims then a social resilience threat has occurred.
Social (Status Assessment)	For all cities (i), if number of detected social resilience threats is low, then City Social Resilience Status is high.
	For all cities (i), if number of detected social resilience threats is high, then City Social Resilience Status is low.
Socio-economic (Threats Detection)	For all individuals (x) in the population, if x has low economic status and at the same time has mental health issue, then a socioeconomic resilience threat has occurred.
Socio-economic (Status Assessment)	For all cities (i), if number of detected socioeconomic resilience threats is low, then City Socioeconomic Resilience Status is high.
	For all cities (i), if number of detected socioeconomic resilience threats is high, then City Socioeconomic Resilience Status is low.

3.3 Detection and Assessment

Detection of economic and social resilience threats is performed to indicate the level of city resilience status by considering cities relevance data and contextual information. The relevance data includes cities unemployment and loss of income rate and mental health and suicide cases. The threats detection is performed by implementing the checking rules for each indicator. As the detection and assessment processes are part of the UQM framework and the UQM phases are performed in cycle, the detection can be performed one level at a time starting from the Economic level and followed by the social level to improve the effectiveness of the threats detection. The detection includes the process of keeping tract the specified threats and finally, reporting the number of detected resilience threats to determine city resilience status. Figure 3 presents the detection and assessment process flow and the input and output data.

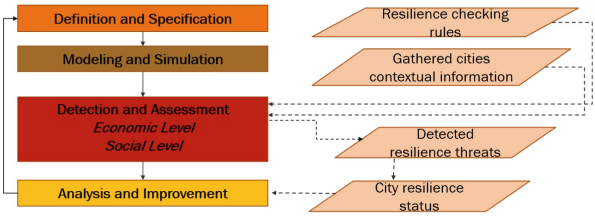

Fig. 3. Detection and Assessment process flow

3.4 Analysis and Improvement

After performing resilience threats detection, in this phase, the resilience threats are presented to show cities resilience status for economic and social indicators. The analysis of the detection results can be used by city authorities to improve economic and social resilience levels by reconsidering the policies. The improvement could also be recommended to increase the effectiveness of the detection. New resilience indicators and checking rules for the next detection cycle may be proposed.

4 Experiment Procedure

This experiment aims to detect resilience threats that could occur in smart cities. The resilience requirements and the possible threats defined in Sect. 3 were referred. The UQM detection and assessment process was incorporated within smart cities models and executed to perform threats detection.

The relevance economic data that are the number of labour forces and unemployment rate for KL, Penang and Malacca cities presented by Department of Statistics Malaysia (DOSM) [11] were used during the the simulation. The number of population for the three cities represent the number of labour forces in those three cities. The defined cities resilience indicators and checking rules were executed within the model during simulation to detect resilience threats. To utilize the checking rules, relevance social data that are the mental health and suicide cases is collected and generated based on the reported rate [12][13]. Finally, the effectiveness of the resilience detection will be evaluated (Table 4).

The UQM Assessment procedures reported the number of threats detected by social and economic indicators and calculated the total number of all detected threats as follows:

1. For each city, the number of Economic Resilience Threats is obtained by keeping track of the number of income losses and unemployment within the population in the specified year.
2. For each city, the number of Social Resilience Threats is obtained by keeping track the number of mental health issues and suicide cases within the population in the specified year.

Table 4. Relevance data for KL, Penang and Malacca [11]

Cities	Year	# Population (Labour Forces) '000	# Employed '000
KL	**2019**	863.4	841.0
	2020	910.6	874.6
Penang	**2019**	852.3	835.6
	2020	863.4	832.9
Malacca	**2019**	432.9	428.9
	2020	426.8	417.3

Table 5. Number of Economic Resilience threats detection and assessment results.

Cities	Year	# Known Unemployed '000	Economic Resilience Threats		City Economic Resilience Status
			# Detected Unemploy-ment '000	# Detected Loss of Income '000	
KL	**2019**	22.4	19	12	High
	2020	36.0	242	143	Low
Penang	**2019**	16.7	126	10	High
	2020	30.6	116	152	Low
Malacca	**2019**	4.6	77	2	High
	2020	9.4	55	74	Low

5 Results and Discussion

5.1 Resilience Threats Detection Results

The experiment was executed for Kuala Lumpur (KL), Penang and Malacca cities for the year 2019 and 2020. The results for each simulated city for the specified years are presented in Table 5 and Table 6. The table displays the results of the detected cities resilience threats for the three cities at social and economic levels. Table 5 presents the number of detected unemployment and loss of income among labour forces in KL, Penang and Malacca. Table 6 shows the number of detected mental health issues, suicide victims and mental health issues among individuals with low economic status. Finally, the cities' economic and socioeconomic resilience statuses are also presented in both tables. In 2020, which is during the pandemic, the cities resilience status is low due to many threats that occur in the cities.

