A framework: Implementation of smart city concept towards evacuation route mapping in disaster management system

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Abstract. Due to the complex nature of disaster, elaborating smart city environment has being important matter in term of enhancing the resilience, awareness and preparedness. Therefore, this research propose a collaborative framework of disaster awareness system that can integrate multiple data resources in smart city ecosystem. The system architecture consist of four tiers; (1) sensor tier, which is responsible for retrieving and updating information about reality from sensors; (2) database tier, which is responsible for collecting information from related domain resources (3) decision support tier, with respect to examine the continuously updated situations for making emergency decision; and (4) alert tier, which is responsible for informing and warning citizens who living within risk area. By using earthquake impact assessment of Taiwan earthquake, the framework is built in knowledge to evaluate service area of hospital and provide evacuation route using network analyst. From infrastructure perspective, standards are introduced to resolve the various heterogeneity issues between different stakeholders. The result of hospital service area analysis is 1207 km² and decreases about 474.5 km² after the earthquake. Moreover, the comparison of route analysis between before and after earthquake indicates that the implementation of smart city concept and network analyst sucessfully minimize travel time until 10 minutes.

1. Introduction
During the past decade, disasters are the major reason for many deaths, injuries, homeless of population along with extensive property damages. Supposedly the casualties regarding to the mortality rate and sociality impact caused by weather-related disasters, United Nations Office for Disaster Risk Reduction (UNISDR) and Belgian-based Centre for Research on the Epidemiology of Disasters (CRED) report since first climate change in 1995. They demonstrated that 606,000 lives had been lost and 4.1 billion people had been injured, left homeless or demand emergency assistance [1]. A growing understanding about disaster impact triggers disaster organization in different countries has its particular actions in managing the impact of the disaster. So as to the main task of disaster management which is organizing the people to face upon disaster [2], disaster management consist of three phases; pre-disaster, during disaster, and post disaster [3]. Those phases are related to the reaction upon disaster involving mitigation, preparedness, response, and recovery that was continuously turning and developing corresponding to real disaster situation [4], [5].
In the most case, disaster management was associated with mapping to identify the impact particularly for doing response phase [6]–[8]. The mapping for disaster involves several technologies such as Global Positioning System (GPS), photogrammetry, remote sensing, Geographic Information System (GIS). The use of which has been proven that spatial location is very crucial for identifying the further characteristic of disaster [4], [9] and the scope of emergency response has grown tremendously over the past years. ESRI (2006) summarized the key elements of emergency management encompass early warning systems, communication systems, networks of emergency responders, shelter facilities, and evacuation plan. Those elements are quite related to the collaboration of disaster-related stakeholders. Due to the complex nature of disaster nowadays, the collaboration requires a new thinking that integrates the cross-domain demands of data, technology and policy.

Smart city definition as a city that we can not only automatically serving people, building, traffic system, but also enable us to monitor, analyze, and plan the city to improve the efficiency, equity, and quality of life in real time [10]. As the key concept of smart city is gathering and continuously updating data information by real-time from cross domain resources [10], [11], developing smart city has been a trending solution in term of enhancing the quality of human life e.g. economic, humanity, political, particularly in disaster management. City is regarded as smart when the components have been fulfilled including smart people, smart economy, smart living, smart environment, smart mobility, smart government [11]–[13]. While the necessary data information of smart city is relied on the use of monitoring system embedded within the city functions[14].

Egarding to apply smart city concept into disaster management, this research was focused on preparedness and response phase by providing a collaborative framework of disaster awareness system for supporting decision making. The framework is built upon a proposed four tiers architecture which consist of sensor tier, data distribution tier, decision support tier, and alert tier. The architecture is illustrated in figure 1.

2. Methodology

2.1 Fonts in equation editor (or mathtype)

This research propose ‘four tiers architecture’ as the the framework mechanism to be applied as the implementation of smart city concept. This four tiers architecture consists of sensor tier, data distribution tier, decision support tier, and alert tier. The architecture is illustrated in figure 1.
Figure 1. Proposed four tiers architecture of this research

Sensor tier is responsible for monitoring environment and updating observations from sensors where deployed at critical facilities where may draw crowd such as parking, station, tourist attraction, dock. Embedding sensors is also carried out on the infrastructure to continuously monitor the real-time situation e.g. precipitation, water level, seismic activity, and congestion. The information from sensor may dynamically change unless those sensors get damage, consequently those sensors are no longer able to continuously monitor the environment. In case when the observations from sensors reach the hazard threshold and/or the sensors get damage, it may indicate disaster will happen. After the information has been proceed, web service will send alert to the critical location in which CCTV has been installed beforehand. The sensor deployment requires a collaboration of different professional agencies e.g. fire department, water resource department, and disaster reduction department according to their assigned responsibilities.

Data distribution tier is responsible for collecting information from related domain resources and updating database based on updated information from sensor observations. This tier will integrate those information along with updated information into a collaborative database server. This tier will be handled by a common internet-based sharing mechanism. Decision support tier is responsible for examining the continuously updated situations for supporting emergency decision and further automatically triggering sensor service to monitor risk area. This tier is divided into two parts; (1) pre-disaster analysis relying on historical disaster scenario to determine the service area of facilities and eventually generating emergency response plan. This pre-disaster analysis will conduct several times in order to approach the real situation; (2) during disaster which is carried out after knowing the risk area by triggering surveillance camera on the critical location and updating the current situation and further doing actions.

Dealing with transportation issue, the framework provides routes for resources deployment and victim evacuation to hospitals and shelters as well. This tier is handled by an internet-based mechanism that integrates the Emergency Operation Center (EOC) and related agencies. Alert tier is responsible for warning and informing citizens who living around risk area under threat. The alert is delivered through variety of way e.g. television, mobile phone, and radio. By information from decision support tier, the message is occupied with the information of damaged bridge, closed road, and eventually alternative routes. This tier is handled by a single responsible agency to deliver alert encompass all kind of disasters. While the dissemination of the alert message is according to the scope of the disaster risk area particularly in the critical location.
2.2 Standards
From smart city perspective, a standardization is the apparent solution for dealing with heterogeneity issue among the interaction of cross-domain related stakeholders. In the framework, the standardization is used for sensor tier and alert tier.

Sensor tier follows Sensor Web Enablement (SWE) standards published by Open Geospatial Consortium (OGC) which offers observation service standards called Sensor Observation Service (SOS). By following these standards, different stakeholders can access the sensor information even without knowing how the information is gathered or stored since the information was already modelled, stored, retrieved, shared, analyzed, and visualized by sensor web [15].

Alert tier follows a standardization alert message format developed by emergency management technical committee of Organization for the Advancement of Structured Information Standard (OASIS) called Common Alerting Protocol (CAP). CAP is a simple but general format for exchanging all hazard emergency alerts and public warnings over all kind of networks and ensuring that the message shares the same format regardless the tool used to create the message [16]. The contents compose of an <alert> segment, which may content one or more <info> segments, each of which may include one or more <area>, and/or <resource> segments [17].

2.3. Impact analysis
The framework is established concerning with transportation issue by using network analyst to find the shortest and the fastest routes between many pairs of points. The route analysis is used to find some shelters and hospitals as well as the routes for resource deployment in which the locations are the nearest from risk area based on distance and/or travel time. The analysis was carried out based on historical disaster data produced by National Science and Technology Center for Disaster Reduction (NCDR). Beside the historical disaster, NCDR provided some risk assessments with respect to such historical disaster consist of; public infrastructure damage e.g. road and bridge, building damage, population at risk, and impacted power outage area. By doing the simulations, the weakness area of disaster was determined to do further actions for the next disaster.

The first analysis within the network analyst module is generating service area. Furthermore, examining the number of injured population and the number of damaged building in which either covered or not covered by service area. The second analysis is generating the fastest and shortest routes as illustrated in figure 5. The input elements consist of road network as network dataset, historical disaster as incidents, and hospital as well as shelters as facilities. Meanwhile, risk area analysis is carried upon damaged building and impacted population for generating evacuation and resource deployment routes. Prior to do the analysis, the restrictions such as one-way, U-turn, cross section road, road hierarchy and the impedance was set up. Thereby, the simulation approach to the real situation of transportation. In order to know the efficiency of network analyst, the comparison between before and after earthquake was conducted based on several indicators such as travel time and distance of routes and service area.