Table 6. Number of Social Resilience threats detection and assessment results.

Cities	Year	# Known Mental Health Issues '000	Social Resilience Threats		Socio-economic Resilience Threats	City Social and Socio-economic Resilience Status
			# Detected Mental Health Issues '000	# Detected Suicide Victims '000	# Detected Mental Health Issues Among Low Income '000	
KL	**2019**	259	268	0	17	High
	2020	273	447	0	184	Low
Penang	**2019**	130	324	0	67	High
	2020	128	375	0	126	Low
Malacca	**2019**	256	176	0	36	High
	2020	259	203	0	59	Low

6 Conclusion and Future Work

In short, this research explores the possibility to assess economic and social resilience properties in smart cities by using modeling and simulation method. Based on the identified gaps in the literature, UQM framework is proposed by adapting TDQM principle to manage the resilience as one of the quality properties. This research contributes to the detection of resilience threats that occur during and after crisis.

In general view, this work complements the existing urban quality management works and urban quality properties solutions by focusing on resilience management during pandemic. The framework is general enough to be used for managing any urban quality properties such as smartness or sustainability as well as other resilience indicators.

In the future, other applications from different research fields such as social sciences, software engineering, data sciences or artificial intelligence can make use of the UQM detection and assessment output to perform better analytics and to produce visualizations that can benefits many researchers.

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References

1. K. Rus, V. Kilar, D. Koren, Resilience assessment of complex urban systems to natural disasters: A new literature review. International Journal of Disaster Risk Reduction (2018): n. pag. DOI: https://doi.org/10.1016/J.IJDRR.2018.05.015
2. City Resilience Index. https://www.cityresilienceindex.org (Accessed on 15th April 2022)
3. S. Zhua, D. Lia, and H. Feng. Is smart city resilient? Evidence from China. Sustainable Cities and Society. Volume 50, October 2019, 101636. DOI: https://doi.org/10.1016/j.scs.2019.101636
4. A. Bastaminia, M. R. Rezaei, and M. H. Saraei. Evaluating the components of social and economic resilience: After two large earthquake disasters Rudbar 1990 and Bam 2003. JAMBA - Journal of Disaster Risk Studies. Published online 2017 Apr 25. DOI: https://doi.org/10.4102/jamba.v9i1.368
5. Building Urban Economic Resilience During and After COVID-19 https://www.un.org/development/desa/da/building-urban-economic-resilience-during-and-after-covid-19/ (Accessed on 18th June 2022)
6. A.M.A. Saja, A. Goonetilleke, M. Teo, A.M. Ziyath, A critical review of social resilience assessment frameworks in disaster management, International Journal of Disaster Risk Reduction (2019). DOI: https://doi.org/10.1016/j.ijdrr.2019.101096.
7. S. Takahashi, D. Sallach, J. Rouchier. Advancing Social Simulation: The First World Congress, Springer, 2007 p. 354, ISBN 978-4-431-73150-4
8. 9. M. Steinbacher, M. Raddant, F. Karimi, et al. Advances in the agent-based modeling of economic and social behavior. SN Bus Econ 1, 99 (2021). DOI: https://doi.org/10.1007/s43546-021-00103-3
9. Anylogic. https://www.anylogic.com/ (Accessed on 15th April 2022)
10. Richard Y Wang. Total Data Quality Management. Communications of the ACM, 41: 58–65, 1998. ISSN 00010782. doi: https://doi.org/10.1145/269012.269022. URL http://portal.acm.org/citation.cfm?id=269022.
11. Department of Statistics Malaysia (DOSM). https://www.dosm.gov.my (Accessed on 15th April 2022)
12. Resolving mental illness issues in Malaysia. https://umsc.my/umsc_news/resolving-mental-illness-issues-in-malaysia/ (Accessed on 15th April 2022)
13. B. Lew, K. Kairi, D. Lester et al. Looking Into Recent Suicide Rates and Trends in Malaysia: A Comparative Analysis. Front. Psychiatry, 05 January 2022 | DOI: https://doi.org/10.3389/fpsyt.2021.770252