2.4 Study Area and dataset
Considering the historical earthquake occured in October, 2017 with magnitude 5.3 and depth 15.8 km that caused National Cheng Kung University Hospital overload of patient capacity due to the casualties, this research choose Tainan county as the study area (figure 2). However, this research uses the simulated disaster data from (Taiwan Earthquake Impact Research and Information Application (TERIA) platform. TERIA Platform data were provided by NCDR in order to implement the proposed framework.
The dataset is generated from a comprehensive impact and damage scenario analysis caused by presumed earthquake M6.9 with source depth 10 km occurred at (23.08, 120.36) in the center of Tainan. These impact analysis generated various direct-impact assessments including; building damages, impacted populations, road damages, bridge damages, and electricity pipeline damages, etc. Building damage, impacted populations and damaged electricity pipeline area is represented by grid. Meanwhile, damaged road and damaged bridge are represented by line and point respectively. The severity of damage was categorized as light, medium, and extensive in that represented by difference colors.

3. Experimental result
The location of earthquake is highlighted in figure 3b. The experiment assumed the earthquake had caused the critical bridge got damages as well as roads. Consequently, the damaged roads were closed. The simulation assumed the closed road and damaged bridge as barriers since no longer able to be passed through. The service area of 13 hospitals in Tainan would be executed before (figure 3a) and after the earthquake occurred in a particular location (figure 3b) in order to compare the area where is not covered by service area after the earthquake occurred. Service area analysis applies travel time of vehicles as the impedance. The impedance is set to 10, 15, and 30 minutes away from hospital. Figure 3a depicts the result of service area analysis before Tainan earthquake that covers about 1207 km² or equal to a half of Tainan county. The result of service area is represented by purple color gradation in which dark to light purple represents 10, 15, and 30 minutes coverage area respectively.
Figure 3. The result of service area of hospital (a) before earthquake (b) after earthquake

Figure 3b depicts the service area of hospital after earthquake. 19 damaged bridges 1872 segments of damaged roads are applied in the analysis process that cause the service area significantly changes. The major changes are highlighted in urban area due to the existence of damaged road, the coverage prone to be narrow particularly the coverage of 30 minutes impedance. Figure 4 depicts the comparisons between before and after earthquake. Before earthquake is represented by the gradation color of purple, while the after earthquake is represented by the gradation color of green. The result shows the service area significantly changes except the western part of Tainan city since the location is far from the earthquake. The major changes also happens to the surrounding area of two hospitals since they are temporarily out of service due to the earthquake. According to the comparison in table 1, the unserviceable area increases to 474.5 km².
Table 1. Comparison of service area

| Impedance   | Comparison of service area (km²) |
|-------------|----------------------------------|
|             | Before                           | After               |
| 10 minutes  | 198,6817958                      | 114,768134          |
| 15 minutes  | 333,5895147                      | 191,715279          |
| 30 minutes  | 1207,439915                      | 732,936431          |

Figure 4. Service area changes

The earthquake left losses towards surrounding populations, particularly their lives. The impacted population of disaster was divided in variety of levels; (1) those who dead, (2) those who seriously injured and need hospitalized, (3) those who moderately injured and no need hospitalized, and (4) those who slightly injured. From service area analysis, the impacted populations of level 2 and 3 within risk area will be transported to the hospitals. Figure 5 depicts the comparisons of route analysis between before and after earthquake. The test cases are based on the condition of extreme-injured population (represented by black point) to be moved to the closest hospital (Annan Hospital) because of facing damaged roads and damaged bridges. The case shown here is by specifying Beiliao village (北寮村) as the starting point and National Cheng Kung University hospital as the destination. The yellow lines refer to the suggested route of before earthquake, while the blue lines refers to the suggested route of after earthquake. The result shows the time travel of before earthquake is 74 minutes, while the after earthquake increases to 97 minutes.
Figure 5. The result of evacuation route between before and after earthquake

Figure 6. Route comparison

Figure 7. Alternative route

Figure 6 shows the route analysis comparison of 中坑村 village to the closest hospital based on time impedance which is Annan hospital. The yellow line refers to the fastest route offered by network analyst before earthquake, while the light blue line refers to the suggested route after earthquake. Before
earthquake, the travel time of yellow line is 43 minutes. After earthquake occurs and bridges damage, the route would require 99 minutes to reach Annan hospital. This route is assumed as the best estimation considering the updated status of bridge and road condition. Otherwise by knowing earlier the updated situation of bridge and road where located along the route from the sensors, network analyst will suggest the best alternative route as depicted in figure 7. It spends 52 minutes to reach closest hospital. Such that, deploying sensors at critical bridge and road demonstrates its superior capability in updating real time situation when earthquake occurred.

4. Discussion
This paper has presented the design of disaster alerting framework based on smart city concept which aims to support decision maker in the EOC. Smart city requires technologies to support the integration of information, public participation, social agents, and information security[19]. The adaptation of smart city concept in this research lies on several elements including the involvement of sensor deployment, the centralization of data, the use of standardization of data format and the collaboration of cross related-disaster domain within a single framework. There can be no agency responsible for all coordinating of many different components that involved in the smart city, since the city regarded as constellations of groups so that multi-stakeholder municipally-based partnership between governance and agencies from the bottom up as well as the top down [20].

The existence of sensor becomes more precious in the response phase due to the dynamic and time-sensitive of nature during disaster. Nevertheless, the data gathering and sharing often generated in heterogeneity due to each organization has each regulation. As towards sensor tier, deploying all different kind of sensors cannot rely on the responsibility of individual agency or government. Instead, different responsible agencies and governments will participate in deploying and observing according to their objective [21]. Since many different sensors are built by different manufactures and deployed by different stakeholders, participate in the data aggregation. There must be numerous amount of heterogeneous data produced by varying format. Likewise the alert tier, usually public receive the alert in a variety of media such as television, radio, phone. Consequently, the information become redundant and confound the public.

Therefore, the standardization was introduced in the framework to solve the heterogeneity issue in gathering necessary data from cross domain stakeholders. The standardization consist of SWE and CAP to be applied upon sensor and alert tier respectively. SWE vision is to facilitate the connection between different sensor networks using Web and to connect the heterogeneous sensors each other become a unified access [22], [23]. Without explicit standards, it is difficult to realize the communication between sensors [21]. Unless using explicit standards, any clients including disaster stakeholders can access the sensor observation and be able to deploy those sensors regardless the specification of sensor as long as still following the standards. While CAP vision is centralizing the message format for all disaster by eliminating the need for multiple custom software interfaces for many warning services (OASIS). The sources can be from disaster observation center, Internet of Things (IoT) such as sensor web or even people’s witness.

This research dominantly takes the role of data distribution tier and decision support tier, particularly in retrieving all necessary data from different stakeholders and do the analysis with respect to transportation issue. By utilizing historical disaster data from responsible agencies in Tainan, the research intend to explore the knowledge of the area whose tendency of higher probability at risk when disaster occurred. Due to the disaster cannot be predicted precisely particularly the location, the impact of disaster cannot be analyzed before the disaster occurred. Instead, the impact of disaster can be assessed after disaster occur. Therefore, the proper approach is using a disaster simulation by historical disaster data [9]. Such historical disaster was very critical in the risk area analysis. The knowledge consist of whatsoever at risk area e.g. the number of populations, households, buildings, public infrastructures and the facilities with respect to the emergency disaster response e.g. hospital, shelter,
depot. By knowing those information beforehand, the EOC can more effectively make decision and do any actions for further disaster.

From the result of service area, the tendency of shifting mostly happening where the barrier more located. Likewise the route analysis, the tendency of choosing another facility is in the urban area as well (figure 2 and 3). Because of the urban area has more vulnerable infrastructures rather than rural area or mountain area. Since the vulnerability refers to propensity of exposed elements, such as human being, livelihoods, and assets that affected by disaster [3], [25]. Based on the route analysis, decision maker in the EOC can prepare an action plan regarding to the impact of the disaster beforehand. Decision maker adjusts those decisions by analyzing the spatial relationship between the damage, critical infrastructure, and available resources in the recognizable context of developing situational awareness[5].

5. Conclusion
This research implement the concept of smart city towards disaster management particularly disaster preparedness and response. The ability of smart city in providing real-time data service and integrating the related stakeholders in a single based mechanism initiates the framework built upon a proposed four tires architecture. From the preliminary result, it proves that network analyst can effectively support decision support tier with respect to transportation issue. In addition, utilizing sensor web and alert service will ease the decision maker to monitor and be aware before evaluate the impact on critical infrastructure. Moreover, the framework built under the international standardization format to deal with heterogeneity. Eventually, the proposed approach enables the successful and interoperable communications between stakeholders with specified responsibility to improve the welfare of human beings.

6. Recommendation
For further development, the implication of sensor deployment of four tiers architecture is the key action to pursue the effectiveness of the framework. Instead of using comprehensive impact analysis from historical disaster data. Furthermore, this research framework should be established in a single web-based interface based on the dynamical impact of recent disaster. Such that, decision makers can monitor the dynamical information every time to support decision making process.

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